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ORIGINAL RESEARCH

Comparative Evaluation of Dentinal Microcracks after Root End Cavity Preparation Using Different Imaging Techniques: An In-Vitro Study

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ABSTRACT

Background: *The purpose of root-end cavity preparation is to remove irritants from the root canal system inaccessible to the operator via a coronal entry. However, this predisposes the tooth to microcrack formation which further increases the possibility of bacterial contamination and susceptibility to root fracture.* ***Aim:*** *To evaluate and compare the dentinal microcrack formation after root-end cavity preparation with bur and ultrasonic tips using different imaging techniques.* ***Methodology:*** *Forty atraumaticaly freshly extracted, single-root premolars were collected for the study. All the samples were decoronated and working length was established. Biomchanical preparation was done till F4 protaper and obturated using single cone obturation technique. Root resection was carried out and number of cracks was evaluated using Stereomicroscope, Dental Operating Microscope and CBCT. Samples were then divided into four groups of 10 teeth each depending on the instrument used for retrocavity preparation: Group 1 (control): no preparation was done, Group 2: retrocavity prepared with stainless steel ultrasonic tip, Group 3: retrocavity prepared with diamond coated ultrasonic tip, Group 4: retrocavity prepared with stainless steel round bur. Samples were immersed in methylene blue dye and number of cracks were again evaluated using the three imaging techniques. Percentage increase in the number of cracks was calculated and data was subjected to statistical analysis using Wilcoxon and Kruskan Wallis Test. The level of statistical significance was set at 5% .* ***Results:*** *With stereomicroscope and Operating Microscope, maximum increase in the percentage of microcracks was observed in Group 2 (Stainless steel retrotip) followed by Group 3 (Diamond coated retrotip) and Group 4 (Stainless steel bur).* ***Conclusion:*** *Within the limitation of the study, it was concluded that there was increase in the percentage of microcracks after root end resection and root end cavity preparation. Stainless steel ultrasonic tips produced more dentinal cracks as compared to diamond-coated ultrasonic tips followed by stainless steel bur. Also, more number of microcracks was observed in stereomicroscope as compared to Dental Operating Microscope.*

Keywords: *Microcracks, Root End Resection, Root End Preparation, Ultrasonic Retrotip*

Introduction

Endodontic surgeries are indicated in cases of failed root canal cases, large periapical lesions, natural or iatrogenic obstructions. This surgical intervention involves root end resection, root end cavity preparation, root end filling and bacteria tight closure of the root canal system. The purpose of root end cavity preparation is to remove irritants from the root canal system which are inaccessible to the operator through a coronal entry.[1] Conventionally, the root-end cavity was prepared with stainless steel burs and low speed hand piece but had several disadvantages like difficult access, preparation not being parallel to canal and risk of perforation. The advent of ultrasonic tips provided numerous advantages over conventional burs including deeper cavity depths allowing more retention, preparations following line of root canal, thus preserving the canal morphology and cleaner surfaces than created with burs. Previously, stainless steel ultrasonic tips were developed but they had lesser cutting efficiency and longer preparation time. This led to the introduction of diamond coated and zirconium nitride retrotips.[2] Irrespective of the type of bur or ultrasonic tips used for retro preparation of cavity, the contact between the instrument and canal walls during preparation creates some stress in dentin and leads to microcrack formation. These microcracks can create a direct communication between the root canal and the periodontium which leads to invasion of the local bacteria in the apical ramifications, such as isthmuses, canal fins and lateral canals which can penetrates in these cracks and prevent further healing of the tissues. According to Saunders et al.,[3] most of the dentin cracks are found in 21% of roots after doing root end cavity preparation by using ultrasonic instrument tips and high-speed burs. Previous studies have used Stereomicroscopy, Scanning electron microscope (SEM), Cone Beam Computed Tomography (CBCT), Micro-computed tomography (micro-CT), Dental operating microscope for evaluation of dentinal microcracks after root end cavity preparation. Till date, no study has been done to evaluate microcrack formation using Stainless Steel round bur, Diamond and Stainless Steel ultrasonic tips under Stereomicroscope, Cone Beam Computed Tomography (CBCT) and Dental Operating Microscope. Thus, the aim of this study was to compare the dentinal microcrack formation after root end cavity preparation using different imaging techniques.

Materials and Methods

Ethical clearance for the study was attained from Institutional Ethical Committee. Forty freshly extracted premolars with straight canal and free of external cracks were selected and decoronated using a high-speed diamond bur to a standardized root length of 17 mm. A 10K file was inserted into the root canal until the tip of file was visible at the apical foramen and the working length was established by deducting 0.5 mm from this length. The samples were prepared with Protaper Universal (PTU) rotary file (Dentsply Maillefer, Switzerland) up to F4. Between the use of each file, the canals were irrigated with 5ml of 3% NaOCl (Neelkanth, Orthodent Pvt. Ltd, India) and at last 3ml of 17% Ethylenediamine Tetraacetic acid (Prevest Dentpro Limited) for 1 min followed by 5ml normal saline (Kunal Remedies Pvt. Ltd, India). Samples were obturated with gutta percha and AH plus sealer (Dentsply, Konstanz, Germany) by using single-cone technique. Samples were stored for 1 week at 37°C and 100% humidity to allow the sealer to set.[4]

Root End Resection and Root End Cavity Preparation

Coronal 2 mm roots were embedded in Putty impression material (Dentsply Aquasil Soft Putty) such that the long axis of root was perpendicular to the horizontal plane. In all the samples, apical 3 mm of the apex were resected perpendicular to the long axis of the root using H23LR Tungsten carbide bur (Komet, Gebr. Brasseler, Lemgo, Germnya) under continuous irrigation with water spray.[5] Samples were removed from putty blocks and stored in 1% methylene blue dye for 24 hours followed by rinsing in water for 1 minute to improve microcrack visualization. The number of microcracks were evaluated in all the samples using CBCT (Triana Tm Open Dental Software Nnt.), Stereomicroscope ((Alco StereoZoom, 40 x magnification) and Dental Operating Microscope (Prima Dnt Surgical Microscope, Labo America), 16 x magnification)

Grouping of Samples

All 40 samples were divided into 4 groups of 10 teeth each depending on the bur/tips used for retro-cavity preparation. Root end cavity was prepared in all samples unto depth of 3 mm:

Group 1: No cavity was prepared.

Group 2: Smooth stainless steel retrotip (LeSentier, Switzerland) was used at the power settings recommended by the manufacturer.

Group 3: Diamond-coated ultrasonic retrotip (Satelec Merignac, Cedex, France) was used with ultrasonic device at the highest power setting recommended.

Group 4: Stainless steel Round Bur (Dentsply) was used in slow speed contra-angle handpiece (Kavo, Biberach, Germany)

The root end preparation of each group was done under internal water cooling followed by rinsing with 5ml water. Samples were again stored in 1% methylene blue dye for 24 hours followed by rinsing in water for 1 minute to improve microcrack visualization. The number of microcracks formed after retro-cavity preparation were evaluated in all the samples using CBCT, Stereomicroscope and Dental Operating Microscope following the same protocol as in pre-operative microcrack evaluation.[6] If there were microcracks on the external surface of the root and on the internal root canal wall, this was accepted as having "crack," and the number was noted. As the number of microcracks observed preoperatively was different in each sample, the percentage of microcracks was calculated to standardize the procedure, and the increase in percentage number of microcracks was evaluated this is in accordance with the studies of Barreto et al.,[7] Singh et al.,[8] and Arias et al.,[9] Wilcoxon and Kruskan Wallis test were performed using Statistical Package for the Social Sciences 13.0 software. The level of statistical significance was set at 5%.

Results

The mean percentage increase in the number of dentinal cracks in the experimental groups from root resection to root end cavity preparation as observed under both Stereomicroscope and Dental Operating Microscope are shown in Table 1. Since no microcracks were observed with CBCT imaging, this method was excluded from evaluation. Maximum percentage increase in cracks as visualized under Stereomicroscope and Dental Operating Microscope were seen in Group 2 (Stainless Steel Retrotips) followed by Group 3 (Diamond Coated Retrotips) and Group 4 (Stainless steel burs). Inter-microscope comparison of percentage increase in number of microcracks is shown in Table 2. Although percentage increase in microcracks was more with Stereomicroscope than Dental Operating Microscope, this difference was statistically non significant.

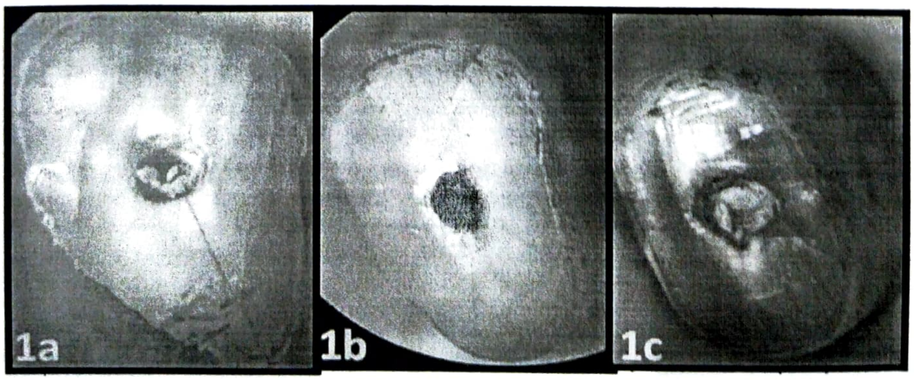


Figure 1 (a-c): Microcracks observed under stereomicroscope after root end cavity preparation with (1a) Stainless steel coated ultrasonic tip, (1b) Diamond coated ultrasonic tip, (1c) Stainless steel bur.

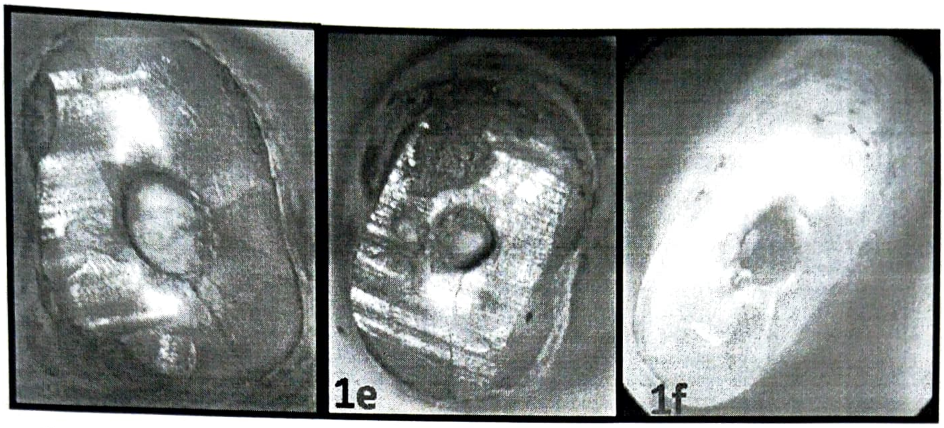


Figure 1 (d-f): Microcracks observed under dental operating microscope after root end cavity preparation with (1d) Stainless steel coated ultrasonic tip, (1e) Diamond coated ultrasonic tip, (1f) Stainless steel Bur

Table 1: Intergroup comparison of mean percentage increase in cracks seen under Stereomicroscope and DOM

	Percentage Increase in Cracks	
	Stereomicroscope	**DOM**
	Mean ± SD	**Mean± SD**
Group 1 (Control)	$.00 \pm .00^{a,b}$	$.00 \pm .00^{a,b}$
Group 2 (Stainless Steel Retrotip)	$105 \pm 64.33^{a,c}$	80 ± 63.24^{a}
Group 3 (Diamond coated Retrotip)	90 ± 73.78^{b}	70 ± 82.32^{b}
Group 4 (Stainless steel Bur)	35 ± 47.43^{c}	20 ± 42.16

P value < 0.05 was considered statistically significant. Values with same superscript in each column indicate statistically significant difference

Graph 1: Intergroup Comparison of Mean Percentage Increase in Cracks

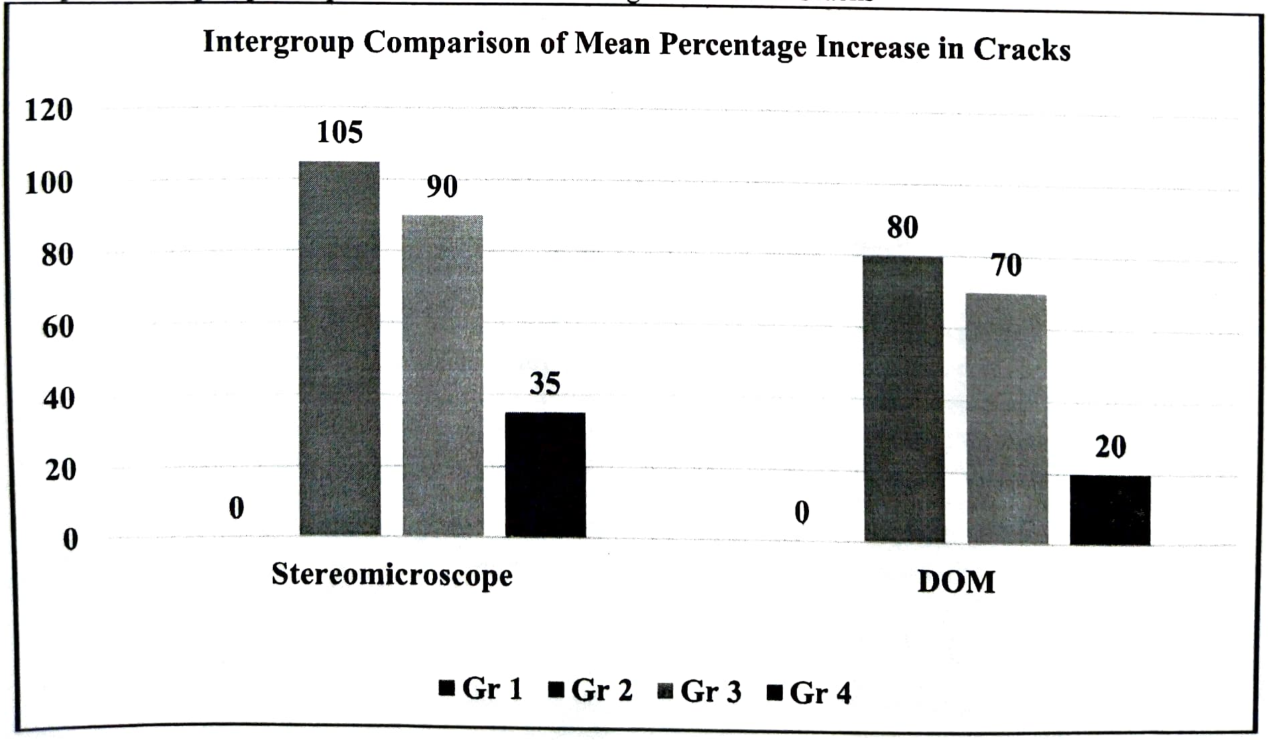
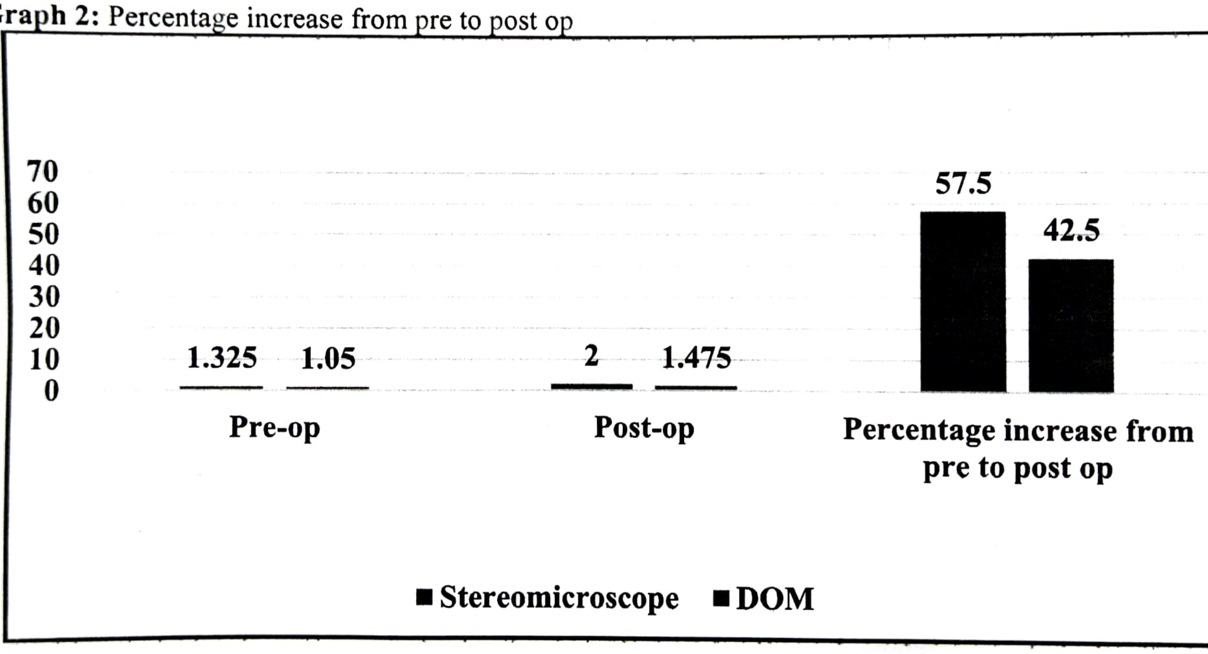


Table 2: Inter-microscope comparison of number of cracks Pre-operatively (after root end cavity preparation), Post-operatively (after rot end resection) and mean percentage increase in cracks

		Mean± SD	P value
Pre-op	**Stereomicroscope**	1.3250±.52563	<0.001, S
	DOM	1.0500±.22072	
Post-op	**Stereomicroscope**	2.0000±.93370	<0.001, S
	DOM	1.4750±.64001	
Percentage increase from pre to post op	**Stereomicroscope**	57.5000±67.51068	0.096, NS
	DOM	42.5000±63.59931	

SD: Standard deviation

Graph 2: Percentage increase from pre to post op



Discussion

The aim of this study was to compare the dentinal microcrack formation after root end cavity preparation using different imaging techniques. Standardization of the procedure was done to minimize the errors. Only freshly extracted, intact, non-carious, single-canal human mandibular premolars with single apical foramen were selected. Obturation was done using single cone technique as it applies minimal pressure as compared to other filling techniques that apply compaction forces on the root canal walls leading to dentinal microcrack formation.[10] Roots were resected 3 mm from the apex with the help of a micromotor handpiece and carbide bur since large number of apical ramifications and lateral canals exist at least 3 mm from the root end. Thus, root-end amputations of <3 mm may not remove all lateral canals and apical ramifications, increasing the risk of reinfection and eventual failure. The traditional technique uses a bevel angle of 45–60 degrees to facilitate access and visibility when using large surgical instruments. The modern technique uses a shallow bevel angle of 0–10 degrees to expose fewer dentinal tubules. Minimization of the bevel angle during root resection is one of the most important developments in endodontic microsurgery. Therefore, in our study, the bevel angle was kept at zero degrees.[11] Various methods have been employed to detect microcrack formation after root end cavity preparation like

Scanning Electron Microscope, Stereomicroscope, Dental Operating Microscope, Cone Beam Computed Tomography. In this study, methylene blue dye technique was used along with dental operating microscope, stereomicroscope and CBCT which, according to Wright et al. is a precise method for studying cracks.[12] Results of our study showed that Group 2 (Stainless Steel Retrotip) showed maximum percentage increase in microcracks after retro cavity preparation followed by Group 3 (Diamond coated retrotip) and Group 4 (Stainless Steel Bur). This may be attributed to the fact that Stainless steel retrotips are less efficient than Diamond coated ultrasonic tips and prepare retrocavities in more time than diamond coated ultrasonic retrotips. More contact time of Stainless steel tips with tooth surface leads to more frictional heat thereby producing more number of cracks. Also, it has been observed that Stainless steel ultrasonic tip bounces off the root surface during retro cavity preparation resulting in ragged and chipped surface, thus contributing to microcrack formation. This is in accordance to study by Gunes et al., and Aydinbelge et al.,[13] who reported that stainless steel ultrasonic tips required more time for root end cavity preparation than diamond coated ultrasonic tips. Similarly, Navarre & Steiman et al.,[14] also reported that diamond coated retrotip prepared root-end cavity faster than the stainless steel tip. Batista de Faria-Junior et al.,[15] and Khabbaz et al.,[16] also observed that diamond-coated tips have better cutting efficiency than stainless steel retrotips. Stainless steel burs produced least number of cracks as compared to ultrasonic retrotips for the same reason stated above that they require less time for retrocavity preparation than ultrasonic tips leading to fewer cracks. Gondim et al.[17] reported that no significant differences in chipping and cracking area were detected in treatments with stainless steel burs and diamond-coated tips, but stainless steel retrotips showed a greater number of teeth with cracking and a larger chipping area, probably due to the longer preparation time needed. In the present study, a significantly higher percentage of dentinal microcracks were observed with Stereomicroscope than Dental Operating microscope. However, the differences were not statistically significant. This is in accordance with some previous studies that reported more no. of microcracks with stereomicroscope than dental operating microscope.[18,19,20] No dentinal microcracks were observed with CBCT method. This is in accordance with the study by Capar and coworkers who reported no microcracks were detected with CBCT. Since there was the increase in the percentage of microcracks after root end cavity preparation with stainless ultrasonic tips, diamond coated tips and stainless steel bur as observed with stereomicroscope and dental operating microscope, null hypothesis was rejected. The limitation of this study includes the lack of clinical environment to simulate the oral environmental conditions.

Conclusion

Within the limitations of this study, it can be concluded that there is a significant increase in the induction and propagation of microcracks from root end resection to root end cavity preparation and stainless steel ultrasonic tips produced more dentinal cracks as compared to diamond-coated ultrasonic tips followed by stainless steel bur. Also, more number of microcracks was observed in stereomicroscope as compared to dental operating microscope. Thus, it can be proposed that in clinical scenario, diamond coated ultrasonic retrotips should be preferred over stainless steel burs or retrotips since they provide better control of retrocavity preparation than burs and produce fewer cracks than stainless steel tips. Further studies should be directed at conducting such researches with newer modalities of retrocavity preparation and performed in vivo to extrapolate the results clinically.

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ORIGINAL RESEARCH

Comparative Evaluation of Different Storage Media on the Survival of pdl Cells: An In-Vitro Study

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ABSTRACT

Introduction: The extraoral dry time and the storage media used to store teeth before reimplantation have the greatest impact on the prognosis of avulsed teeth.

Aim: The purpose of this study was to evaluate and compare the efficacy of different storage media on viability of periodontal ligament cells at different time periods.

Materials and Methods: Fifty freshly extracted sound teeth with healthy PDL were selected for the present study. Teeth were divided into four groups with 10 teeth each depending on the storage media (HBSS, COCONUT WATER, ALOE VERA, MILK) used for storing freshly extracted teeth. Remaining 10 samples were divided into 2 groups with 5 teeth each to serve as control. Cell viability in each group was checked at 1hr, 2hrs, 4 hrs, 8 hrs and 24 hrs time period. The data were tabulated and subjected to statistical analysis using One way Analysis of Variance (ANOVA) with post hoc analysis (Tukey HSD) for comparison of means. The statistical software namely SPSS 21.0 was used to analysis of the data.

Results: The results indicated PDL cell viability was maximum at 1 hour time interval in all the groups and decreased over a period of time. Also, HBSS showed maximum percentage of viable PDL cells followed by Coconut water, Aloe Vera and milk at all time intervals tested.

Conclusion: It can be concluded that HBSS is the gold standard for the preservation of viable cells for a longer period followed by Coconut water and Aloe Vera.

Keywords: Periodontal Ligament Cells, HBSS, Coconut Water, Aloe Vera, Milk

INTRODUCTION

Tooth avulsion is defined as the complete loss of a tooth out of the alveolar bone socket as a result of an accident and represents severe traumatic dental injury. In children and adolescents, tooth avulsion typically affects the incisors, and it is frequently accompanied with unpredictability in the course of therapy and a financial burden. The most common age range is between 7 and 14 years.[1] Prognosis after reimplanting an avulsed tooth is largely dependent on extra-alveolar time and the storage media used to store the avulsed tooth. Therapeutic effectiveness of storage media depends on its osmolarity, pH, nutrient content,

and temperature of the media in order to sustain the viability of periodontal cells. The periodontal ligament cells should be able to undergo mitosis to create clones of damaged PDL fibroblasts that will cover the damaged surfaces of the root. Storage media should also be sterile, inexpensive, and readily available.[2] Various storage mediums are available like Hanks Balanced Salt Solution (HBSS), Aloe Vera, Coconut Water, Milk, tap water, saliva, ViaSpan, propolis, culture media, egg albumin, salvia officinalis, morusrubra, Emdogain, Eagle's medium, cryoprotective agents are available.[3] HBSS is a sterile, physiologically balanced isotonic standard salt solution that is commonly used in biomedical research to support the growth of various cell types. This solution is nontoxic; biocompatible with PDL cells; and the ingredients in HBSS can sustain and reconstitute the PDL cells depleted cellular components. HBSS is essential for cell survival because it is non-toxic, highly nutritive, and has an appropriate pH balance and osmolality. However, HBSS is not readily available to be used by the patient at the accident site.[4,5] Aloevera is a cactus-like plant in the Liliaceae family. It contains anti-inflammatory, antioxidant, antibacterial, antifungal, and anticarcinogenic properties as well as vitamins, enzymes, minerals, sugars, salicylic acids, and amino acids. For up to 9 hours, aloe vera at 10%, 30%, and 50% concentrations performed similarly to supplemented culture media.[4,6] The coconut, also known as the "tree of life," is a natural drink that is produced biologically and hermetically inside the coconut. Coconut water is the liquid endosperm of the coconut, and it is high in amino acids, proteins, vitamins, and minerals. It is a hypotonic solution that is more acidic than plasma and has a specific gravity of about 1.020, which is comparable to blood plasma.[5,7] Milk is significantly better than other solutions because its physiological properties, such as pH and osmolality, compatibility with PDL cells; however, because it is easy to obtain and free of bacteria, it is critical that it be used within the first 20 minutes after avulsion. Milk, as a gland secretion, contains epithelial growth factor, which stimulates the proliferation and regeneration of Malassez's epithelial cell rests and activates alveolar bone resorption. This eventually helps to isolate the bone tissue from the tooth and reduces the likelihood of ankylosis. Milk was as effective as HBSS for storing avulsed teeth for up to 6 hours, but it could not revive the degenerated cells.[5,8] In addition to storage media, extraoral time has been shown to influence maintaining cell viability. The purpose of this study is to evaluate and compare the efficacy of different storage media on viability of periodontal ligament cells at different time periods. Till date, no study has been done to comparatively evaluate different storage media (HBSS, Aloe Vera gel, Coconut water, Milk) at different timings on the survival of PDL cells. So, the aim of the study was to compare & evaluate the different storage media on the survival of periodontal ligament cells.The null hypothesis was that there is no difference in the number of viable cells in different storage media at different time intervals.

MATERIALS AND METHODS

The current study was conducted in the Dept. of Conservative Dentistry and Endodontics at IDST, Modinagar, UP after ethical approval from the Institutional Ethical Committee. Fifty freshly extracted teeth with intact crowns, closed apexes, and healthy PDL were obtained from the Dept of Oral & Maxillofacial Surgery in, IDST College, Modinagar.UP. Teeth with intact crown, closed apex and healthy PDLwere selected for the study. Teeth with cracks, fractures and bone losswere excluded from the study. Immediately after extraction, all the teeth were stored in respective storage media for the study purpose in order to maintain equal baseline standardity for viable cells. Fifty teeth were divided into four groups with 10 teeth each depending on the storage media used for storing freshly extracted teeth. Remaining 10 samples were divided into 2 groups to serve as control:

Group 1 (N = 5) Positive Control, Group 2 (N = 5) Negative Control (Tap Water), Group 3 (N = 10) Hbss, Group 4 (N = 10) Aloe Vera Gel, Group 5 (N = 10) Natural Coconut, Group 6 (N = 10) Milk.

Coronal 3mm of periodontal ligament was removed with sterile curette to remove the cells that might have been damaged during extraction and the teeth were transferred to storage media by holding the crown portion with extraction forceps and not disturbing the viable cells on root surface. The PDL tissue was scrapped and collected from the root portions of the teeth with the help of sterile curette from different storage media. These were incubated for 30 minutes in 15ml Falcons tubes with a 2.5ml solution of 0.2mg/ml-1 of collagenase and 2.4mg/ml-1 dispase grade II in phosphate buffered saline. After incubation, 50 μl of foetal bovine serum was added to each test tube. All the tubes were centrifuged for 4 minutes at 1000rpm.After centrifugation, the supernatant was removed with sterile micropipettes, and the cells were labelled with trypan blue staining. After the trypan blue exclusion test, the cells are viewed under 40X magnification with the help of hemocytometer to count the viable and non-viable cells.[4] The cells that take up the stain are non-viable cells and the cells that do not take the stain are viable cells. [(Total cells - Stained cells)/ Total Cells] X100 was used to calculate the viable cell percentage. Cell viability in each group were checked at 1 hr, 2 hrs, 4 hrs, 8 hrs and 24 hrs time period. Between each time period, the samples were stored in their respective storage media. The results were tabulated and subjected to statistical analysis using One way Analysis of Variance (ANOVA) with post hoc analysis (Tukey HSD) for comparison of means. The statistical software namely SPSS 21.0 was used to analysis of the data. P value <0.05 was considered statistically significant.

RESULTS

Positive control (collagenase and dispase II) showed maximum number of viable PDL cells at different time periods (1,2,4,8 and 24 hrs) while the negative control (Tap water) showed least number of viable cells. The results indicated that HBSS showed maximum percentage of viable PDL cells followed by Coconut water, Aloe vera and milk. (Table 1) Viability of cells in decreasing order was Group 1 (Positive Control)>Group 3 (HBSS)>Group 5 (Coconut water)>Group 4 (Aloe Vera)>Group 6 (Milk)>Group 2 (Tap Water) at all the time periods tested. Same superscript in each row depicts, statistically non-significant difference at different time intervals. Same superscript across a column depicts, statistically non-significant difference between the groups.

Table 1: Inter and intra group comparison for percentage of viable cells at different time intervals among different groups

Groups/ Time intervals (hrs)	1 hr	2 hr	4 hr	8 hr	24 hr
Group 1 (positive control)	67.0±2.75	-	-	-	-
Group II (Tap water)	$9.2±0.83^{a}$	$2.2±2.48^{abcd}$	$0.2±0.4^{be}$	$0.0±0.0^{ce}$	$0.0±0.0^{d}$
Group III (HBSS)	$54.0±2.0^{a}$	$52.5±1.0^{ab}$	$51.6±0.84^{b}$	49.9±0.99	47.0±0.84
Group IV (Alovera Gel)	$37.2±0.91^{1}$	$30.9±0.99^{a}$	$29.4±1.42^{a}$	26.2±3.22	11.8±1.54
Group V (Coconut water)	$42.8±1.22^{1}$	$42.0±1.15^{ab}$	$40.2±1.61^{b}$	$38.0±1.41^{c}$	$36.8±0.78^{c}$
Group VI (Milk)	26.0±0.94	$21.2±0.99^{a}$	$19.2±0.99^{a}$	11.7±1.25	3.50±1.08

DISCUSSION

The aim of this study was to compare & evaluate different storage media on the survival of periodontal ligament cells. Results of our study showed that maximum percentage of viable cells was seen in Group 3 (HBSS) followed by Group 5 (Coconut water), Group 4 (Aloe Vera gel), Group 6 (Milk) and Group 2 (Tap Water) at all time intervals tested. Group 3 (HBSS) showed maximum number of viable cells at all time periods when compared to other groups. This can be attributed to its optimal pH (7.4), osmolality (280 mosmol kg-1) and its constituents. It contains sodium chloride, D-glucose, potassium chloride, sodium bicarbonate, potassium phosphate, calcium chloride, and magnesium sulphate (monobasic) anhydrous.[2] These key metabolites helpreconstitute the depleted cellular components of the PDL cells, thus maintaining their viability for longer duration. Studies have reported that root resorption is delayed when avulsed tooth is soaked in HBSS for 30 minutes after extra oral dry time of 15-60 minutes.[9] The results of the study are in agreement with those of Hwang et al.who reported that HBSS maintains 90% of cell viability for 24 hours.[10]Adeli et al also reported maximum cell viability with HBSS as storage media when compared with tap water, whole milk, green tea extract and sucrose.[11] However, the results of this study are contradictory to study by Souza et al who reported that HBSS is inferior to milk. This difference could be attributed to lower temperature of HBSS and milk in their study. Lower temperature decreases the efficacy of HBSS due to low nutrient availability and formation of tetrazolium salts in formazan crystals. Group V (Coconut water) showed less percentage of viable cells than HBSS but more than other groups at all time intervals. Natural coconut water is sterile and has 93% water and 5% sugar, which gives it a high osmolalityIt contains a lot of proteins, vitamins, and minerals like potassium, calcium, and magnesium. Also, it shows mitotic, clonogenic activity and growth promoting characteristics that helps maintain the viability of PDL cells. Quimol et al stated that coconut water helps the cells form a monolayer by adhering to the culture wells and helps in maintaining viability similar to HBSS.[5] The findings of the study disagree with Moreira-Neto etal who stated that coconut water at 37^0C was less effective than milk in maintaining the cell viability.[13] Aloe vera gel (Group 4) showed less cell viability than HBSS and Coconut water but more than milk and tap water. This could be attributed to its optimal pH and its constituent parenchymal tissue (inner pulp) which contains proteins, lipids, amino acids, and other vital nutrients. Also, it contains catalase enzyme, an antioxidant that converts hydrogen peroxide to water and oxygen and suppression of the generation of these free radicals may improve the effectiveness of cell preservation and prevent lipid peroxidation.[14] Martin etal stated that the high success rate of alovera extract in protecting the cell viability might be due to its antibacterial and antifungal properties.[15] The results of our study are in accordance to the study conducted by Fulzele et al who demonstrated that aloe vera maintained PDL cells viability over a period of 120 mins.[14]Buttke et al. also proposed that storing avulsed teeth in medium containing one or more antioxidants found in alovera extract could improve reimplantation success.[16] Moazzami F. et al stated that aloe vera may be useful in the replantation of avulsed teeth because of its fibroblast stimulating properties.[17] Group 6 (Milk) showed less percentage of viable cells than HBSS, coconut water and aloevera but more than tap water at all time intervals tested. Milk has osmolality of 270 mOsm/kg and pH of 6.5 to 7.2, which is similar to extracellular fluid. The current study's findings contradict those of Olson et al, who reported that milk had a significant advantage over HBSS at 8 and 12 hours. Lekic et al stated that milk was effective for a short period of time and lost its effectiveness after 2-6 hours in vitro, and only cold milk was suitable for the preservation of the proliferation capacity of PDL cells.[18] Since milk is readily available in almost all situations, so it is widely accepted as a storage medium for short-term storage of avulsed teeth. Group 2 (Tap Water) showed least number of viable cells initially and gradually become zero at 24 hrs time interval. In this

study, tap water was used as a negative control. The pH of tap water ranges from 7.4 to 7.79, with an osmolality of 30 mOsm/kg. It is unsuitable for use as a storage medium for avulsed teeth due to bacterial contamination, hypotonicity, non-physiological pH, and osmolality, which promotes PDL cell lysis.[10,19] The results of our study are in agreement with several studies who found that cells stored in water do not retain their morphology, resulting in visible destruction and rapid cell death.[20] The findings were consistent with Blomlof's study, which found that water is damaging to PDL cells and is not a good storage medium at any time.Some studies have suggested that it could be used as a storage medium for very short periods of time where there are no other options. However, results of our study indicated that tap water was the least desirable storage medium. In view of this, tap water should be used only to avoid tooth dehydration, but it is inadequate for conservation of avulsed teeth.[21,22] Results of the present study showed that PDL cell viability was maximum at 1 hour time interval in all the groups and decreased over a period of time. Since there is no study done till date to evaluate the efficacy of HBSS, Coconut water, Aloe vera, Milk and tap water on the survival of the periodontal ligament cells at different time intervals, the results of this study cannot be contradicted or corroborated. Since there is a difference in the number of viable cells in different storage media at different time intervals, the null hypothesis was rejected. There is no ideal storage media till date, hence according to the results obtained HBSS and Coconut water can be used as long-term storage media and Aloe vera and Milk can be used as a short-term storage media.

CONCLUSION

Within the limitations of the study, it can be concluded that HBSS is the gold standard for the preservation of viable cells for a longer period followed by Coconut water and Aloe vera. In absence of HBSS, Coconut water is the best choice for the storage of avulsed teeth as it is easily available. Milk can also be used as short-term storage media of avulsed teeth. Further studies should be directed with different storage medias and also with different time periods, to evaluate which storage media best suits for the preserving the avulsed teeth for a longer period of time.

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Comparison of the Microleakages of Four Root-End Filling Materials: An In Vitro Study

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Abstract

Introduction: When a nonsurgical endodontic treatment is ineffective, surgery is necessary. This entails putting a retrofilling to seal the tooth's apex. Exposing the lesion, performing a curettage, exposing the root apex, resecting it, preparing the root end, and lastly filling the cavity with the proper material are all steps in endodontic surgery. Thus, the aim of this study is to compare the apical microleakage of four root-end filling materials in cavities prepared using ultrasonic retro tip in in vitro conditions.

Materials and Methods: An in vitro study was conducted on 60 extracted single-rooted teeth and was cut at the cementoenamel junction (CEJ). They were biomechanically prepared and obturated. Apical 3 mm root-end resection was done using a diamond disc. Root-end cavities were made using an ultrasonic retro tip. Teeth were separated into four groups and filled with SuperEBA® ethoxy-benzoic acid (EBA; Keystone Industries, New Jersey), mineral trioxide aggregate (MTA), Biodentine (Septodont, France), and TotalFill Bioceramic Root Repair Material (BC RRM; FKG Dentaire Sàrl, Switzerland). The samples were kept in methylene blue dye and split longitudinally. The degree of dye penetration was observed under a stereomicroscope and scored. Finally, the results were analyzed.

Results: TotalFill BC RRM and Biodentine showed the least apical microleakage ($p < 0.05$). Group 1 samples had the highest mean microleakage, followed by Group 2, Group 3, and Group 4 samples.

Conclusion: All of the sample groups showed some evidence of microleakage, but not all of the samples showed leaking. SuperEBA (Group 1) demonstrated the highest microleakage when compared to the other groups.

Categories: Dentistry
Keywords: root canal treatment, endodontics, totalfill bioceramic root repair material, retrograde filling, apical microleakage

Introduction

A root canal treatment is the most commonly employed treatment to disinfect and fill the root canal system three-dimensionally. However, sometimes, despite thorough chemomechanical preparation and obturation, orthograde treatment may fail [1]. Periapical surgery is indicated when there is excessive root canal calcification, separated instruments extending beyond the apex, iatrogenic perforations, ledges or shoulder, and teeth restored with crowns or post and core. It may also be used in symptomatic cases that have not responded to conventional root canal treatment [2]. Periradicular surgery includes debridement and curettage, root apex exposure and resection, and retrograde cavity preparation followed by appropriate filling material insertion [3]. In addition, after a 1-year postoperative follow-up, the success rate of periapical surgery for patients with periapical lesions was 73.9% [4]. One of the typical clinical conditions affecting the periradicular tissues are periapical lesions [5]. One of the most commonly performed procedures for surgical endodontic treatment is retrograde obturation, which uses a variety of techniques and materials [6].

A retrograde filling is important to create an apical seal that prevents the microleakage of remaining irritants into periradicular tissues [7]. The prime factor that impacts a successful periapical surgery is the selection of retrograde filling material. Initially, amalgam, silver cones, gold foil, gutta-percha (GP), composite resins, zinc oxide eugenol (ZOE) cement, polycarboxylate cement, zinc phosphate cement, glass ionomer cement (GIC), and titanium screws were used for the same [8]. SuperEBA® ethoxy-benzoic acid (EBA) Cement (Keystone Industries, New Jersey) is a type of reinforced ZOE cement with 68% EBA and 32% eugenol. ZOE cement as a root-end filling material was unsuccessful; nevertheless, the reinforced variant showed better results [9]. Mineral trioxide aggregate is considered an ideal retrograde material [1]. Mineral trioxide aggregate (MTA) possesses significant qualities, such a high pH, biocompatibility, fixing power despite humidity, periradicular regeneration, and osteoinductive ability [10]. Biodentine (Septodont, France) is calcium silicate-based cement with high biocompatibility. It shows better physical and chemical properties, such as reduced time for setting and increased mechanical properties that make it a compatible root-end filling material [11]. A reparative biocompatible substance that seals perforations and does not

irritate surrounding tissues is required in cases of extensive perforation [12].

TotalFill Bioceramic Root Repair Material (BC RRM; FKG Dentaire Sàrl, Switzerland) is a premixed material either in putty or syringe form. Its main components are calcium silicates and zirconium oxide. This material showed superior healing in periradicular surgery. It sets fast and shows improved handling properties. In addition, biocompatibility is analogous to MTA [13]. Apical seals attained through a retrograde filling material can be evaluated by the depth of the dye penetration, fluid-filtration technique, radioisotope or bacteria penetration, or electrochemical methods. The dye penetration technique is the prevalent and easily performed method [14]. The fluid filtration technique evaluates the endodontic and restorative sealers' capacity for sealing. As a result, this method has established credibility in the field of study evaluating apical and coronal microleakage. Because of this, compared to the dye method, the fluid filtration method relied on quantitative measurements of fluid passage within the interfaces; both procedures produced results that were comparable in earlier studies [15]. To date, no in vitro studies have been conducted to compare and evaluate apical microleakage after using SuperEBA, MTA, Biodentine, and TotalFill BC RRM in cavities prepared using ultrasonic retro tips [16,17]. The present in vitro study aims to compare the apical microleakage of four root-end filling materials in cavities prepared using ultrasonic retro tips and evaluate the results. The null hypothesis was that there would be no significant difference in the apical microleakage amid the four chosen materials.

Materials And Methods

The sample size was calculated using the formula $n = Z^2 P (1-P) d^2$, where n is the sample size, Z is the statistic corresponding to the level of confidence, and P is the expected prevalence. A power of 0.80 with an alpha (α) level of 0.05 (confidence level = 95%), and a sample size of 60 was considered for the total samples. A total of 60 single-rooted extracted teeth, which were periodontally compromised and indicated for extraction, were collected from the Department of Oral & Maxillofacial Surgery, IDST. Soft tissues and deposits were mechanically removed from all the samples using Gracey curettes, and teeth were inspected under a stereomicroscope microscope (Carl Zeiss, Jena, Germany) for examining the number of canals, cracks/defects, and decay. The specimens were stored in 10% formalin until use.

Teeth with single root and single canal, closed apex, without fractures, resorption, or cracks were included. Multirooted teeth and teeth with extra canals, open apex, root caries, and calcification were excluded. The coronal part of the teeth was sectioned horizontally along the long axis with a diamond disc, at the cementoenamel junction (CEJ) level or below, to standardize the root length (15 mm).

Pre-operative radiography was performed, and access openings were created with an access bur (Dentsply Maillefer, USA). The working length was estimated radiographically with a #10 K-file, and a #40 K-file was used as the master apical file (Mani Inc., Japan). Ethylenediaminetetraacetic acid (EDTA) liquid irrigation was performed first (Prevest DenPro, India), and then 5% sodium hypochlorite irrigation was performed (Prevest DenPro, India), followed by saline irrigation. The canals were dried and obturated with lateral compaction technique using 2% gutta-percha (GP) cones (Meta Biomed, Korea) and AH Plus (Dentsply Maillefer, Ballaigues, Switzerland) as the root canal sealer.

Following obturation, cavities were filled with composite resin. The treated teeth were kept in saline for one week. Then, teeth were kept in an incubator (Binder, Tuttlingen, Germany), which has a specification of 535 L of interior space with a footprint of just 0.58 m2 at 100% humidity at 37 °C for five days. The apical 3 mm was cut using a straight fissure bur. Class I cavity was prepared in the root end with an ultrasonic retro tip to a depth of 3 mm. The samples were randomly divided into four groups with 15 teeth each: Group 1 (N = 15) retrograde cavity filled with SuperEBA, Group 2 (N = 15) with MTA, Group 3 (N = 15) with Biodentine, and Group 4 (N = 15) with TotalFill BC RRM.

The materials were manipulated according to the manufacturers' instructions, followed by filling the cavities. The teeth were stored in 100% humidity at 37 °C for five days. The prepared retro-cavities underwent cleaning, saline irrigation, and drying. Then, they were coated with nail varnish, except for the apical 1 mm, and dried. Next, the teeth were placed in 1% methylene blue dye for up to 48 h. The roots were washed and split into longitudinal sections along the long axis using a diamond disc. Dye penetration was examined under a stereomicroscope, and the scoring was done on a scale of 0 to 4 (Figure 1).

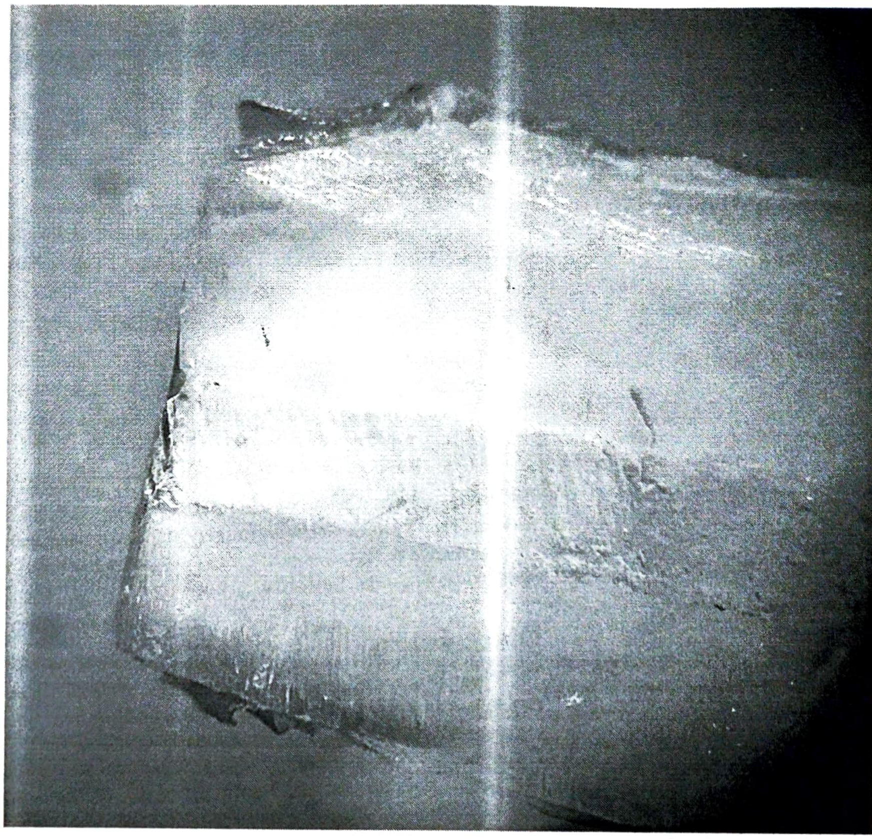

FIGURE 1: Stereomicroscopic image of the setup tested

This in vitro study was conducted in the Department of Conservative Dentistry and Endodontics at Institute of Dental Studies & Technologies (IDST), Kadrabad, Modinagar, Ghaziabad, Uttar Pradesh, India. Ethical clearance was obtained from the Institutional Review Board (IRB) with IRB number IDST/IEC/2019/PG/11.

Statistical analysis

Data were analyzed with IBM SPSS Statistics for Windows, Version 21 (Released 2012; IBM Corp., Armonk, New York, United States. As the main outcome variable was ordinal, non-parametric tests, such as Kruskal-Wallis and Mann-Whitney U tests, were utilized for the analysis.

Results

Table *1* shows the description of microleakage scores among all the study groups.

Microleakage score					
	N (number)	Mean (M)	Standard deviation	95% confidence interval for the mean	
				Lower bound	Upper bound
Group 1	15	1.4000	0.63246	1.0498	1.7502
Group 2	15	0.8667	0.51640	0.5807	1.1526
Group 3	15	0.4000	0.50709	0.1192	0.6808
Group 4	15	0.2000	0.41404	-0.0293	0.4293

TABLE 1: Description of the microleakage scores among all the study groups

Table *2* shows the post-hoc pairwise comparison by the Mann-Whitney U test.

Comparisons	P-values of the pairwise comparison by the Mann-Whitney U test
Group 1 vs. Group 2	0.019
Group 1 vs. Group 3	<0.001
Group 1 vs. Group 4	<0.001
Group 2 vs. Group 3	0.022
Group 2 vs. Group 4	0.001
Group 3 vs. Group 4	0.240

TABLE 2: Post-hoc pairwise comparison by the Mann-Whitney U test

The findings indicate that microleakages in Group 3 and Group 4 samples were significantly lesser than in those in Group 2 samples and were further significantly lower than those in Group 1 samples. No significant difference could be found between Group 3 and Group 4 samples. The mean microleakage of Group 1 samples was maximum, followed by Group 2, Group 3, and Group 4 samples.

Discussion

The accomplishment of periapical surgery is highly dependent on a proper apical seal. Retrograde filling materials are proposed to limit or avoid leakage into periapical tissues [15]. This study intended to test the microleakage of four retrograde materials. Ultrasonic retro tips are better than burs for retro preparation. The preparation of root-end cavity with ultrasonic tips causes negligible destruction to the root canal morphology. They are precise, conservative, and cleaner. The cutting bevel is 90° to the long axis of the root, which reduces the number of patent dentinal tubules at the open end and minimizes microleakage [18].

Ishikawa et al. assessed the retrograde cavity preparation with US retro tip and concluded that the use of US retro tip reduced the time taken in root-end cavity preparation [19]. The resulting cavities were more precise, and the US tips were more efficient in cutting than conventional burs. In this study, stainless-steel ultrasonic tip with diamond coating was used. The angle of root-end resection affects the leakage, so a 90° resection angle was selected here as it is considered more acceptable by previous studies. A resection depth of 3 mm reduces the lateral canals by 93% and apical ramifications by 98% [20].

The most commonly used method to evaluate the sealing property of retrograde materials is dye leakage. It can provide an estimate of the sealing property in various clinical conditions. In the present study, the linear penetration of 1% methylene blue dye was measured. Methylene blue is commonly used because of its small molecular weight that aids in penetrability [21]. The disadvantage of this method is that the dye molecules are smaller in size than bacteria, which can result in an overestimation of the bacteria's penetration levels due to microleakage [20]. Lucena-Martin et al. showed that the transverse root section method results in the loss of dye and dentine portion [22]. Consequently, the longitudinal sectioning method was performed here to evaluate dye penetration into filling materials.

Epoxy resin-based AH Plus sealer shows high flowability, and it can penetrate dentinal tubules at deeper levels. Increased polymerization boosts the interlocking of the sealer material and dentin [23]. Therefore, in this study, AH Plus root canal sealer was chosen for obturation. Of all the materials used for retrograde filling, the least microleakage was observed for TotalFill BC RRM (Group 4), followed by Biodentine (Group 3), MTA (Group 2), and SuperEBA (Group 1). SuperEBA is broadly studied for retrograde fillings, and it has shown satisfactory properties. Greer et al. and Suntimuntanakul et al. observed that SuperEBA EBA Cement shows a higher sealing property when compared to a few other retrograde filling materials [24]. The results of our study are in agreement with other studies in which MTA showed improved marginal seal than other retrograde filling materials, such as GIC, amalgam, light cure GIC, and SuperEBA [25]. This can be because of the hydroxyapatite-like crystal formation at material-root canal dentine interfaces, which results in excellent adhesion preventing the penetration of the dye [26]. MTA has always shown less leakage than SuperEBA; there was no or minimal dye leakage in the majority of MTA specimens [27]. Similarly, Bates et al. traced microleakage in dental amalgam, SuperEBA, and MTA and concluded that it was the least in MTA [28]. Biodentine shows superior characteristics to MTA as it sets faster, thus reducing the risk of bacterial contamination [29]. Biodentine exhibits superior sealing properties than MTA [30]. In addition, it exhibits better biomineralization than MTA, with broader calcium-rich layer formation. Radeva et al. also found similar results as this study; they concluded that Biodentine shows greater sealing ability than MTA [31].

TotalFill BC RRM is available in the premixed syringe delivery system or putty form. It is extremely resistant

to washout. It has calcium phosphate monobasic as an additional agent that enhances hydroxyapatite formation. It shows properties, such as wear resistance, biocompatibility, chemical durability, and aesthetics [32].

Nonetheless, this study has some limitations. Instead of employing a scanning electron microscope (SEM) or confocal microscope, which may have provided significantly more information and reliable results, the investigation was conducted with a rather limited sample size. The research used only a few materials other materials are not tested, so it could be a limitation. The materials used in the study also will have limitations regarding their properties and hence in the future, a long-term trial could be done on various other materials. As a result, additional research including more samples is needed.

Conclusions

Although not all of the samples had leakages, all of the sample groups displayed some degree of microleakage. When compared to the other groups, SuperEBA demonstrated the highest level of microleakage. Comparing the two materials to the other materials, TotalFill BC RRM and Biodentine demonstrated the least amount of apical microleakage. Therefore, it is possible to suggest using these materials. A larger sample size should be used in in vivo experiments in the future to study the interactions between the sealing cement that were used, as well as the therapeutic significance and consequences of solubility over time.

Additional Information

Disclosures

Human subjects: All authors have confirmed that this study did not involve human participants or tissue. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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GRAPHENE IN DENTISTRY

A Review

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Abstract

Graphene has many unique properties and research shows it has many applications in dentistry. Though there are challenges seen in the use of Graphene, Graphene has shown promising results in Dentistry.

INTRODUCTION

Graphene, a single layer of carbon atoms arranged in a hexagonal lattice, has been the subject of intense research in recent years due to its unique properties. These properties include high electrical conductivity, mechanical strength, high thermal conductivity, and biocompatibility, which make it a promising material for use in various fields, including dentistry.

APPLICATIONS IN DENTISTRY

One of the main applications of graphene in dentistry is in the development of dental restorative materials. Traditional dental restorative materials, such as amalgam and composite resin, have certain limitations, such as poor mechanical properties, low durability and poor biocompatibility. Graphene, on the other hand, has excellent mechanical properties, high durability and biocompatibility, making it a suitable material for dental restorative materials.

Graphene-based composites have been developed for use in dental restorations, with the aim of improving the mechanical properties and biocompatibility of traditional dental restorative materials. In a study published in the Journal of Dentistry, graphene-based composites were found to have improved mechanical properties, high durability and better resistance to wear compared to traditional composite resins.[1] Furthermore, in a study published in the Journal of Biomedical Materials Research Part A, graphene-based composites were found to have improved biocompatibility compared to traditional composite resins.[2]

Another application of graphene in dentistry is in the development of dental implant materials. Dental implant materials, such as titanium, have certain limitations. Graphene, on the other hand, has excellent biocompatibility and Osseo integration (the process of the implant fusing with the surrounding bone tissue) properties, making it a suitable material for dental implant materials.

Graphene-based composites have been developed for use in dental implant materials, with the aim of improving the biocompatibility and osseointegration properties of traditional dental implant materials. In a study published in the Journal of Biomedical Materials Research Part B: Applied Biomaterials, graphene-based composites were found to have improved biocompatibility and osseointegration properties compared to traditional titanium dental implant materials.[3] Another study found that Graphene Oxide (GO) coated titanium implant surfaces significantly improved the osteogenic differentiation of human bone marrow-derived mesenchymal stem cells.[4]

In addition to restorative and implant materials, graphene has also been explored as an antimicrobial agent in dentistry. Microbes such as Streptococcus mutans, a primary causative agent of dental caries, can colonize on the surface of restorative materials and dental implants leading to secondary caries. Graphene has been shown to have potent antimicrobial activity against a wide range of microorganisms, including S. mutans.[5] This opens up the possibility of incorporating graphene into dental restorative and implant materials to improve their antimicrobial properties.

CHALLENGES

Despite the promising potential of graphene in dentistry, there are still some challenges that need to be addressed before its widespread use in clinical practice.

One of the main challenges is the lack of long-term data on the safety and effectiveness of graphene-based materials in dental applications.

Another major challenge is the cost and scalability of producing graphene. Graphene is currently produced through a labor-intensive process known as exfoliation, which can be expensive and difficult to scale up for industrial use.[6] As reported by M.R. Bhat, et al. in their study "The Biomedical Applications of Graphene and Graphene Oxide: An Overview" cost is a significant barrier for the large-scale use of graphene in biomedical applications.

Another challenge is the lack of proper functionalization of graphene. The surface of graphene is highly hydrophobic, which makes it difficult to functionalize with biomolecules such as proteins or DNA. This can limit its ability to interact with cells or tissues in the body.[7] As discussed by L. Zhang, et al. in their study "Graphene in dental materials: a review", the lack of proper functionalization of graphene is a critical issue that needs to be addressed.

Additionally, the cytotoxicity of graphene to oral cells has been reported in some studies. This can be a concern for its dental application as it may cause toxicity to oral cells. As noted by A. Kaur, et al in their study "Graphene in Dentistry: A Review of Current Applications and Future Perspectives", the cytotoxicity of graphene needs to be evaluated before its use in dental applications.[8]

CONCLUSION

Despite these challenges, the potential of graphene in dentistry is significant, and further research in this field is warranted. The use of graphene-based materials in dental treatments has the potential to revolutionize the field of dentistry, by providing more durable and biocompatible restorative and implant materials, and by improving the antimicrobial properties of dental materials.

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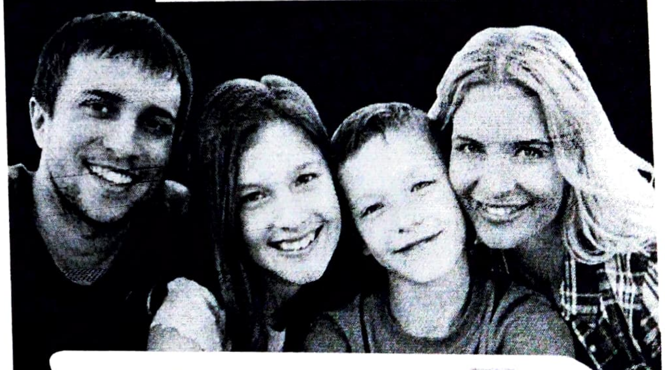

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Comparison of the Microleakages of Four Root-End Filling Materials: An In Vitro Study

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Abstract

Introduction: When a nonsurgical endodontic treatment is ineffective, surgery is necessary. This entails putting a retrofilling to seal the tooth's apex. Exposing the lesion, performing a curettage, exposing the root apex, resecting it, preparing the root end, and lastly filling the cavity with the proper material are all steps in endodontic surgery. Thus, the aim of this study is to compare the apical microleakage of four root-end filling materials in cavities prepared using ultrasonic retro tip in in vitro conditions.

Materials and Methods: An in vitro study was conducted on 60 extracted single-rooted teeth and was cut at the cementoenamel junction (CEJ). They were biomechanically prepared and obturated. Apical 3 mm root-end resection was done using a diamond disc. Root-end cavities were made using an ultrasonic retro tip. Teeth were separated into four groups and filled with SuperEBA® ethoxy-benzoic acid (EBA; Keystone Industries, New Jersey), mineral trioxide aggregate (MTA), Biodentine (Septodont, France), and TotalFill Bioceramic Root Repair Material (BC RRM; FKG Dentaire Sàrl, Switzerland). The samples were kept in methylene blue dye and split longitudinally. The degree of dye penetration was observed under a stereomicroscope and scored. Finally, the results were analyzed.

Results: TotalFill BC RRM and Biodentine showed the least apical microleakage ($p < 0.05$). Group 1 samples had the highest mean microleakage, followed by Group 2, Group 3, and Group 4 samples.

Conclusion: All of the sample groups showed some evidence of microleakage, but not all of the samples showed leaking. SuperEBA (Group 1) demonstrated the highest microleakage when compared to the other groups.

Categories: Dentistry
Keywords: root canal treatment, endodontics, totalfill bioceramic root repair material, retrograde filling, apical microleakage

Introduction

A root canal treatment is the most commonly employed treatment to disinfect and fill the root canal system three-dimensionally. However, sometimes, despite thorough chemomechanical preparation and obturation, orthograde treatment may fail [1]. Periapical surgery is indicated when there is excessive root canal calcification, separated instruments extending beyond the apex, iatrogenic perforations, ledges or shoulder, and teeth restored with crowns or post and core. It may also be used in symptomatic cases that have not responded to conventional root canal treatment [2]. Periradicular surgery includes debridement and curettage, root apex exposure and resection, and retrograde cavity preparation followed by appropriate filling material insertion [3]. In addition, after a 1-year postoperative follow-up, the success rate of periapical surgery for patients with periapical lesions was 73.9% [4]. One of the typical clinical conditions affecting the periradicular tissues are periapical lesions [5]. One of the most commonly performed procedures for surgical endodontic treatment is retrograde obturation, which uses a variety of techniques and materials [6].

A retrograde filling is important to create an apical seal that prevents the microleakage of remaining irritants into periradicular tissues [7]. The prime factor that impacts a successful periapical surgery is the selection of retrograde filling material. Initially, amalgam, silver cones, gold foil, gutta-percha (GP), composite resins, zinc oxide eugenol (ZOE) cement, polycarboxylate cement, zinc phosphate cement, glass ionomer cement (GIC), and titanium screws were used for the same [3]. SuperEBA® ethoxy-benzoic acid (EBA) Cement (Keystone Industries, New Jersey) is a type of reinforced ZOE cement with 68% EBA and 32% eugenol. ZOE cement as a root-end filling material was unsuccessful; nevertheless, the reinforced variant showed better results [9]. Mineral trioxide aggregate is considered an ideal retrograde material [1]. Mineral trioxide aggregate (MTA) possesses significant qualities, such a high pH, biocompatibility, fixing power despite humidity, periradicular regeneration, and osteoinductive ability [10]. Biodentine (Septodont, France) is calcium silicate-based cement with high biocompatibility. It shows better physical and chemical properties, such as reduced time for setting and increased mechanical properties that make it a compatible root-end filling material [11]. A reparative biocompatible substance that seals perforations and does not

irritate surrounding tissues is required in cases of extensive perforation [12].

TotalFill Bioceramic Root Repair Material (BC RRM; FKG Dentaire Sàrl, Switzerland) is a premixed material either in putty or syringe form. Its main components are calcium silicates and zirconium oxide. This material showed superior healing in periradicular surgery. It sets fast and shows improved handling properties. In addition, biocompatibility is analogous to MTA [13]. Apical seals attained through a retrograde filling material can be evaluated by the depth of the dye penetration, fluid-filtration technique, radioisotope or bacteria penetration, or electrochemical methods. The dye penetration technique is the prevalent and easily performed method [14]. The fluid filtration technique evaluates the endodontic and restorative sealers' capacity for sealing. As a result, this method has established credibility in the field of study evaluating apical and coronal microleakage. Because of this, compared to the dye method, the fluid filtration method relied on quantitative measurements of fluid passage within the interfaces; both procedures produced results that were comparable in earlier studies [15]. To date, no in vitro studies have been conducted to compare and evaluate apical microleakage after using SuperEBA, MTA, Biodentine, and TotalFill BC RRM in cavities prepared using ultrasonic retro tips [16,17]. The present in vitro study aims to compare the apical microleakage of four root-end filling materials in cavities prepared using ultrasonic retro tips and evaluate the results. The null hypothesis was that there would be no significant difference in the apical microleakage amid the four chosen materials.

Materials And Methods

The sample size was calculated using the formula $n = Z^2 P (1-P) d^2$, where n is the sample size, Z is the statistic corresponding to the level of confidence, and P is the expected prevalence. A power of 0.80 with an alpha (α) level of 0.05 (confidence level = 95%), and a sample size of 60 was considered for the total samples. A total of 60 single-rooted extracted teeth, which were periodontally compromised and indicated for extraction, were collected from the Department of Oral & Maxillofacial Surgery, IDST. Soft tissues and deposits were mechanically removed from all the samples using Gracey curettes, and teeth were inspected under a stereomicroscope microscope (Carl Zeiss, Jena, Germany) for examining the number of canals, cracks/defects, and decay. The specimens were stored in 10% formalin until use.

Teeth with single root and single canal, closed apex, without fractures, resorption, or cracks were included. Multirooted teeth and teeth with extra canals, open apex, root caries, and calcification were excluded. The coronal part of the teeth was sectioned horizontally along the long axis with a diamond disc, at the cementoenamel junction (CEJ) level or below, to standardize the root length (15 mm).

Pre-operative radiography was performed, and access openings were created with an access bur (Dentsply Maillefer, USA). The working length was estimated radiographically with a #10 K-file, and a #40 K-file was used as the master apical file (Mani Inc., Japan). Ethylenediaminetetraacetic acid (EDTA) liquid irrigation was performed first (Prevest DenPro, India), and then 5% sodium hypochlorite irrigation was performed (Prevest DenPro, India), followed by saline irrigation. The canals were dried and obturated with lateral compaction technique using 2% gutta-percha (GP) cones (Meta Biomed, Korea) and AH Plus (Dentsply Maillefer, Ballaigues, Switzerland) as the root canal sealer.

Following obturation, cavities were filled with composite resin. The treated teeth were kept in saline for one week. Then, teeth were kept in an incubator (Binder, Tuttlingen, Germany), which has a specification of 535 L of interior space with a footprint of just 0.58 m2 at 100% humidity at 37 °C for five days. The apical 3 mm was cut using a straight fissure bur. Class I cavity was prepared in the root end with an ultrasonic retro tip to a depth of 3 mm. The samples were randomly divided into four groups with 15 teeth each: Group 1 (N = 15) retrograde cavity filled with SuperEBA, Group 2 (N = 15) with MTA, Group 3 (N = 15) with Biodentine, and Group 4 (N = 15) with TotalFill BC RRM.

The materials were manipulated according to the manufacturers' instructions, followed by filling the cavities. The teeth were stored in 100% humidity at 37 °C for five days. The prepared retro-cavities underwent cleaning, saline irrigation, and drying. Then, they were coated with nail varnish, except for the apical 1 mm, and dried. Next, the teeth were placed in 1% methylene blue dye for up to 48 h. The roots were washed and split into longitudinal sections along the long axis using a diamond disc. Dye penetration was examined under a stereomicroscope, and the scoring was done on a scale of 0 to 4 (Figure 1).

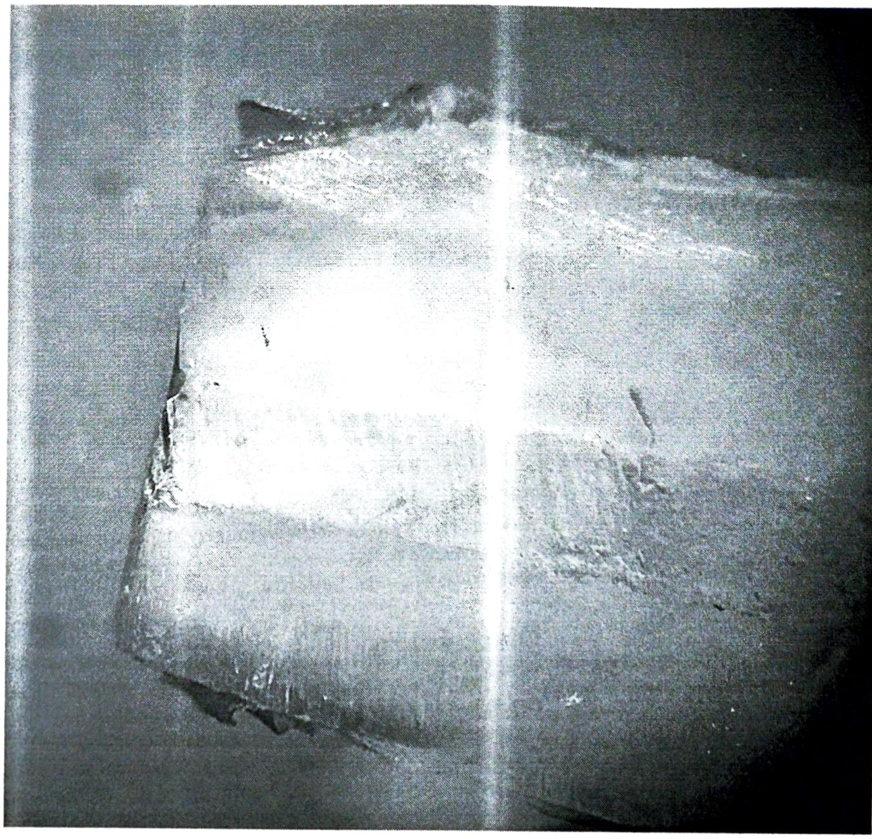

FIGURE 1: Stereomicroscopic image of the setup tested

This in vitro study was conducted in the Department of Conservative Dentistry and Endodontics at Institute of Dental Studies & Technologies (IDST), Kadrabad, Modinagar, Ghaziabad, Uttar Pradesh, India. Ethical clearance was obtained from the Institutional Review Board (IRB) with IRB number IDST/IEC/2019/PG/11.

Statistical analysis

Data were analyzed with IBM SPSS Statistics for Windows, Version 21 (Released 2012; IBM Corp., Armonk, New York, United States. As the main outcome variable was ordinal, non-parametric tests, such as Kruskal-Wallis and Mann-Whitney U tests, were utilized for the analysis.

Results

Table *1* shows the description of microleakage scores among all the study groups.

Microleakage score					
	N (number)	Mean (M)	Standard deviation	95% confidence interval for the mean	
				Lower bound	Upper bound
Group 1	15	1.4000	0.63246	1.0498	1.7502
Group 2	15	0.8667	0.51640	0.5807	1.1526
Group 3	15	0.4000	0.50709	0.1192	0.6808
Group 4	15	0.2000	0.41404	-0.0293	0.4293

TABLE 1: Description of the microleakage scores among all the study groups

Table *2* shows the post-hoc pairwise comparison by the Mann-Whitney U test.

Comparisons	P-values of the pairwise comparison by the Mann-Whitney U test
Group 1 vs. Group 2	0.019
Group 1 vs. Group 3	<0.001
Group 1 vs. Group 4	<0.001
Group 2 vs. Group 3	0.022
Group 2 vs. Group 4	0.001
Group 3 vs. Group 4	0.240

TABLE 2: Post-hoc pairwise comparison by the Mann-Whitney U test

The findings indicate that microleakages in Group 3 and Group 4 samples were significantly lesser than in those in Group 2 samples and were further significantly lower than those in Group 1 samples. No significant difference could be found between Group 3 and Group 4 samples. The mean microleakage of Group 1 samples was maximum, followed by Group 2, Group 3, and Group 4 samples.

Discussion

The accomplishment of periapical surgery is highly dependent on a proper apical seal. Retrograde filling materials are proposed to limit or avoid leakage into periapical tissues [15]. This study intended to test the microleakage of four retrograde materials. Ultrasonic retro tips are better than burs for retro preparation. The preparation of root-end cavity with ultrasonic tips causes negligible destruction to the root canal morphology. They are precise, conservative, and cleaner. The cutting bevel is 90° to the long axis of the root, which reduces the number of patent dentinal tubules at the open end and minimizes microleakage [18].

Ishikawa et al. assessed the retrograde cavity preparation with US retro tip and concluded that the use of US retro tip reduced the time taken in root-end cavity preparation [19]. The resulting cavities were more precise, and the US tips were more efficient in cutting than conventional burs. In this study, stainless-steel ultrasonic tip with diamond coating was used. The angle of root-end resection affects the leakage, so a 90° resection angle was selected here as it is considered more acceptable by previous studies. A resection depth of 3 mm reduces the lateral canals by 93% and apical ramifications by 98% [20].

The most commonly used method to evaluate the sealing property of retrograde materials is dye leakage. It can provide an estimate of the sealing property in various clinical conditions. In the present study, the linear penetration of 1% methylene blue dye was measured. Methylene blue is commonly used because of its small molecular weight that aids in penetrability [21]. The disadvantage of this method is that the dye molecules are smaller in size than bacteria, which can result in an overestimation of the bacteria's penetration levels due to microleakage [20]. Lucena-Martin et al. showed that the transverse root section method results in the loss of dye and dentine portion [22]. Consequently, the longitudinal sectioning method was performed here to evaluate dye penetration into filling materials.

Epoxy resin-based AH Plus sealer shows high flowability, and it can penetrate dentinal tubules at deeper levels. Increased polymerization boosts the interlocking of the sealer material and dentin [23]. Therefore, in this study, AH Plus root canal sealer was chosen for obturation. Of all the materials used for retrograde filling, the least microleakage was observed for TotalFill BC RRM (Group 4), followed by Biodentine (Group 3), MTA (Group 2), and SuperEBA (Group 1). SuperEBA is broadly studied for retrograde fillings, and it has shown satisfactory properties. Greer et al. and Suntimuntanakul et al. observed that SuperEBA EBA Cement shows a higher sealing property when compared to a few other retrograde filling materials [24]. The results of our study are in agreement with other studies in which MTA showed improved marginal seal than other retrograde filling materials, such as GIC, amalgam, light cure GIC, and SuperEBA [25]. This can be because of the hydroxyapatite-like crystal formation at material-root canal dentine interfaces, which results in excellent adhesion preventing the penetration of the dye [26]. MTA has always shown less leakage than SuperEBA; there was no or minimal dye leakage in the majority of MTA specimens [27]. Similarly, Bates et al. traced microleakage in dental amalgam, SuperEBA, and MTA and concluded that it was the least in MTA [28]. Biodentine shows superior characteristics to MTA as it sets faster, thus reducing the risk of bacterial contamination [29]. Biodentine exhibits superior sealing properties than MTA [30]. In addition, it exhibits better biomineralization than MTA, with broader calcium-rich layer formation. Radeva et al. also found similar results as this study; they concluded that Biodentine shows greater sealing ability than MTA [31].

TotalFill BC RRM is available in the premixed syringe delivery system or putty form. It is extremely resistant

to washout. It has calcium phosphate monobasic as an additional agent that enhances hydroxyapatite formation. It shows properties, such as wear resistance, biocompatibility, chemical durability, and aesthetics [32].

Nonetheless, this study has some limitations. Instead of employing a scanning electron microscope (SEM) or confocal microscope, which may have provided significantly more information and reliable results, the investigation was conducted with a rather limited sample size. The research used only a few materials other materials are not tested, so it could be a limitation. The materials used in the study also will have limitations regarding their properties and hence in the future, a long-term trial could be done on various other materials. As a result, additional research including more samples is needed.

Conclusions

Although not all of the samples had leakages, all of the sample groups displayed some degree of microleakage. When compared to the other groups, SuperEBA demonstrated the highest level of microleakage. Comparing the two materials to the other materials, TotalFill BC RRM and Biodentine demonstrated the least amount of apical microleakage. Therefore, it is possible to suggest using these materials. A larger sample size should be used in in vivo experiments in the future to study the interactions between the sealing cement that were used, as well as the therapeutic significance and consequences of solubility over time.

Additional Information

Disclosures

Human subjects: All authors have confirmed that this study did not involve human participants or tissue. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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(27)

ORIGINAL RESEARCH

Comparative Evaluation of Dentinal Microcracks after Root End Cavity Preparation Using Different Imaging Techniques: An In-Vitro Study

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ABSTRACT

Background: *The purpose of root-end cavity preparation is to remove irritants from the root canal system inaccessible to the operator via a coronal entry. However, this predisposes the tooth to microcrack formation which further increases the possibility of bacterial contamination and susceptibility to root fracture.* ***Aim:*** *To evaluate and compare the dentinal microcrack formation after root-end cavity preparation with bur and ultrasonic tips using different imaging techniques.* ***Methodology:*** *Forty atraumaticaly freshly extracted, single-root premolars were collected for the study. All the samples were decoronated and working length was established. Biomchanical preparation was done till F4 protaper and obturated using single cone obturation technique. Root resection was carried out and number of cracks was evaluated using Stereomicroscope, Dental Operating Microscope and CBCT. Samples were then divided into four groups of 10 teeth each depending on the instrument used for retrocavity preparation: Group 1 (control): no preparation was done, Group 2: retrocavity prepared with stainless steel ultrasonic tip, Group 3: retrocavity prepared with diamond coated ultrasonic tip, Group 4: retrocavity prepared with stainless steel round bur. Samples were immersed in methylene blue dye and number of cracks were again evaluated using the three imaging techniques. Percentage increase in the number of cracks was calculated and data was subjected to statistical analysis using Wilcoxon and Kruskan Wallis Test. The level of statistical significance was set at 5%.* ***Results:*** *With stereomicroscope and Operating Microscope, maximum increase in the percentage of microcracks was observed in Group 2 (Stainless steel retrotip) followed by Group 3 (Diamond coated retrotip) and Group 4 (Stainless steel bur).* ***Conclusion:*** *Within the limitation of the study, it was concluded that there was increase in the percentage of microcracks after root end resection and root end cavity preparation. Stainless steel ultrasonic tips produced more dentinal cracks as compared to diamond-coated ultrasonic tips followed by stainless steel bur. Also, more number of microcracks was observed in stereomicroscope as compared to Dental Operating Microscope.*

Keywords: *Microcracks, Root End Resection, Root End Preparation, Ultrasonic Retrotip*

Introduction

Endodontic surgeries are indicated in cases of failed root canal cases, large periapical lesions, natural or iatrogenic obstructions. This surgical intervention involves root end resection, root end cavity preparation, root end filling and bacteria tight closure of the root canal system. The purpose of root end cavity preparation is to remove irritants from the root canal system which are inaccessible to the operator through a coronal entry.[1] Conventionally, the root-end cavity was prepared with stainless steel burs and low speed hand piece but had several disadvantages like difficult access, preparation not being parallel to canal and risk of perforation. The advent of ultrasonic tips provided numerous advantages over conventional burs including deeper cavity depths allowing more retention, preparations following line of root canal, thus preserving the canal morphology and cleaner surfaces than created with burs. Previously, stainless steel ultrasonic tips were developed but they had lesser cutting efficiency and longer preparation time. This led to the introduction of diamond coated and zirconium nitride retrotips.[2] Irrespective of the type of bur or ultrasonic tips used for retro preparation of cavity, the contact between the instrument and canal walls during preparation creates some stress in dentin and leads to microcrack formation. These microcracks can create a direct communication between the root canal and the periodontium which leads to invasion of the local bacteria in the apical ramifications, such as isthmuses, canal fins and lateral canals which can penetrates in these cracks and prevent further healing of the tissues. According to Saunders et al.,[3] most of the dentin cracks are found in 21% of roots after doing root end cavity preparation by using ultrasonic instrument tips and high-speed burs. Previous studies have used Stereomicroscopy, Scanning electron microscope (SEM), Cone Beam Computed Tomography (CBCT), Micro-computed tomography (micro-CT), Dental operating microscope for evaluation of dentinal microcracks after root end cavity preparation. Till date, no study has been done to evaluate microcrack formation using Stainless Steel round bur, Diamond and Stainless Steel ultrasonic tips under Stereomicroscope, Cone Beam Computed Tomography (CBCT) and Dental Operating Microscope. Thus, the aim of this study was to compare the dentinal microcrack formation after root end cavity preparation using different imaging techniques.

Materials and Methods

Ethical clearance for the study was attained from Institutional Ethical Committee. Forty freshly extracted premolars with straight canal and free of external cracks were selected and decoronated using a high-speed diamond bur to a standardized root length of 17 mm. A 10K file was inserted into the root canal until the tip of file was visible at the apical foramen and the working length was established by deducting 0.5 mm from this length. The samples were prepared with Protaper Universal (PTU) rotary file (Dentsply Maillefer, Switzerland) up to F4. Between the use of each file, the canals were irrigated with 5ml of 3% NaOCl (Neelkanth, Orthodent Pvt. Ltd, India) and at last 3ml of 17% Ethylenediamine Tetraacetic acid (Prevest Dentpro Limited) for 1 min followed by 5ml normal saline (Kunal Remedies Pvt. Ltd, India). Samples were obturated with gutta percha and AH plus sealer (Dentsply, Konstanz, Germany) by using single-cone technique. Samples were stored for 1 week at 37°C and 100% humidity to allow the sealer to set.[4]

Root End Resection and Root End Cavity Preparation

Coronal 2 mm roots were embedded in Putty impression material (Dentsply Aquasil Soft Putty) such that the long axis of root was perpendicular to the horizontal plane. In all the samples, apical 3 mm of the apex were resected perpendicular to the long axis of the root using H23LR Tungsten carbide bur (Komet, Gebr. Brasseler, Lemgo, Germnya) under continuous irrigation with water spray.[5] Samples were removed from putty blocks and stored in 1% methylene blue dye for 24 hours followed by rinsing in water for 1 minute to improve microcrack visualization. The number of microcracks were evaluated in all the samples using CBCT (Triana Tm Open Dental Software Nnt.), Stereomicroscope ((Alco StereoZoom, 40 x magnification) and Dental Operating Microscope (Prima Dnt Surgical Microscope, Labo America), 16 x magnification)

Grouping of Samples

All 40 samples were divided into 4 groups of 10 teeth each depending on the bur/tips used for retro-cavity preparation. Root end cavity was prepared in all samples unto depth of 3 mm:

Group 1: No cavity was prepared.

Group 2: Smooth stainless steel retrotip (LeSentier, Switzerland) was used at the power settings recommended by the manufacturer.

Group 3: Diamond-coated ultrasonic retrotip (Satelec Merignac, Cedex, France) was used with ultrasonic device at the highest power setting recommended.

Group 4: Stainless steel Round Bur (Dentsply) was used in slow speed contra-angle handpiece (Kavo, Biberach, Germany)

The root end preparation of each group was done under internal water cooling followed by rinsing with 5ml water. Samples were again stored in 1% methylene blue dye for 24 hours followed by rinsing in water for 1 minute to improve microcrack visualization. The number of microcracks formed after retro-cavity preparation were evaluated in all the samples using CBCT, Stereomicroscope and Dental Operating Microscope following the same protocol as in pre-operative microcrack evaluation.[6] If there were microcracks on the external surface of the root and on the internal root canal wall, this was accepted as having "crack," and the number was noted. As the number of microcracks observed preoperatively was different in each sample, the percentage of microcracks was calculated to standardize the procedure, and the increase in percentage number of microcracks was evaluated this is in accordance with the studies of Barreto et al.,[7] Singh et al.,[8] and Arias et al.,[9] Wilcoxon and Kruskan Wallis test were performed using Statistical Package for the Social Sciences 13.0 software. The level of statistical significance was set at 5%.

Results

The mean percentage increase in the number of dentinal cracks in the experimental groups from root resection to root end cavity preparation as observed under both Stereomicroscope and Dental Operating Microscope are shown in Table 1. Since no microcracks were observed with CBCT imaging, this method was excluded from evaluation. Maximum percentage increase in cracks as visualized under Stereomicroscope and Dental Operating Microscope were seen in Group 2 (Stainless Steel Retrotips) followed by Group 3 (Diamond Coated Retrotips) and Group 4 (Stainless steel burs). Inter-microscope comparison of percentage increase in number of microcracks is shown in Table 2. Although percentage increase in microcracks was more with Stereomicroscope than Dental Operating Microscope, this difference was statistically non significant.

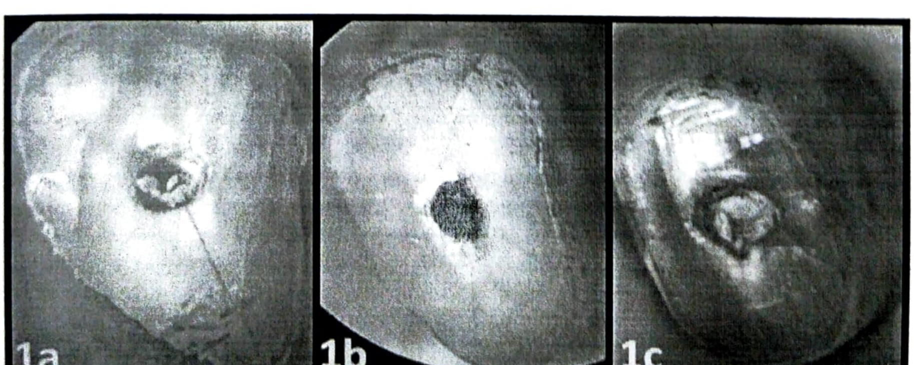


Figure 1 (a-c): Microcracks observed under stereomicroscope after root end cavity preparation with (1a) Stainless steel coated ultrasonic tip, (1b) Diamond coated ultrasonic tip, (1c) Stainless steel bur.

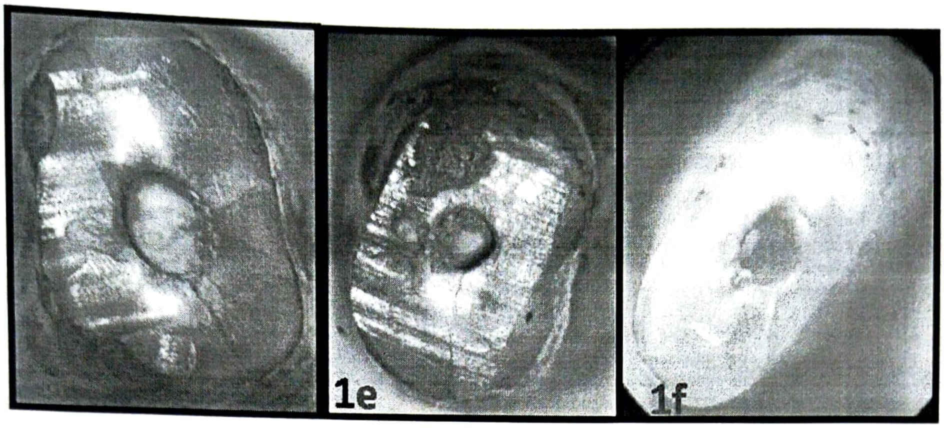


Figure 1 (d-f): Microcracks observed under dental operating microscope after root end cavity preparation with (1d) Stainless steel coated ultrasonic tip, (1e) Diamond coated ultrasonic tip, (1f) Stainless steel Bur

Table 1: Intergroup comparison of mean percentage increase in cracks seen under Stereomicroscope and DOM

Percentage Increase in Cracks		
	Stereomicroscope	**DOM**
	Mean ± SD	**Mean± SD**
Group 1 (Control)	.00 ±.00[a,b]	.00±.00[a,b]
Group 2 (Stainless Steel Retrotip)	105 ±64.33[a,c]	80±63.24[a]
Group 3 (Diamond coated Retrotip)	90 ±73.78[b]	70±82.32[b]
Group 4 (Stainless steel Bur)	35 ±47.43[c]	20±42.16
P value < 0.05 was considered statistically significant. Values with same superscript in each column indicate statistically significant difference		

Graph 1: Intergroup Comparison of Mean Percentage Increase in Cracks

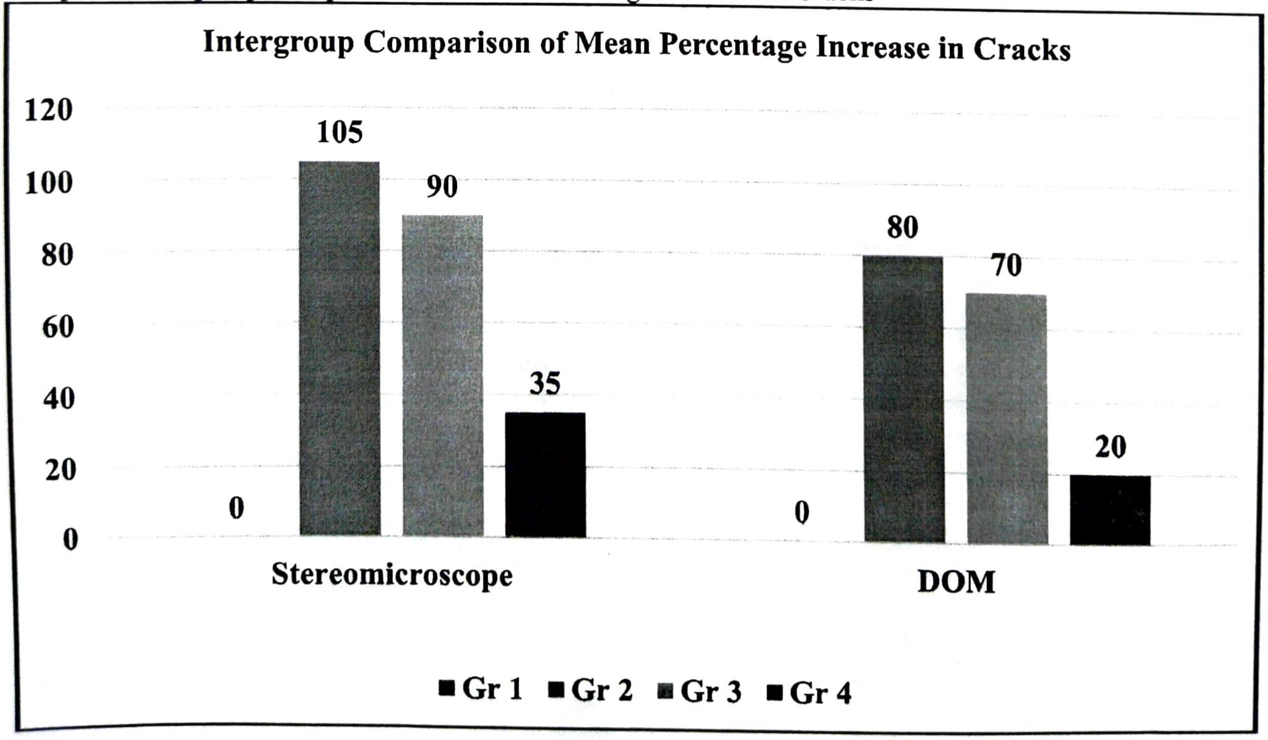
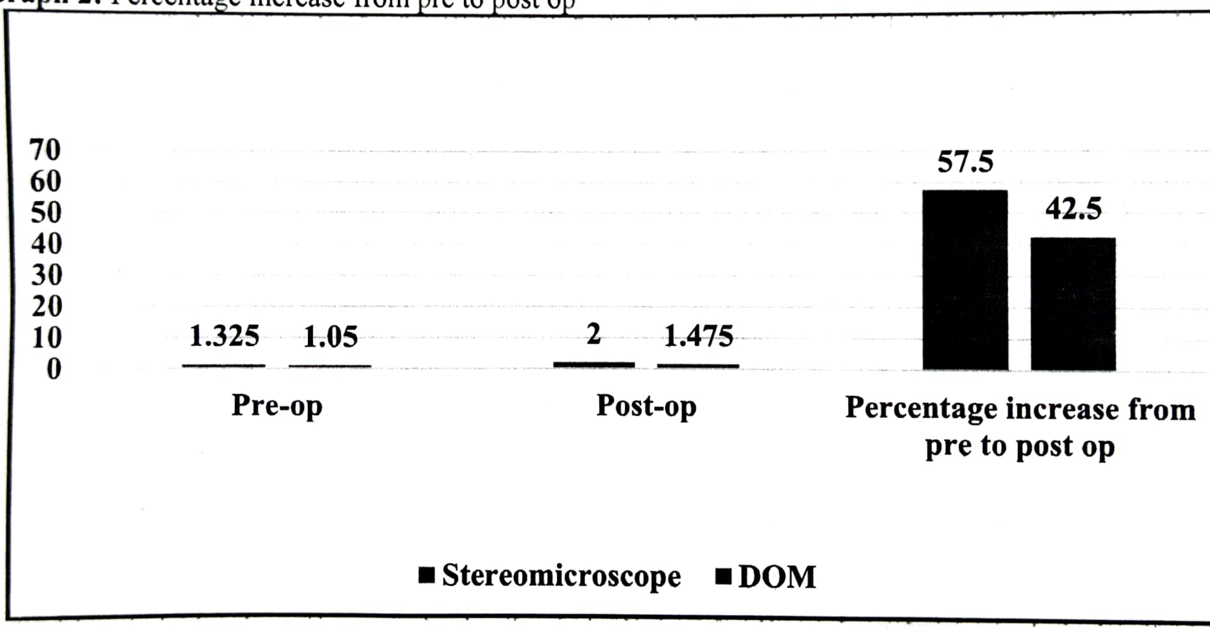


Table 2: Inter-microscope comparison of number of cracks Pre-operatively (after root end cavity preparation), Post-operatively (after rot end resection) and mean percentage increase in cracks

		Mean± SD	P value
Pre-op	**Stereomicroscope**	1.3250±.52563	<0.001, S
	DOM	1.0500±.22072	
Post-op	**Stereomicroscope**	2.0000±.93370	<0.001, S
	DOM	1.4750±.64001	
Percentage increase from pre to post op	**Stereomicroscope**	57.5000±67.51068	0.096, NS
	DOM	42.5000±63.59931	

SD: Standard deviation

Graph 2: Percentage increase from pre to post op



Discussion

The aim of this study was to compare the dentinal microcrack formation after root end cavity preparation using different imaging techniques. Standardization of the procedure was done to minimize the errors. Only freshly extracted, intact, non-carious, single-canal human mandibular premolars with single apical foramen were selected. Obturation was done using single cone technique as it applies minimal pressure as compared to other filling techniques that apply compaction forces on the root canal walls leading to dentinal microcrack formation.[10] Roots were resected 3 mm from the apex with the help of a micromotor handpiece and carbide bur since large number of apical ramifications and lateral canals exist at least 3 mm from the root end. Thus, root-end amputations of <3 mm may not remove all lateral canals and apical ramifications, increasing the risk of reinfection and eventual failure. The traditional technique uses a bevel angle of 45–60 degrees to facilitate access and visibility when using large surgical instruments. The modern technique uses a shallow bevel angle of 0–10 degrees to expose fewer dentinal tubules. Minimization of the bevel angle during root resection is one of the most important developments in endodontic microsurgery. Therefore, in our study, the bevel angle was kept at zero degrees.[11] Various methods have been employed to detect microcrack formation after root end cavity preparation like

Scanning Electron Microscope, Stereomicroscope, Dental Operating Microscope, Cone Beam Computed Tomography. In this study, methylene blue dye technique was used along with dental operating microscope, stereomicroscope and CBCT which, according to Wright et al. is a precise method for studying cracks.[12] Results of our study showed that Group 2 (Stainless Steel Retrotip) showed maximum percentage increase in microcracks after retro cavity preparation followed by Group 3 (Diamond coated retrotip) and Group 4 (Stainless Steel Bur). This may be attributed to the fact that Stainless steel retrotips are less efficient than Diamond coated ultrasonic tips and prepare retrocavities in more time than diamond coated ultrasonic retrotips. More contact time of Stainless steel tips with tooth surface leads to more frictional heat thereby producing more number of cracks. Also, it has been observed that Stainless steel ultrasonic tip bounces off the root surface during retro cavity preparation resulting in ragged and chipped surface, thus contributing to microcrack formation. This is in accordance to study by Gunes et al., and Aydinbelge et al.,[13] who reported that stainless steel ultrasonic tips required more time for root end cavity preparation than diamond coated ultrasonic tips. Similarly, Navarre & Steiman et al.,[14] also reported that diamond coated retrotip prepared root-end cavity faster than the stainless steel tip. Batista de Faria-Junior et al.,[15] and Khabbaz et al.,[16] also observed that diamond-coated tips have better cutting efficiency than stainless steel retrotips. Stainless steel burs produced least number of cracks as compared to ultrasonic retrotips for the same reason stated above that they require less time for retrocavity preparation than ultrasonic tips leading to fewer cracks. Gondim et al.[17] reported that no significant differences in chipping and cracking area were detected in treatments with stainless steel burs and diamond-coated tips, but stainless steel retrotips showed a greater number of teeth with cracking and a larger chipping area, probably due to the longer preparation time needed. In the present study, a significantly higher percentage of dentinal microcracks were observed with Stereomicroscope than Dental Operating microscope. However, the differences were not statistically significant. This is in accordance with some previous studies that reported more no. of microcracks with stereomicroscope than dental operating microscope.[18,19,20] No dentinal microcracks were observed with CBCT method. This is in accordance with the study by Capar and coworkers who reported no microcracks were detected with CBCT. Since there was the increase in the percentage of microcracks after root end cavity preparation with stainless ultrasonic tips, diamond coated tips and stainless steel bur as observed with stereomicroscope and dental operating microscope, null hypothesis was rejected. The limitation of this study includes the lack of clinical environment to simulate the oral environmental conditions.

Conclusion

Within the limitations of this study, it can be concluded that there is a significant increase in the induction and propagation of microcracks from root end resection to root end cavity preparation and stainless steel ultrasonic tips produced more dentinal cracks as compared to diamond-coated ultrasonic tips followed by stainless steel bur. Also, more number of microcracks was observed in stereomicroscope as compared to dental operating microscope. Thus, it can be proposed that in clinical scenario, diamond coated ultrasonic retrotips should be preferred over stainless steel burs or retrotips since they provide better control of retrocavity preparation than burs and produce fewer cracks than stainless steel tips. Further studies should be directed at conducting such researches with newer modalities of retrocavity preparation and performed in vivo to extrapolate the results clinically.

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Comparison of the Microleakages of Four Root-End Filling Materials: An In Vitro Study

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Abstract

Introduction: When a nonsurgical endodontic treatment is ineffective, surgery is necessary. This entails putting a retrofilling to seal the tooth's apex. Exposing the lesion, performing a curettage, exposing the root apex, resecting it, preparing the root end, and lastly filling the cavity with the proper material are all steps in endodontic surgery. Thus, the aim of this study is to compare the apical microleakage of four root-end filling materials in cavities prepared using ultrasonic retro tip in in vitro conditions.

Materials and Methods: An in vitro study was conducted on 60 extracted single-rooted teeth and was cut at the cementoenamel junction (CEJ). They were biomechanically prepared and obturated. Apical 3 mm root-end resection was done using a diamond disc. Root-end cavities were made using an ultrasonic retro tip. Teeth were separated into four groups and filled with SuperEBA® ethoxy-benzoic acid (EBA; Keystone Industries, New Jersey), mineral trioxide aggregate (MTA), Biodentine (Septodont, France), and TotalFill Bioceramic Root Repair Material (BC RRM; FKG Dentaire Sàrl, Switzerland). The samples were kept in methylene blue dye and split longitudinally. The degree of dye penetration was observed under a stereomicroscope and scored. Finally, the results were analyzed.

Results: TotalFill BC RRM and Biodentine showed the least apical microleakage ($p < 0.05$). Group 1 samples had the highest mean microleakage, followed by Group 2, Group 3, and Group 4 samples.

Conclusion: All of the sample groups showed some evidence of microleakage, but not all of the samples showed leaking. SuperEBA (Group 1) demonstrated the highest microleakage when compared to the other groups.

Categories: Dentistry
Keywords: root canal treatment, endodontics, totalfill bioceramic root repair material, retrograde filling, apical microleakage

Introduction

A root canal treatment is the most commonly employed treatment to disinfect and fill the root canal system three-dimensionally. However, sometimes, despite thorough chemomechanical preparation and obturation, orthograde treatment may fail [1]. Periapical surgery is indicated when there is excessive root canal calcification, separated instruments extending beyond the apex, iatrogenic perforations, ledges or shoulder, and teeth restored with crowns or post and core. It may also be used in symptomatic cases that have not responded to conventional root canal treatment [2]. Periradicular surgery includes debridement and curettage, root apex exposure and resection, and retrograde cavity preparation followed by appropriate filling material insertion [3]. In addition, after a 1-year postoperative follow-up, the success rate of periapical surgery for patients with periapical lesions was 73.9% [4]. One of the typical clinical conditions affecting the periradicular tissues are periapical lesions [5]. One of the most commonly performed procedures for surgical endodontic treatment is retrograde obturation, which uses a variety of techniques and materials [6].

A retrograde filling is important to create an apical seal that prevents the microleakage of remaining irritants into periradicular tissues [7]. The prime factor that impacts a successful periapical surgery is the selection of retrograde filling material. Initially, amalgam, silver cones, gold foil, gutta-percha (GP), composite resins, zinc oxide eugenol (ZOE) cement, polycarboxylate cement, zinc phosphate cement, glass ionomer cement (GIC), and titanium screws were used for the same [3]. SuperEBA® ethoxy-benzoic acid (EBA) Cement (Keystone Industries, New Jersey) is a type of reinforced ZOE cement with 68% EBA and 32% eugenol. ZOE cement as a root-end filling material was unsuccessful; nevertheless, the reinforced variant showed better results [9]. Mineral trioxide aggregate is considered an ideal retrograde material [1]. Mineral trioxide aggregate (MTA) possesses significant qualities, such a high pH, biocompatibility, fixing power despite humidity, periradicular regeneration, and osteoinductive ability [10]. Biodentine (Septodont, France) is calcium silicate-based cement with high biocompatibility. It shows better physical and chemical properties, such as reduced time for setting and increased mechanical properties that make it a compatible root-end filling material [11]. A reparative biocompatible substance that seals perforations and does not

irritate surrounding tissues is required in cases of extensive perforation [12].

TotalFill Bioceramic Root Repair Material (BC RRM; FKG Dentaire Sàrl, Switzerland) is a premixed material either in putty or syringe form. Its main components are calcium silicates and zirconium oxide. This material showed superior healing in periradicular surgery. It sets fast and shows improved handling properties. In addition, biocompatibility is analogous to MTA [13]. Apical seals attained through a retrograde filling material can be evaluated by the depth of the dye penetration, fluid-filtration technique, radioisotope or bacteria penetration, or electrochemical methods. The dye penetration technique is the prevalent and easily performed method [14]. The fluid filtration technique evaluates the endodontic and restorative sealers' capacity for sealing. As a result, this method has established credibility in the field of study evaluating apical and coronal microleakage. Because of this, compared to the dye method, the fluid filtration method relied on quantitative measurements of fluid passage within the interfaces; both procedures produced results that were comparable in earlier studies [15]. To date, no in vitro studies have been conducted to compare and evaluate apical microleakage after using SuperEBA, MTA, Biodentine, and TotalFill BC RRM in cavities prepared using ultrasonic retro tips [16,17]. The present in vitro study aims to compare the apical microleakage of four root-end filling materials in cavities prepared using ultrasonic retro tips and evaluate the results. The null hypothesis was that there would be no significant difference in the apical microleakage amid the four chosen materials.

Materials And Methods

The sample size was calculated using the formula $n = Z^2 P (1-P) d^2$, where n is the sample size, Z is the statistic corresponding to the level of confidence, and P is the expected prevalence. A power of 0.80 with an alpha (α) level of 0.05 (confidence level = 95%), and a sample size of 60 was considered for the total samples. A total of 60 single-rooted extracted teeth, which were periodontally compromised and indicated for extraction, were collected from the Department of Oral & Maxillofacial Surgery, IDST. Soft tissues and deposits were mechanically removed from all the samples using Gracey curettes, and teeth were inspected under a stereomicroscope microscope (Carl Zeiss, Jena, Germany) for examining the number of canals, cracks/defects, and decay. The specimens were stored in 10% formalin until use.

Teeth with single root and single canal, closed apex, without fractures, resorption, or cracks were included. Multirooted teeth and teeth with extra canals, open apex, root caries, and calcification were excluded. The coronal part of the teeth was sectioned horizontally along the long axis with a diamond disc, at the cementoenamel junction (CEJ) level or below, to standardize the root length (15 mm).

Pre-operative radiography was performed, and access openings were created with an access bur (Dentsply Maillefer, USA). The working length was estimated radiographically with a #10 K-file, and a #40 K-file was used as the master apical file (Mani Inc., Japan). Ethylenediaminetetraacetic acid (EDTA) liquid irrigation was performed first (Prevest DenPro, India), and then 5% sodium hypochlorite irrigation was performed (Prevest DenPro, India), followed by saline irrigation. The canals were dried and obturated with lateral compaction technique using 2% gutta-percha (GP) cones (Meta Biomed, Korea) and AH Plus (Dentsply Maillefer, Ballaigues, Switzerland) as the root canal sealer.

Following obturation, cavities were filled with composite resin. The treated teeth were kept in saline for one week. Then, teeth were kept in an incubator (Binder, Tuttlingen, Germany), which has a specification of 535 L of interior space with a footprint of just 0.58 m2 at 100% humidity at 37 °C for five days. The apical 3 mm was cut using a straight fissure bur. Class I cavity was prepared in the root end with an ultrasonic retro tip to a depth of 3 mm. The samples were randomly divided into four groups with 15 teeth each: Group 1 (N = 15) retrograde cavity filled with SuperEBA, Group 2 (N = 15) with MTA, Group 3 (N = 15) with Biodentine, and Group 4 (N = 15) with TotalFill BC RRM.

The materials were manipulated according to the manufacturers' instructions, followed by filling the cavities. The teeth were stored in 100% humidity at 37 °C for five days. The prepared retro-cavities underwent cleaning, saline irrigation, and drying. Then, they were coated with nail varnish, except for the apical 1 mm, and dried. Next, the teeth were placed in 1% methylene blue dye for up to 48 h. The roots were washed and split into longitudinal sections along the long axis using a diamond disc. Dye penetration was examined under a stereomicroscope, and the scoring was done on a scale of 0 to 4 (Figure 1).

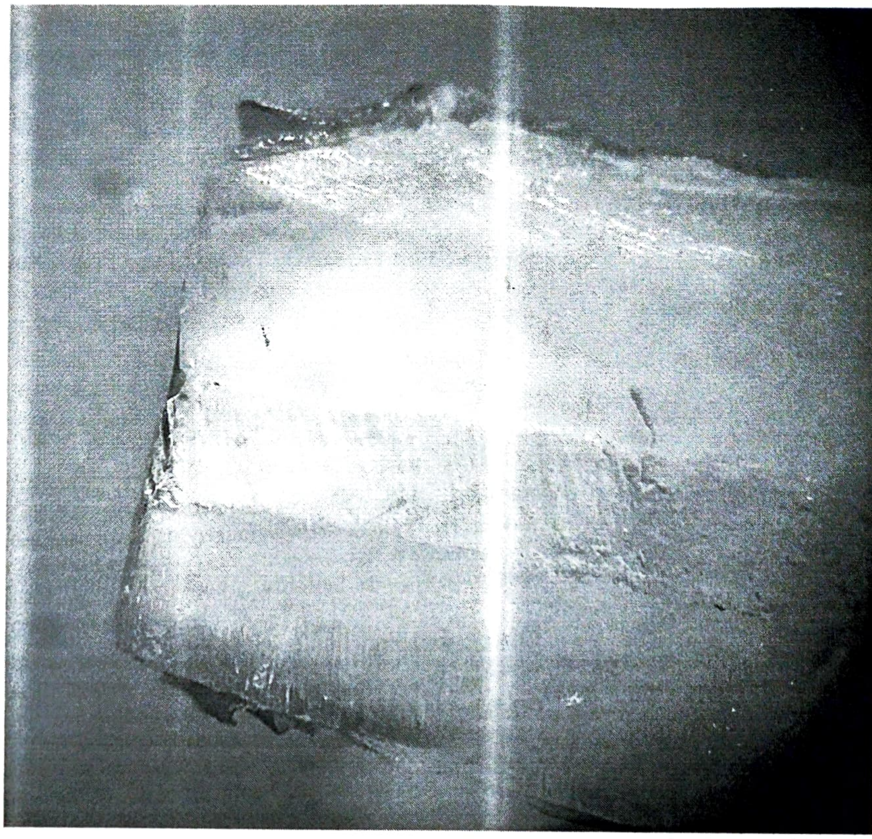

FIGURE 1: Stereomicroscopic image of the setup tested

This in vitro study was conducted in the Department of Conservative Dentistry and Endodontics at Institute of Dental Studies & Technologies (IDST), Kadrabad, Modinagar, Ghaziabad, Uttar Pradesh, India. Ethical clearance was obtained from the Institutional Review Board (IRB) with IRB number IDST/IEC/2019/PG/11.

Statistical analysis

Data were analyzed with IBM SPSS Statistics for Windows, Version 21 (Released 2012; IBM Corp., Armonk, New York, United States. As the main outcome variable was ordinal, non-parametric tests, such as Kruskal-Wallis and Mann-Whitney U tests, were utilized for the analysis.

Results

Table *1* shows the description of microleakage scores among all the study groups.

Microleakage score					
	N (number)	Mean (M)	Standard deviation	95% confidence interval for the mean	
				Lower bound	Upper bound
Group 1	15	1.4000	0.63246	1.0498	1.7502
Group 2	15	0.8667	0.51640	0.5807	1.1526
Group 3	15	0.4000	0.50709	0.1192	0.6808
Group 4	15	0.2000	0.41404	-0.0293	0.4293

TABLE 1: Description of the microleakage scores among all the study groups

Table *2* shows the post-hoc pairwise comparison by the Mann-Whitney U test.

Comparisons	P-values of the pairwise comparison by the Mann-Whitney U test
Group 1 vs. Group 2	0.019
Group 1 vs. Group 3	<0.001
Group 1 vs. Group 4	<0.001
Group 2 vs. Group 3	0.022
Group 2 vs. Group 4	0.001
Group 3 vs. Group 4	0.240

TABLE 2: Post-hoc pairwise comparison by the Mann-Whitney U test

The findings indicate that microleakages in Group 3 and Group 4 samples were significantly lesser than in those in Group 2 samples and were further significantly lower than those in Group 1 samples. No significant difference could be found between Group 3 and Group 4 samples. The mean microleakage of Group 1 samples was maximum, followed by Group 2, Group 3, and Group 4 samples.

Discussion

The accomplishment of periapical surgery is highly dependent on a proper apical seal. Retrograde filling materials are proposed to limit or avoid leakage into periapical tissues [15]. This study intended to test the microleakage of four retrograde materials. Ultrasonic retro tips are better than burs for retro preparation. The preparation of root-end cavity with ultrasonic tips causes negligible destruction to the root canal morphology. They are precise, conservative, and cleaner. The cutting bevel is 90° to the long axis of the root, which reduces the number of patent dentinal tubules at the open end and minimizes microleakage [18].

Ishikawa et al. assessed the retrograde cavity preparation with US retro tip and concluded that the use of US retro tip reduced the time taken in root-end cavity preparation [19]. The resulting cavities were more precise, and the US tips were more efficient in cutting than conventional burs. In this study, stainless-steel ultrasonic tip with diamond coating was used. The angle of root-end resection affects the leakage, so a 90° resection angle was selected here as it is considered more acceptable by previous studies. A resection depth of 3 mm reduces the lateral canals by 93% and apical ramifications by 98% [20].

The most commonly used method to evaluate the sealing property of retrograde materials is dye leakage. It can provide an estimate of the sealing property in various clinical conditions. In the present study, the linear penetration of 1% methylene blue dye was measured. Methylene blue is commonly used because of its small molecular weight that aids in penetrability [21]. The disadvantage of this method is that the dye molecules are smaller in size than bacteria, which can result in an overestimation of the bacteria's penetration levels due to microleakage [20]. Lucena-Martin et al. showed that the transverse root section method results in the loss of dye and dentine portion [22]. Consequently, the longitudinal sectioning method was performed here to evaluate dye penetration into filling materials.

Epoxy resin-based AH Plus sealer shows high flowability, and it can penetrate dentinal tubules at deeper levels. Increased polymerization boosts the interlocking of the sealer material and dentin [23]. Therefore, in this study, AH Plus root canal sealer was chosen for obturation. Of all the materials used for retrograde filling, the least microleakage was observed for TotalFill BC RRM (Group 4), followed by Biodentine (Group 3), MTA (Group 2), and SuperEBA (Group 1). SuperEBA is broadly studied for retrograde fillings, and it has shown satisfactory properties. Greer et al. and Suntimuntanakul et al. observed that SuperEBA EBA Cement shows a higher sealing property when compared to a few other retrograde filling materials [24]. The results of our study are in agreement with other studies in which MTA showed improved marginal seal than other retrograde filling materials, such as GIC, amalgam, light cure GIC, and SuperEBA [25]. This can be because of the hydroxyapatite-like crystal formation at material-root canal dentine interfaces, which results in excellent adhesion preventing the penetration of the dye [26]. MTA has always shown less leakage than SuperEBA; there was no or minimal dye leakage in the majority of MTA specimens [27]. Similarly, Bates et al. traced microleakage in dental amalgam, SuperEBA, and MTA and concluded that it was the least in MTA [28]. Biodentine shows superior characteristics to MTA as it sets faster, thus reducing the risk of bacterial contamination [29]. Biodentine exhibits superior sealing properties than MTA [30]. In addition, it exhibits better biomineralization than MTA, with broader calcium-rich layer formation. Radeva et al. also found similar results as this study; they concluded that Biodentine shows greater sealing ability than MTA [31].

TotalFill BC RRM is available in the premixed syringe delivery system or putty form. It is extremely resistant

to washout. It has calcium phosphate monobasic as an additional agent that enhances hydroxyapatite formation. It shows properties, such as wear resistance, biocompatibility, chemical durability, and aesthetics [32].

Nonetheless, this study has some limitations. Instead of employing a scanning electron microscope (SEM) or confocal microscope, which may have provided significantly more information and reliable results, the investigation was conducted with a rather limited sample size. The research used only a few materials other materials are not tested, so it could be a limitation. The materials used in the study also will have limitations regarding their properties and hence in the future, a long-term trial could be done on various other materials. As a result, additional research including more samples is needed.

Conclusions

Although not all of the samples had leakages, all of the sample groups displayed some degree of microleakage. When compared to the other groups, SuperEBA demonstrated the highest level of microleakage. Comparing the two materials to the other materials, TotalFill BC RRM and Biodentine demonstrated the least amount of apical microleakage. Therefore, it is possible to suggest using these materials. A larger sample size should be used in in vivo experiments in the future to study the interactions between the sealing cement that were used, as well as the therapeutic significance and consequences of solubility over time.

Additional Information

Disclosures

Human subjects: All authors have confirmed that this study did not involve human participants or tissue. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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ORIGINAL RESEARCH

Comparative Evaluation of Different Storage Media on the Survival of pdl Cells: An In-Vitro Study

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ABSTRACT

Introduction: The extraoral dry time and the storage media used to store teeth before reimplantation have the greatest impact on the prognosis of avulsed teeth.
Aim: The purpose of this study was to evaluate and compare the efficacy of different storage media on viability of periodontal ligament cells at different time periods.
Materials and Methods: Fifty freshly extracted sound teeth with healthy PDL were selected for the present study. Teeth were divided into four groups with 10 teeth each depending on the storage media (HBSS, COCONUT WATER, ALOE VERA, MILK) used for storing freshly extracted teeth. Remaining 10 samples were divided into 2 groups with 5 teeth each to serve as control. Cell viability in each group was checked at 1hr, 2hrs, 4 hrs, 8 hrs and 24 hrs time period. The data were tabulated and subjected to statistical analysis using One way Analysis of Variance (ANOVA) with post hoc analysis (Tukey HSD) for comparison of means. The statistical software namely SPSS 21.0 was used to analysis of the data.
Results: The results indicated PDL cell viability was maximum at 1 hour time interval in all the groups and decreased over a period of time. Also, HBSS showed maximum percentage of viable PDL cells followed by Coconut water, Aloe Vera and milk at all time intervals tested.
Conclusion: It can be concluded that HBSS is the gold standard for the preservation of viable cells for a longer period followed by Coconut water and Aloe Vera.
Keywords: Periodontal Ligament Cells, HBSS, Coconut Water, Aloe Vera, Milk

INTRODUCTION

Tooth avulsion is defined as the complete loss of a tooth out of the alveolar bone socket as a result of an accident and represents severe traumatic dental injury. In children and adolescents, tooth avulsion typically affects the incisors, and it is frequently accompanied with unpredictability in the course of therapy and a financial burden. The most common age range is between 7 and 14 years.[1] Prognosis after reimplanting an avulsed tooth is largely dependent on extra-alveolar time and the storage media used to store the avulsed tooth. Therapeutic effectiveness of storage media depends on its osmolarity, pH, nutrient content,

and temperature of the media in order to sustain the viability of periodontal cells. The periodontal ligament cells should be able to undergo mitosis to create clones of damaged PDL fibroblasts that will cover the damaged surfaces of the root. Storage media should also be sterile, inexpensive, and readily available.[2] Various storage mediums are available like Hanks Balanced Salt Solution (HBSS), Aloe Vera, Coconut Water, Milk, tap water, saliva, ViaSpan, propolis, culture media, egg albumin, salvia officinalis, morusrubra, Emdogain, Eagle's medium, cryoprotective agents are available.[3] HBSS is a sterile, physiologically balanced isotonic standard salt solution that is commonly used in biomedical research to support the growth of various cell types. This solution is nontoxic; biocompatible with PDL cells; and the ingredients in HBSS can sustain and reconstitute the PDL cells depleted cellular components. HBSS is essential for cell survival because it is non-toxic, highly nutritive, and has an appropriate pH balance and osmolality. However, HBSS is not readily available to be used by the patient at the accident site.[4,5] Aloevera is a cactus-like plant in the Liliaceae family. It contains anti-inflammatory, antioxidant, antibacterial, antifungal, and anticarcinogenic properties as well as vitamins, enzymes, minerals, sugars, salicylic acids, and amino acids. For up to 9 hours, aloe vera at 10%, 30%, and 50% concentrations performed similarly to supplemented culture media.[4,6] The coconut, also known as the "tree of life," is a natural drink that is produced biologically and hermetically inside the coconut. Coconut water is the liquid endosperm of the coconut, and it is high in amino acids, proteins, vitamins, and minerals. It is a hypotonic solution that is more acidic than plasma and has a specific gravity of about 1.020, which is comparable to blood plasma.[5,7] Milk is significantly better than other solutions because its physiological properties, such as pH and osmolality, compatibility with PDL cells; however, because it is easy to obtain and free of bacteria, it is critical that it be used within the first 20 minutes after avulsion. Milk, as a gland secretion, contains epithelial growth factor, which stimulates the proliferation and regeneration of Malassez's epithelial cell rests and activates alveolar bone resorption. This eventually helps to isolate the bone tissue from the tooth and reduces the likelihood of ankylosis. Milk was as effective as HBSS for storing avulsed teeth for up to 6 hours, but it could not revive the degenerated cells.[5,8] In addition to storage media, extraoral time has been shown to influence maintaining cell viability. The purpose of this study is to evaluate and compare the efficacy of different storage media on viability of periodontal ligament cells at different time periods. Till date, no study has been done to comparatively evaluate different storage media (HBSS, Aloe Vera gel, Coconut water, Milk) at different timings on the survival of PDL cells. So, the aim of the study was to compare & evaluate the different storage media on the survival of periodontal ligament cells.The null hypothesis was that there is no difference in the number of viable cells in different storage media at different time intervals.

MATERIALS AND METHODS

The current study was conducted in the Dept. of Conservative Dentistry and Endodontics at IDST, Modinagar, UP after ethical approval from the Institutional Ethical Committee. Fifty freshly extracted teeth with intact crowns, closed apexes, and healthy PDL were obtained from the Dept of Oral & Maxillofacial Surgery in, IDST College, Modinagar.UP. Teeth with intact crown, closed apex and healthy PDLwere selected for the study. Teeth with cracks, fractures and bone losswere excluded from the study. Immediately after extraction, all the teeth were stored in respective storage media for the study purpose in order to maintain equal baseline standardity for viable cells. Fifty teeth were divided into four groups with 10 teeth each depending on the storage media used for storing freshly extracted teeth. Remaining 10 samples were divided into 2 groups to serve as control:

Group 1 (N = 5) Positive Control, Group 2 (N = 5) Negative Control (Tap Water), Group 3 (N = 10) Hbss, Group 4 (N = 10) Aloe Vera Gel, Group 5 (N = 10) Natural Coconut, Group 6 (N = 10) Milk.

Coronal 3mm of periodontal ligament was removed with sterile curette to remove the cells that might have been damaged during extraction and the teeth were transferred to storage media by holding the crown portion with extraction forceps and not disturbing the viable cells on root surface. The PDL tissue was scrapped and collected from the root portions of the teeth with the help of sterile curette from different storage media. These were incubated for 30 minutes in 15ml Falcons tubes with a 2.5ml solution of 0.2mg/ml-1 of collagenase and 2.4mg/ml-1 dispase grade II in phosphate buffered saline. After incubation, 50 µl of foetal bovine serum was added to each test tube. All the tubes were centrifuged for 4 minutes at 1000rpm.After centrifugation, the supernatant was removed with sterile micropipettes, and the cells were labelled with trypan blue staining. After the trypan blue exclusion test, the cells are viewed under 40X magnification with the help of hemocytometer to count the viable and non-viable cells.[4] The cells that take up the stain are non-viable cells and the cells that do not take the stain are viable cells. [(Total cells - Stained cells)/ Total Cells] X100 was used to calculate the viable cell percentage. Cell viability in each group were checked at 1 hr, 2 hrs, 4 hrs, 8 hrs and 24 hrs time period. Between each time period, the samples were stored in their respective storage media. The results were tabulated and subjected to statistical analysis using One way Analysis of Variance (ANOVA) with post hoc analysis (Tukey HSD) for comparison of means. The statistical software namely SPSS 21.0 was used to analysis of the data. P value <0.05 was considered statistically significant.

RESULTS

Positive control (collagenase and dispase II) showed maximum number of viable PDL cells at different time periods (1,2,4,8 and 24 hrs) while the negative control (Tap water) showed least number of viable cells. The results indicated that HBSS showed maximum percentage of viable PDL cells followed by Coconut water, Aloe vera and milk. (Table 1) Viability of cells in decreasing order was Group 1 (Positive Control)>Group 3 (HBSS)>Group 5 (Coconut water)>Group 4 (Aloe Vera)>Group 6 (Milk)>Group 2 (Tap Water) at all the time periods tested. Same superscript in each row depicts, statistically non-significant difference at different time intervals. Same superscript across a column depicts, statistically non-significant difference between the groups.

Table 1: Inter and intra group comparison for percentage of viable cells at different time intervals among different groups

Groups/ Time intervals (hrs)	1 hr	2 hr	4 hr	8 hr	24 hr
Group 1 (positive control)	67.0±2.75	-	-	-	-
Group II (Tap water)	9.2 ± 0.83^{a}	2.2 ± 2.48^{abcd}	0.2 ± 0.4^{be}	0.0 ± 0.0^{ce}	0.0 ± 0.0^{d}
Group III (HBSS)	54.0 ± 2.0^{a}	52.5 ± 1.0^{ab}	51.6 ± 0.84^{b}	49.9±0.99	47.0±0.84
Group IV (Alovera Gel)	37.2 ± 0.91^{1}	30.9 ± 0.99^{a}	29.4 ± 1.42^{a}	26.2±3.22	11.8±1.54
Group V (Coconut water)	42.8 ± 1.22^{1}	42.0 ± 1.15^{ab}	40.2 ± 1.61^{b}	38.0 ± 1.41^{c}	36.8 ± 0.78^{c}
Group VI (Milk)	26.0±0.94	21.2 ± 0.99^{a}	19.2 ± 0.99^{a}	11.7±1.25	3.50±1.08

DISCUSSION

The aim of this study was to compare & evaluate different storage media on the survival of periodontal ligament cells. Results of our study showed that maximum percentage of viable cells was seen in Group 3 (HBSS) followed by Group 5 (Coconut water), Group 4 (Aloe Vera gel), Group 6 (Milk) and Group 2 (Tap Water) at all time intervals tested. Group 3 (HBSS) showed maximum number of viable cells at all time periods when compared to other groups. This can be attributed to its optimal pH (7.4), osmolality (280 mosmol kg-1) and its constituents. It contains sodium chloride, D-glucose, potassium chloride, sodium bicarbonate, potassium phosphate, calcium chloride, and magnesium sulphate (monobasic) anhydrous.[2] These key metabolites helpreconstitute the depleted cellular components of the PDL cells, thus maintaining their viability for longer duration. Studies have reported that root resorption is delayed when avulsed tooth is soaked in HBSS for 30 minutes after extra oral dry time of 15-60 minutes.[9] The results of the study are in agreement with those of Hwang et al.who reported that HBSS maintains 90% of cell viability for 24 hours.[10]Adeli et al also reported maximum cell viability with HBSS as storage media when compared with tap water, whole milk, green tea extract and sucrose.[11] However, the results of this study are contradictory to study by Souza et al who reported that HBSS is inferior to milk. This difference could be attributed to lower temperature of HBSS and milk in their study. Lower temperature decreases the efficacy of HBSS due to low nutrient availability and formation of tetrazolium salts in formazan crystals. Group V (Coconut water) showed less percentage of viable cells than HBSS but more than other groups at all time intervals. Natural coconut water is sterile and has 93% water and 5% sugar, which gives it a high osmolalityIt contains a lot of proteins, vitamins, and minerals like potassium, calcium, and magnesium. Also, it shows mitotic, clonogenic activity and growth promoting characteristics that helps maintain the viability of PDL cells. Quimol et al stated that coconut water helps the cells form a monolayer by adhering to the culture wells and helps in maintaining viability similar to HBSS.[5] The findings of the study disagree with Moreira-Neto etal who stated that coconut water at 37^{0}C was less effective than milk in maintaining the cell viability.[13] Aloe vera gel (Group 4) showed less cell viability than HBSS and Coconut water but more than milk and tap water. This could be attributed to its optimal pH and its constituent parenchymal tissue (inner pulp) which contains proteins, lipids, amino acids, and other vital nutrients. Also, it contains catalase enzyme, an antioxidant that converts hydrogen peroxide to water and oxygen and suppression of the generation of these free radicals may improve the effectiveness of cell preservation and prevent lipid peroxidation.[14] Martin etal stated that the high success rate of alovera extract in protecting the cell viability might be due to its antibacterial and antifungal properties.[15] The results of our study are in accordance to the study conducted by Fulzele et al who demonstrated that aloe vera maintained PDL cells viability over a period of 120 mins.[14]Buttke et al. also proposed that storing avulsed teeth in medium containing one or more antioxidants found in alovera extract could improve reimplantation success.[16] Moazzami F. et al stated that aloe vera may be useful in the replantation of avulsed teeth because of its fibroblast stimulating properties.[17] Group 6 (Milk) showed less percentage of viable cells than HBSS, coconut water and aloevera but more than tap water at all time intervals tested. Milk has osmolality of 270 mOsm/kg and pH of 6.5 to 7.2, which is similar to extracellular fluid. The current study's findings contradict those of Olson et al, who reported that milk had a significant advantage over HBSS at 8 and 12 hours. Lekic et al stated that milk was effective for a short period of time and lost its effectiveness after 2-6 hours in vitro, and only cold milk was suitable for the preservation of the proliferation capacity of PDL cells.[18] Since milk is readily available in almost all situations, so it is widely accepted as a storage medium for short-term storage of avulsed teeth. Group 2 (Tap Water) showed least number of viable cells initially and gradually become zero at 24 hrs time interval. In this

study, tap water was used as a negative control. The pH of tap water ranges from 7.4 to 7.79, with an osmolality of 30 mOsm/kg. It is unsuitable for use as a storage medium for avulsed teeth due to bacterial contamination, hypotonicity, non-physiological pH, and osmolality, which promotes PDL cell lysis.[10,19] The results of our study are in agreement with several studies who found that cells stored in water do not retain their morphology, resulting in visible destruction and rapid cell death.[20] The findings were consistent with Blomlof's study, which found that water is damaging to PDL cells and is not a good storage medium at any time.Some studies have suggested that it could be used as a storage medium for very short periods of time where there are no other options. However, results of our study indicated that tap water was the least desirable storage medium. In view of this, tap water should be used only to avoid tooth dehydration, but it is inadequate for conservation of avulsed teeth.[21,22] Results of the present study showed that PDL cell viability was maximum at 1 hour time interval in all the groups and decreased over a period of time. Since there is no study done till date to evaluate the efficacy of HBSS, Coconut water, Aloe vera, Milk and tap water on the survival of the periodontal ligament cells at different time intervals, the results of this study cannot be contradicted or corroborated. Since there is a difference in the number of viable cells in different storage media at different time intervals, the null hypothesis was rejected. There is no ideal storage media till date, hence according to the results obtained HBSS and Coconut water can be used as long-term storage media and Aloe vera and Milk can be used as a short-term storage media.

CONCLUSION

Within the limitations of the study, it can be concluded that HBSS is the gold standard for the preservation of viable cells for a longer period followed by Coconut water and Aloe vera. In absence of HBSS, Coconut water is the best choice for the storage of avulsed teeth as it is easily available. Milk can also be used as short-term storage media of avulsed teeth. Further studies should be directed with different storage medias and also with different time periods, to evaluate which storage media best suits for the preserving the avulsed teeth for a longer period of time.

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(28)

ORIGINAL RESEARCH

Comparative Evaluation of Different Storage Media on the Survival of pdl Cells: An In-Vitro Study

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ABSTRACT

Introduction: The extraoral dry time and the storage media used to store teeth before reimplantation have the greatest impact on the prognosis of avulsed teeth.
Aim: The purpose of this study was to evaluate and compare the efficacy of different storage media on viability of periodontal ligament cells at different time periods.
Materials and Methods: Fifty freshly extracted sound teeth with healthy PDL were selected for the present study. Teeth were divided into four groups with 10 teeth each depending on the storage media (HBSS, COCONUT WATER, ALOE VERA, MILK) used for storing freshly extracted teeth. Remaining 10 samples were divided into 2 groups with 5 teeth each to serve as control. Cell viability in each group was checked at 1hr, 2hrs, 4 hrs, 8 hrs and 24 hrs time period. The data were tabulated and subjected to statistical analysis using One way Analysis of Variance (ANOVA) with post hoc analysis (Tukey HSD) for comparison of means. The statistical software namely SPSS 21.0 was used to analysis of the data.
Results: The results indicated PDL cell viability was maximum at 1 hour time interval in all the groups and decreased over a period of time. Also, HBSS showed maximum percentage of viable PDL cells followed by Coconut water, Aloe Vera and milk at all time intervals tested.
Conclusion: It can be concluded that HBSS is the gold standard for the preservation of viable cells for a longer period followed by Coconut water and Aloe Vera.
Keywords: Periodontal Ligament Cells, HBSS, Coconut Water, Aloe Vera, Milk

INTRODUCTION

Tooth avulsion is defined as the complete loss of a tooth out of the alveolar bone socket as a result of an accident and represents severe traumatic dental injury. In children and adolescents, tooth avulsion typically affects the incisors, and it is frequently accompanied with unpredictability in the course of therapy and a financial burden. The most common age range is between 7 and 14 years.[1] Prognosis after reimplanting an avulsed tooth is largely dependent on extra-alveolar time and the storage media used to store the avulsed tooth. Therapeutic effectiveness of storage media depends on its osmolarity, pH, nutrient content,

and temperature of the media in order to sustain the viability of periodontal cells. The periodontal ligament cells should be able to undergo mitosis to create clones of damaged PDL fibroblasts that will cover the damaged surfaces of the root. Storage media should also be sterile, inexpensive, and readily available.[2] Various storage mediums are available like Hanks Balanced Salt Solution (HBSS), Aloe Vera, Coconut Water, Milk, tap water, saliva, ViaSpan, propolis, culture media, egg albumin, salvia officinalis, morusrubra, Emdogain, Eagle's medium, cryoprotective agents are available.[3] HBSS is a sterile, physiologically balanced isotonic standard salt solution that is commonly used in biomedical research to support the growth of various cell types. This solution is nontoxic; biocompatible with PDL cells; and the ingredients in HBSS can sustain and reconstitute the PDL cells depleted cellular components. HBSS is essential for cell survival because it is non-toxic, highly nutritive, and has an appropriate pH balance and osmolality. However, HBSS is not readily available to be used by the patient at the accident site.[4,5] Aloevera is a cactus-like plant in the Liliaceae family. It contains anti-inflammatory, antioxidant, antibacterial, antifungal, and anticarcinogenic properties as well as vitamins, enzymes, minerals, sugars, salicylic acids, and amino acids. For up to 9 hours, aloe vera at 10%, 30%, and 50% concentrations performed similarly to supplemented culture media.[4,6] The coconut, also known as the "tree of life," is a natural drink that is produced biologically and hermetically inside the coconut. Coconut water is the liquid endosperm of the coconut, and it is high in amino acids, proteins, vitamins, and minerals. It is a hypotonic solution that is more acidic than plasma and has a specific gravity of about 1.020, which is comparable to blood plasma.[5,7] Milk is significantly better than other solutions because its physiological properties, such as pH and osmolality, compatibility with PDL cells; however, because it is easy to obtain and free of bacteria, it is critical that it be used within the first 20 minutes after avulsion. Milk, as a gland secretion, contains epithelial growth factor, which stimulates the proliferation and regeneration of Malassez's epithelial cell rests and activates alveolar bone resorption. This eventually helps to isolate the bone tissue from the tooth and reduces the likelihood of ankylosis. Milk was as effective as HBSS for storing avulsed teeth for up to 6 hours, but it could not revive the degenerated cells.[5,8] In addition to storage media, extraoral time has been shown to influence maintaining cell viability. The purpose of this study is to evaluate and compare the efficacy of different storage media on viability of periodontal ligament cells at different time periods. Till date, no study has been done to comparatively evaluate different storage media (HBSS, Aloe Vera gel, Coconut water, Milk) at different timings on the survival of PDL cells. So, the aim of the study was to compare & evaluate the different storage media on the survival of periodontal ligament cells.The null hypothesis was that there is no difference in the number of viable cells in different storage media at different time intervals.

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RESULTS

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Group VI (Milk)	26.0±0.94	21.2 ± 0.99^{a}	19.2 ± 0.99^{a}	11.7±1.25	3.50±1.08

DISCUSSION

The aim of this study was to compare & evaluate different storage media on the survival of periodontal ligament cells. Results of our study showed that maximum percentage of viable cells was seen in Group 3 (HBSS) followed by Group 5 (Coconut water), Group 4 (Aloe Vera gel), Group 6 (Milk) and Group 2 (Tap Water) at all time intervals tested. Group 3 (HBSS) showed maximum number of viable cells at all time periods when compared to other groups. This can be attributed to its optimal pH (7.4), osmolality (280 mosmol kg-1) and its constituents. It contains sodium chloride, D-glucose, potassium chloride, sodium bicarbonate, potassium phosphate, calcium chloride, and magnesium sulphate (monobasic) anhydrous.[2] These key metabolites helpreconstitute the depleted cellular components of the PDL cells, thus maintaining their viability for longer duration. Studies have reported that root resorption is delayed when avulsed tooth is soaked in HBSS for 30 minutes after extra oral dry time of 15-60 minutes.[9] The results of the study are in agreement with those of Hwang et al.who reported that HBSS maintains 90% of cell viability for 24 hours.[10]Adeli et al also reported maximum cell viability with HBSS as storage media when compared with tap water, whole milk, green tea extract and sucrose.[11] However, the results of this study are contradictory to study by Souza et al who reported that HBSS is inferior to milk. This difference could be attributed to lower temperature of HBSS and milk in their study. Lower temperature decreases the efficacy of HBSS due to low nutrient availability and formation of tetrazolium salts in formazan crystals. Group V (Coconut water) showed less percentage of viable cells than HBSS but more than other groups at all time intervals. Natural coconut water is sterile and has 93% water and 5% sugar, which gives it a high osmolalityIt contains a lot of proteins, vitamins, and minerals like potassium, calcium, and magnesium. Also, it shows mitotic, clonogenic activity and growth promoting characteristics that helps maintain the viability of PDL cells. Quimol et al stated that coconut water helps the cells form a monolayer by adhering to the culture wells and helps in maintaining viability similar to HBSS.[5] The findings of the study disagree with Moreira-Neto etal who stated that coconut water at 37^0C was less effective than milk in maintaining the cell viability.[13] Aloe vera gel (Group 4) showed less cell viability than HBSS and Coconut water but more than milk and tap water. This could be attributed to its optimal pH and its constituent parenchymal tissue (inner pulp) which contains proteins, lipids, amino acids, and other vital nutrients. Also, it contains catalase enzyme, an antioxidant that converts hydrogen peroxide to water and oxygen and suppression of the generation of these free radicals may improve the effectiveness of cell preservation and prevent lipid peroxidation.[14] Martin etal stated that the high success rate of alovera extract in protecting the cell viability might be due to its antibacterial and antifungal properties.[15] The results of our study are in accordance to the study conducted by Fulzele et al who demonstrated that aloe vera maintained PDL cells viability over a period of 120 mins.[14]Buttke et al. also proposed that storing avulsed teeth in medium containing one or more antioxidants found in alovera extract could improve reimplantation success.[16] Moazzami F. et al stated that aloe vera may be useful in the replantation of avulsed teeth because of its fibroblast stimulating properties.[17] Group 6 (Milk) showed less percentage of viable cells than HBSS, coconut water and aloevera but more than tap water at all time intervals tested. Milk has osmolality of 270 mOsm/kg and pH of 6.5 to 7.2, which is similar to extracellular fluid. The current study's findings contradict those of Olson et al, who reported that milk had a significant advantage over HBSS at 8 and 12 hours. Lekic et al stated that milk was effective for a short period of time and lost its effectiveness after 2-6 hours in vitro, and only cold milk was suitable for the preservation of the proliferation capacity of PDL cells.[18] Since milk is readily available in almost all situations, so it is widely accepted as a storage medium for short-term storage of avulsed teeth. Group 2 (Tap Water) showed least number of viable cells initially and gradually become zero at 24 hrs time interval. In this

study, tap water was used as a negative control. The pH of tap water ranges from 7.4 to 7.79, with an osmolality of 30 mOsm/kg. It is unsuitable for use as a storage medium for avulsed teeth due to bacterial contamination, hypotonicity, non-physiological pH, and osmolality, which promotes PDL cell lysis.[10,19] The results of our study are in agreement with several studies who found that cells stored in water do not retain their morphology, resulting in visible destruction and rapid cell death.[20] The findings were consistent with Blomlof's study, which found that water is damaging to PDL cells and is not a good storage medium at any time.Some studies have suggested that it could be used as a storage medium for very short periods of time where there are no other options. However, results of our study indicated that tap water was the least desirable storage medium. In view of this, tap water should be used only to avoid tooth dehydration, but it is inadequate for conservation of avulsed teeth.[21,22] Results of the present study showed that PDL cell viability was maximum at 1 hour time interval in all the groups and decreased over a period of time. Since there is no study done till date to evaluate the efficacy of HBSS, Coconut water, Aloe vera, Milk and tap water on the survival of the periodontal ligament cells at different time intervals, the results of this study cannot be contradicted or corroborated. Since there is a difference in the number of viable cells in different storage media at different time intervals, the null hypothesis was rejected. There is no ideal storage media till date, hence according to the results obtained HBSS and Coconut water can be used as long-term storage media and Aloe vera and Milk can be used as a short-term storage media.

CONCLUSION

Within the limitations of the study, it can be concluded that HBSS is the gold standard for the preservation of viable cells for a longer period followed by Coconut water and Aloe vera. In absence of HBSS, Coconut water is the best choice for the storage of avulsed teeth as it is easily available. Milk can also be used as short-term storage media of avulsed teeth. Further studies should be directed with different storage medias and also with different time periods, to evaluate which storage media best suits for the preserving the avulsed teeth for a longer period of time.

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Comparison of the Microleakages of Four Root-End Filling Materials: An In Vitro Study

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Abstract

Introduction: When a nonsurgical endodontic treatment is ineffective, surgery is necessary. This entails putting a retrofilling to seal the tooth's apex. Exposing the lesion, performing a curettage, exposing the root apex, resecting it, preparing the root end, and lastly filling the cavity with the proper material are all steps in endodontic surgery. Thus, the aim of this study is to compare the apical microleakage of four root-end filling materials in cavities prepared using ultrasonic retro tip in in vitro conditions.

Materials and Methods: An in vitro study was conducted on 60 extracted single-rooted teeth and was cut at the cementoenamel junction (CEJ). They were biomechanically prepared and obturated. Apical 3 mm root-end resection was done using a diamond disc. Root-end cavities were made using an ultrasonic retro tip. Teeth were separated into four groups and filled with SuperEBA® ethoxy-benzoic acid (EBA; Keystone Industries, New Jersey), mineral trioxide aggregate (MTA), Biodentine (Septodont, France), and TotalFill Bioceramic Root Repair Material (BC RRM; FKG Dentaire Sàrl, Switzerland). The samples were kept in methylene blue dye and split longitudinally. The degree of dye penetration was observed under a stereomicroscope and scored. Finally, the results were analyzed.

Results: TotalFill BC RRM and Biodentine showed the least apical microleakage ($p < 0.05$). Group 1 samples had the highest mean microleakage, followed by Group 2, Group 3, and Group 4 samples.

Conclusion: All of the sample groups showed some evidence of microleakage, but not all of the samples showed leaking. SuperEBA (Group 1) demonstrated the highest microleakage when compared to the other groups.

Categories: Dentistry
Keywords: root canal treatment, endodontics, totalfill bioceramic root repair material, retrograde filling, apical microleakage

Introduction

A root canal treatment is the most commonly employed treatment to disinfect and fill the root canal system three-dimensionally. However, sometimes, despite thorough chemomechanical preparation and obturation, orthograde treatment may fail [1]. Periapical surgery is indicated when there is excessive root canal calcification, separated instruments extending beyond the apex, iatrogenic perforations, ledges or shoulder, and teeth restored with crowns or post and core. It may also be used in symptomatic cases that have not responded to conventional root canal treatment [2]. Periradicular surgery includes debridement and curettage, root apex exposure and resection, and retrograde cavity preparation followed by appropriate filling material insertion [3]. In addition, after a 1-year postoperative follow-up, the success rate of periapical surgery for patients with periapical lesions was 73.9% [4]. One of the typical clinical conditions affecting the periradicular tissues are periapical lesions [5]. One of the most commonly performed procedures for surgical endodontic treatment is retrograde obturation, which uses a variety of techniques and materials [6].

A retrograde filling is important to create an apical seal that prevents the microleakage of remaining irritants into periradicular tissues [7]. The prime factor that impacts a successful periapical surgery is the selection of retrograde filling material. Initially, amalgam, silver cones, gold foil, gutta-percha (GP), composite resins, zinc oxide eugenol (ZOE) cement, polycarboxylate cement, zinc phosphate cement, glass ionomer cement (GIC), and titanium screws were used for the same [8]. SuperEBA® ethoxy-benzoic acid (EBA) Cement (Keystone Industries, New Jersey) is a type of reinforced ZOE cement with 68% EBA and 32% eugenol. ZOE cement as a root-end filling material was unsuccessful; nevertheless, the reinforced variant showed better results [9]. Mineral trioxide aggregate is considered an ideal retrograde material [1]. Mineral trioxide aggregate (MTA) possesses significant qualities, such a high pH, biocompatibility, fixing power despite humidity, periradicular regeneration, and osteoinductive ability [10]. Biodentine (Septodont, France) is calcium silicate-based cement with high biocompatibility. It shows better physical and chemical properties, such as reduced time for setting and increased mechanical properties that make it a compatible root-end filling material [11]. A reparative biocompatible substance that seals perforations and does not

irritate surrounding tissues is required in cases of extensive perforation [12].

TotalFill Bioceramic Root Repair Material (BC RRM; FKG Dentaire Sàrl, Switzerland) is a premixed material either in putty or syringe form. Its main components are calcium silicates and zirconium oxide. This material showed superior healing in periradicular surgery. It sets fast and shows improved handling properties. In addition, biocompatibility is analogous to MTA [13]. Apical seals attained through a retrograde filling material can be evaluated by the depth of the dye penetration, fluid-filtration technique, radioisotope or bacteria penetration, or electrochemical methods. The dye penetration technique is the prevalent and easily performed method [14]. The fluid filtration technique evaluates the endodontic and restorative sealers' capacity for sealing. As a result, this method has established credibility in the field of study evaluating apical and coronal microleakage. Because of this, compared to the dye method, the fluid filtration method relied on quantitative measurements of fluid passage within the interfaces; both procedures produced results that were comparable in earlier studies [15]. To date, no in vitro studies have been conducted to compare and evaluate apical microleakage after using SuperEBA, MTA, Biodentine, and TotalFill BC RRM in cavities prepared using ultrasonic retro tips [16,17]. The present in vitro study aims to compare the apical microleakage of four root-end filling materials in cavities prepared using ultrasonic retro tips and evaluate the results. The null hypothesis was that there would be no significant difference in the apical microleakage amid the four chosen materials.

Materials And Methods

The sample size was calculated using the formula $n = Z^2 P (1-P) d^2$, where n is the sample size, Z is the statistic corresponding to the level of confidence, and P is the expected prevalence. A power of 0.80 with an alpha (α) level of 0.05 (confidence level = 95%), and a sample size of 60 was considered for the total samples. A total of 60 single-rooted extracted teeth, which were periodontally compromised and indicated for extraction, were collected from the Department of Oral & Maxillofacial Surgery, IDST. Soft tissues and deposits were mechanically removed from all the samples using Gracey curettes, and teeth were inspected under a stereomicroscope microscope (Carl Zeiss, Jena, Germany) for examining the number of canals, cracks/defects, and decay. The specimens were stored in 10% formalin until use.

Teeth with single root and single canal, closed apex, without fractures, resorption, or cracks were included. Multirooted teeth and teeth with extra canals, open apex, root caries, and calcification were excluded. The coronal part of the teeth was sectioned horizontally along the long axis with a diamond disc, at the cementoenamel junction (CEJ) level or below, to standardize the root length (15 mm).

Pre-operative radiography was performed, and access openings were created with an access bur (Dentsply Maillefer, USA). The working length was estimated radiographically with a #10 K-file, and a #40 K-file was used as the master apical file (Mani Inc., Japan). Ethylenediaminetetraacetic acid (EDTA) liquid irrigation was performed first (Prevest DenPro, India), and then 5% sodium hypochlorite irrigation was performed (Prevest DenPro, India), followed by saline irrigation. The canals were dried and obturated with lateral compaction technique using 2% gutta-percha (GP) cones (Meta Biomed, Korea) and AH Plus (Dentsply Maillefer, Ballaigues, Switzerland) as the root canal sealer.

Following obturation, cavities were filled with composite resin. The treated teeth were kept in saline for one week. Then, teeth were kept in an incubator (Binder, Tuttlingen, Germany), which has a specification of 535 L of interior space with a footprint of just 0.58 m2 at 100% humidity at 37 °C for five days. The apical 3 mm was cut using a straight fissure bur. Class I cavity was prepared in the root end with an ultrasonic retro tip to a depth of 3 mm. The samples were randomly divided into four groups with 15 teeth each: Group 1 (N = 15) retrograde cavity filled with SuperEBA, Group 2 (N = 15) with MTA, Group 3 (N = 15) with Biodentine, and Group 4 (N = 15) with TotalFill BC RRM.

The materials were manipulated according to the manufacturers' instructions, followed by filling the cavities. The teeth were stored in 100% humidity at 37 °C for five days. The prepared retro-cavities underwent cleaning, saline irrigation, and drying. Then, they were coated with nail varnish, except for the apical 1 mm, and dried. Next, the teeth were placed in 1% methylene blue dye for up to 48 h. The roots were washed and split into longitudinal sections along the long axis using a diamond disc. Dye penetration was examined under a stereomicroscope, and the scoring was done on a scale of 0 to 4 (Figure 1).

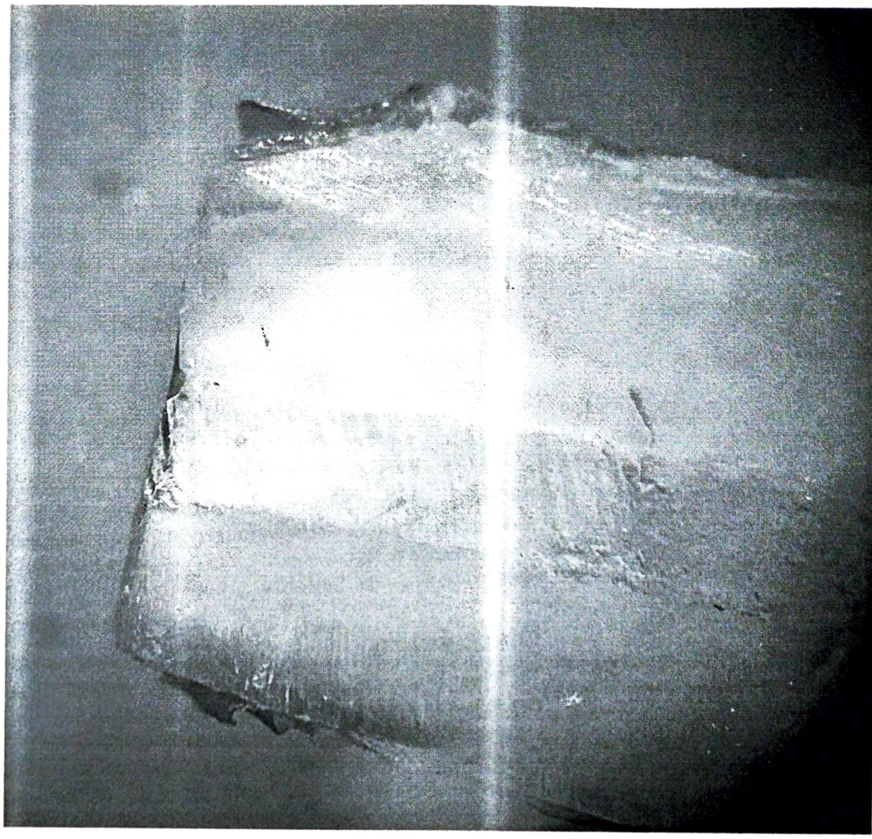

FIGURE 1: Stereomicroscopic image of the setup tested

This in vitro study was conducted in the Department of Conservative Dentistry and Endodontics at Institute of Dental Studies & Technologies (IDST), Kadrabad, Modinagar, Ghaziabad, Uttar Pradesh, India. Ethical clearance was obtained from the Institutional Review Board (IRB) with IRB number IDST/IEC/2019/PG/11.

Statistical analysis

Data were analyzed with IBM SPSS Statistics for Windows, Version 21 (Released 2012; IBM Corp., Armonk, New York, United States. As the main outcome variable was ordinal, non-parametric tests, such as Kruskal-Wallis and Mann-Whitney U tests, were utilized for the analysis.

Results

Table *1* shows the description of microleakage scores among all the study groups.

Microleakage score					
	N (number)	Mean (M)	Standard deviation	95% confidence interval for the mean	
				Lower bound	Upper bound
Group 1	15	1.4000	0.63246	1.0498	1.7502
Group 2	15	0.8667	0.51640	0.5807	1.1526
Group 3	15	0.4000	0.50709	0.1192	0.6808
Group 4	15	0.2000	0.41404	-0.0293	0.4293

TABLE 1: Description of the microleakage scores among all the study groups

Table *2* shows the post-hoc pairwise comparison by the Mann-Whitney U test.

Comparisons	P-values of the pairwise comparison by the Mann-Whitney U test
Group 1 vs. Group 2	0.019
Group 1 vs. Group 3	<0.001
Group 1 vs. Group 4	<0.001
Group 2 vs. Group 3	0.022
Group 2 vs. Group 4	0.001
Group 3 vs. Group 4	0.240

TABLE 2: Post-hoc pairwise comparison by the Mann-Whitney U test

The findings indicate that microleakages in Group 3 and Group 4 samples were significantly lesser than in those in Group 2 samples and were further significantly lower than those in Group 1 samples. No significant difference could be found between Group 3 and Group 4 samples. The mean microleakage of Group 1 samples was maximum, followed by Group 2, Group 3, and Group 4 samples.

Discussion

The accomplishment of periapical surgery is highly dependent on a proper apical seal. Retrograde filling materials are proposed to limit or avoid leakage into periapical tissues [15]. This study intended to test the microleakage of four retrograde materials. Ultrasonic retro tips are better than burs for retro preparation. The preparation of root-end cavity with ultrasonic tips causes negligible destruction to the root canal morphology. They are precise, conservative, and cleaner. The cutting bevel is 90° to the long axis of the root, which reduces the number of patent dentinal tubules at the open end and minimizes microleakage [18].

Ishikawa et al. assessed the retrograde cavity preparation with US retro tip and concluded that the use of US retro tip reduced the time taken in root-end cavity preparation [19]. The resulting cavities were more precise, and the US tips were more efficient in cutting than conventional burs. In this study, stainless-steel ultrasonic tip with diamond coating was used. The angle of root-end resection affects the leakage, so a 90° resection angle was selected here as it is considered more acceptable by previous studies. A resection depth of 3 mm reduces the lateral canals by 93% and apical ramifications by 98% [20].

The most commonly used method to evaluate the sealing property of retrograde materials is dye leakage. It can provide an estimate of the sealing property in various clinical conditions. In the present study, the linear penetration of 1% methylene blue dye was measured. Methylene blue is commonly used because of its small molecular weight that aids in penetrability [21]. The disadvantage of this method is that the dye molecules are smaller in size than bacteria, which can result in an overestimation of the bacteria's penetration levels due to microleakage [20]. Lucena-Martin et al. showed that the transverse root section method results in the loss of dye and dentine portion [22]. Consequently, the longitudinal sectioning method was performed here to evaluate dye penetration into filling materials.

Epoxy resin-based AH Plus sealer shows high flowability, and it can penetrate dentinal tubules at deeper levels. Increased polymerization boosts the interlocking of the sealer material and dentin [23]. Therefore, in this study, AH Plus root canal sealer was chosen for obturation. Of all the materials used for retrograde filling, the least microleakage was observed for TotalFill BC RRM (Group 4), followed by Biodentine (Group 3), MTA (Group 2), and SuperEBA (Group 1). SuperEBA is broadly studied for retrograde fillings, and it has shown satisfactory properties. Greer et al. and Suntimuntanakul et al. observed that SuperEBA EBA Cement shows a higher sealing property when compared to a few other retrograde filling materials [24]. The results of our study are in agreement with other studies in which MTA showed improved marginal seal than other retrograde filling materials, such as GIC, amalgam, light cure GIC, and SuperEBA [25]. This can be because of the hydroxyapatite-like crystal formation at material-root canal dentine interfaces, which results in excellent adhesion preventing the penetration of the dye [26]. MTA has always shown less leakage than SuperEBA; there was no or minimal dye leakage in the majority of MTA specimens [27]. Similarly, Bates et al. traced microleakage in dental amalgam, SuperEBA, and MTA and concluded that it was the least in MTA [28]. Biodentine shows superior characteristics to MTA as it sets faster, thus reducing the risk of bacterial contamination [29]. Biodentine exhibits superior sealing properties than MTA [30]. In addition, it exhibits better biomineralization than MTA, with broader calcium-rich layer formation. Radeva et al. also found similar results as this study; they concluded that Biodentine shows greater sealing ability than MTA [31].

TotalFill BC RRM is available in the premixed syringe delivery system or putty form. It is extremely resistant

to washout. It has calcium phosphate monobasic as an additional agent that enhances hydroxyapatite formation. It shows properties, such as wear resistance, biocompatibility, chemical durability, and aesthetics [32].

Nonetheless, this study has some limitations. Instead of employing a scanning electron microscope (SEM) or confocal microscope, which may have provided significantly more information and reliable results, the investigation was conducted with a rather limited sample size. The research used only a few materials other materials are not tested, so it could be a limitation. The materials used in the study also will have limitations regarding their properties and hence in the future, a long-term trial could be done on various other materials. As a result, additional research including more samples is needed.

Conclusions

Although not all of the samples had leakages, all of the sample groups displayed some degree of microleakage. When compared to the other groups, SuperEBA demonstrated the highest level of microleakage. Comparing the two materials to the other materials, TotalFill BC RRM and Biodentine demonstrated the least amount of apical microleakage. Therefore, it is possible to suggest using these materials. A larger sample size should be used in in vivo experiments in the future to study the interactions between the sealing cement that were used, as well as the therapeutic significance and consequences of solubility over time.

Additional Information

Disclosures

Human subjects: All authors have confirmed that this study did not involve human participants or tissue. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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Comparative Evaluation of the Incidence of Dentin Microcracks Following Biomechanical Preparation Using Four Different Nickel-Titanium Rotary File Systems: An In Vitro Study

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Abstract

Introduction: Biomechanical preparation has gotten easier over time with the development of nickel-titanium (NiTi) rotary instruments. Despite their benefits, research has shown that these files frequently result in microcracks in the root canal dentin, which can fracture the roots. Such mishaps should be prevented, as they compromise the integrity of the root and reduce the long-term survival of endodontically treated teeth.

Materials and methods: This study was conducted at Government Dental College and Hospital, Patiala, Punjab, India. Eighty permanent mandibular premolar teeth were included. All the roots were inspected for any pre-existing cracks or craze lines under a stereomicroscope. The teeth were decoronated and then divided into four groups (n = 20): Group I: TruNatomy, Group II: Neoendo Flex, Group III: ProTaper Gold, and Group IV: 2Shape. The samples were instrumented according to the group to which they belonged. The roots were then sectioned horizontally at 3 mm and 6 mm from the apex and examined under a stereomicroscope at 40x for the presence of microcracks.

Results: The data were analyzed using the IBM SPSS Statistics for Windows, version 26 (released 2019; IBM Corp., Armonk, New York, United States). A chi-square test was applied, and the level of significance was set at $p < 0.05$. The highest incidence of microcracks was associated with ProTaper Gold (65%), followed by Neoendo Flex (45%), TruNatomy (20%), and 2Shape (20%).

Conclusion: All rotary instruments resulted in dentinal damage. ProTaper Gold exhibited the highest frequency of dentin cracks. TruNatomy and 2Shape exhibited satisfactory results with minimal crack formation.

Categories: Dentistry
Keywords: 2shape, trunatomy, stereomicroscope, protaper gold, neoendo flex, dentin microcracks

Introduction

In endodontic therapy, the prognosis is positively connected with the most effective cleaning and shaping techniques [1]. Nickel-titanium (NiTi) rotary instruments have significantly improved root canal preparation since they have made instrumentation easier and faster [2,3]. Human dentin is viscoelastic, and during biomechanical preparation, instruments contact the root canal wall and apply forces that lead to a temporary stress concentration on the dentin. This may result in minor cracks, which can progress into vertical root fractures during obturation, post-placement, and retreatment [4].

Many variables are out of the control of the clinician (natural root morphology, canal shape, size, and dentin thickness); however, factors that can be addressed during treatment to reduce fracture susceptibility include the final canal shape and extent of canal enlargement [5].

The TruNatomy file system (Dentsply Maillefer, Baillagues, Switzerland) has been recently introduced. The manufacturer claims that this new file system provides the clinician with greater ease, time-saving, safety, enhanced cutting efficiency, and mechanical qualities in comparison to earlier generations of rotary files [6].

After extensive exploration of the available literature, it was found that there is a scarcity of adequate information about the influence of these recently introduced Ni-Ti rotary files in the formation of dentinal cracks. Hence, the objective of the current study was to compare the frequency of crack formation in root dentin following root canal preparation using TruNatomy, Neoendo Flex, ProTaper Gold, and 2Shape using a

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stereomicroscope. The null hypothesis was that there would be no significant difference in dentinal microcracks produced among the groups.

Materials And Methods

This study was conducted at Government Dental College and Hospital, Patiala, Punjab, India. Eighty extracted single-rooted human permanent mandibular premolars were selected. Each of the chosen teeth was meticulously cleaned and disinfected before being stored in distilled water. The existence of a single canal was confirmed with mesiodistal and buccolingual angulated radiographs. Teeth with fractures, open apices, curved canals, caries or fillings, and complex anatomical variations were excluded from the study. The external root surfaces of the samples were inspected under a stereomicroscope to detect any pre-existing cracks or craze lines.

The teeth were decoronated to obtain a standard length of 16 mm from the apex. Root surfaces were coated with aluminum foil and embedded in self-cure acrylic resin (DPI, India) to simulate bone. Once the acrylic had set, the roots were retrieved. Aluminum foil was removed, and the void it left was filled with light body impression material (GC Flexceed, GC Corporation, Tokyo, Japan) to mimic the periodontal ligament. The roots were then remounted into the acrylic (Figures *1*-*2*).

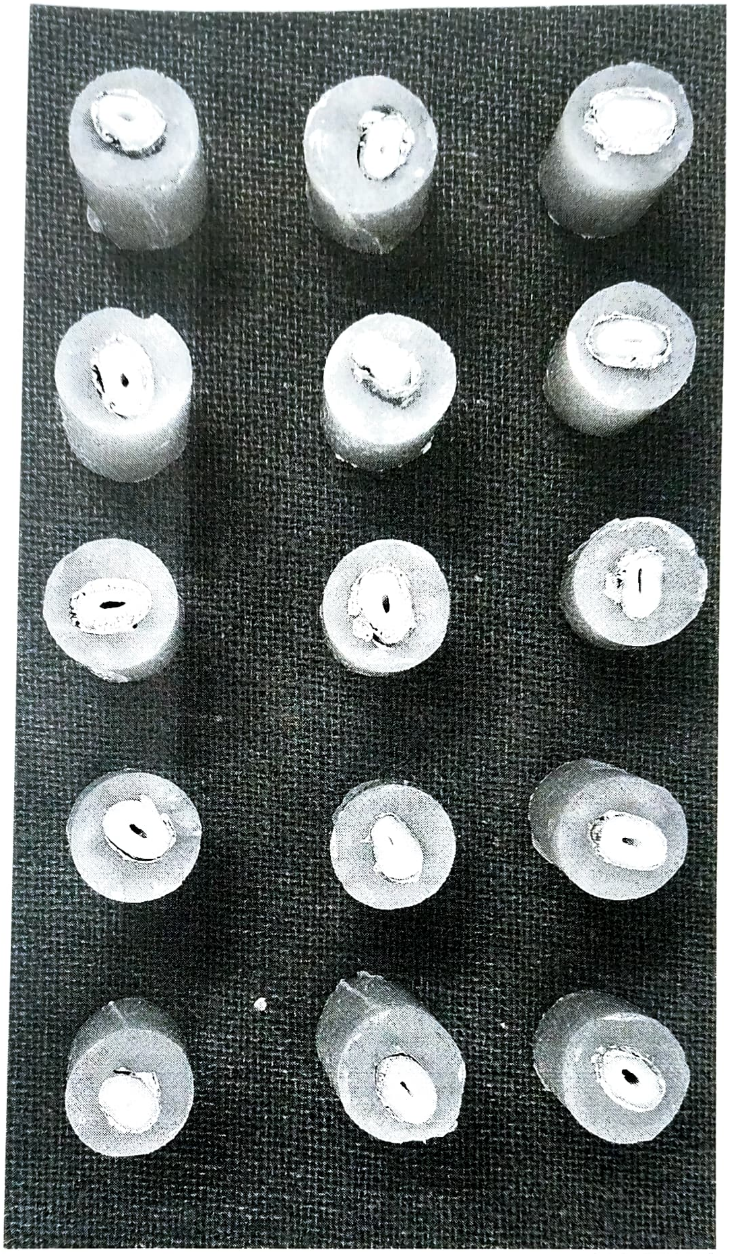

FIGURE 1: Tooth covered with aluminium foil embedded in self-cure acrylic

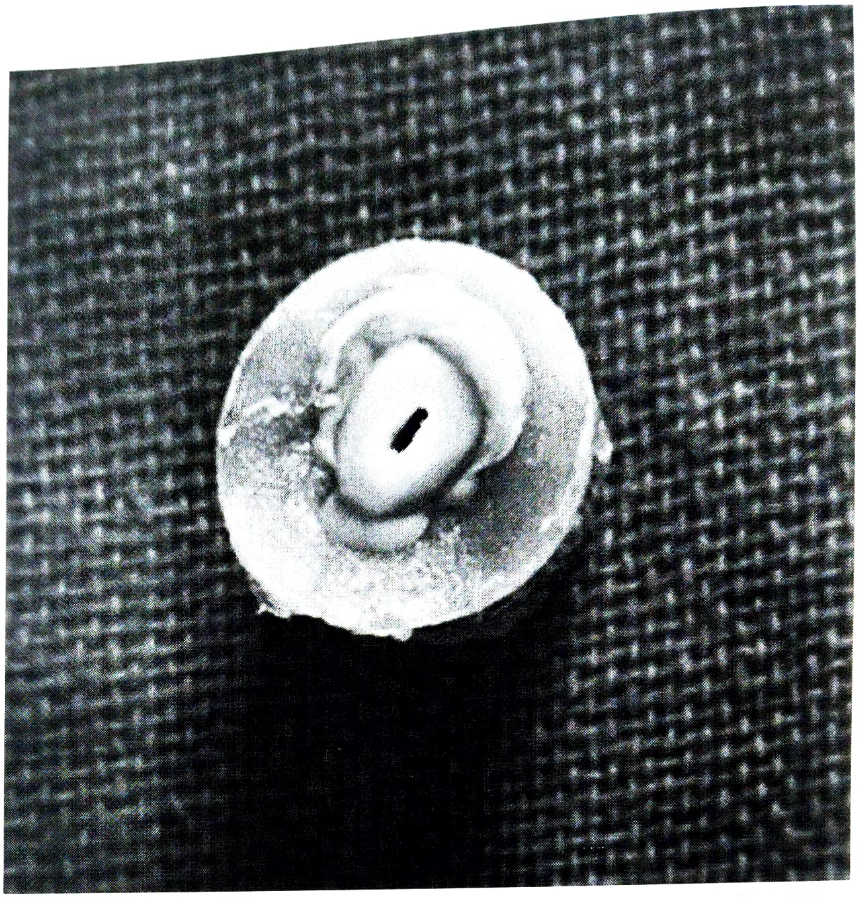

FIGURE 2: Aluminium foil replaced with a light-body impression material

The patency of root canals was established using a #10k file (Mani Inc., Tokyo, Japan), and the working length was measured by inserting a #10k file into the canal until its tip was visible at the apex and 1 mm subtracted from the initial length. A glide path preparation was done using #15K files. Based on the different Ni-Ti files used, the teeth were randomized into four groups with 20 samples in each: Group I: TruNatomy (Dentsply Maillefer, Baillagues, Switzerland), Group II: Neoendo Flex (Orikam Healthcare, India), Group III: ProTaper Gold (Dentsply Maillefer, Baillagues, Switzerland), and Group IV: 2Shape (MicroMega, Besancon, France). Cleaning and shaping were done in all the teeth from Groups 1 to 4 using the respective rotary file systems until instrument size #25 in all four groups.

The endodomotor (X-Smart, DENTSPLY Tulsa Dental Specialties, Tulsa, USA) was set to a torque and speed of 1.5 Ncm and 300 rpm, respectively, for all the groups. Group I: The canals were prepared using the TRN (Dentsply Maillefer, Baillagues, Switzerland) orifice modifier (20/0.08), TRN glider (17/0.02), and TRN Prime (26/0.04). Group II: The canals were prepared using Neoendo Flex (Orikam Healthcare, India) rotary files sequentially according to the manufacturer's recommendation to a size of 25 (0.04). Group III: The canals were prepared using PTG (Dentsply Maillefer, Baillagues, Switzerland) starting with shaping file SX (19/0.04), followed by S1 (18/0.02) and S2 (20/0.04). Thereafter, finishing files were used in a sequence of F1 (20/0.07) and F2 (25/0.08) up to the working length. Group IV: The canals were prepared with 2Shape (MicroMega, Besancon, France) rotary files according to the manufacturer's recommendation using TS1 of size 25 (0.04).

The canals were disinfected with 5% sodium hypochlorite (Prevest DenPro Limited, India) and saline using a syringe and 30-gauge side vent needle (Orikam Healthcare, India) between each instrument change. All the samples were kept moist throughout the procedure to prevent dehydration. The roots were then horizontally sectioned at 3 mm (apical) and 6 mm (middle) from the apex using a diamond disc under water coolant. All the slices were viewed under a stereomicroscope at 40x magnification (Zeiss Stemi 508, Carl Zeiss, Jena, Germany) (Figure 3).

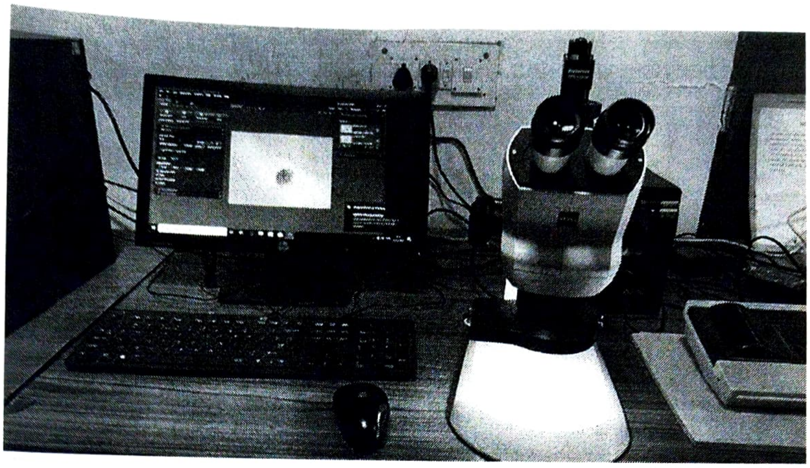

FIGURE 3: Evaluation of microcracks under a stereomicroscope with an attached camera

A single examiner examined each specimen for microcracks, and images were recorded (Figure 4). The results expressed the number of slices with defects in each group. The technique outlined by Karataş et al. [7] was used to separate dentin cracks into two distinct categories: "No crack" is defined as a root canal dentin without any lines or crack extending from the inner canal wall into the outer dentin. "Crack" includes both complete and incomplete cracks. A "complete crack" is defined as a defect with crack lines extending from the inner root canal space up to the outer surface of the root. An "incomplete crack" is a line that extends from the canal wall into the dentin but does not reach the outer surface.

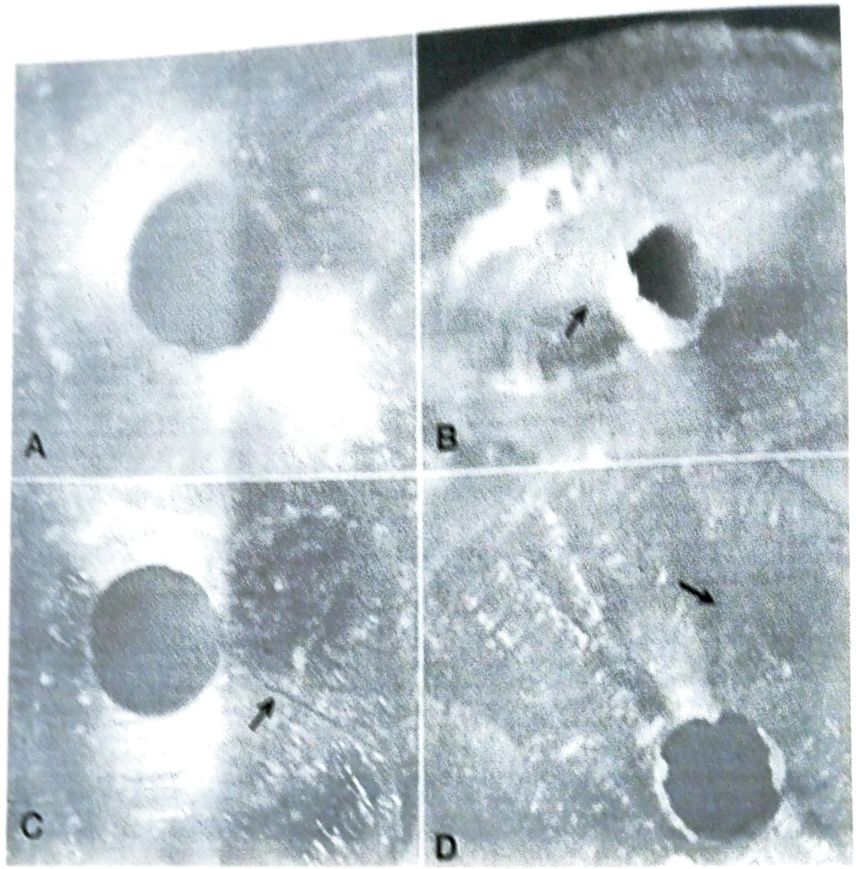

FIGURE 4: Stereomicroscopic images

A: no crack, B: incomplete crack, C & D: complete cracks

Statistical analysis

Data were analyzed using the IBM SPSS Statistics for Windows, version 26 (released 2019; IBM Corp., Armonk, New York, United States), and the level of significance was set at $p<0.05$. Descriptive statistics were performed to assess the mean and standard deviation of the respective groups. Inferential statistics to find out the difference between groups was done using the chi-square test for the proportion.

Results

Dentinal cracks were observed in all experimental groups. ProTaper Gold resulted in the highest number of cracks (65%), followed by Neoendo Flex (45%), and a lesser number of cracks were seen in TruNatomy (20%) and 2Shape (20%) (Table 1).

	Apical	Middle
Group 1 (TruNatomy)	2 (10%)	2 (10%)
Group 2 (Neoendo Flex)	5 (25%)	4 (20%)
Group 3 (ProTaper Gold)	8 (40%)	5 (25%)
Group 4 (2Shape)	1 (5%)	3 (15%)

TABLE 1: Prevalence of dentin cracks in the experimental groups

The frequency of dentinal cracks in Group 1 (Trunatomy) was 2 (10%), Group 2 (Neoendo Flex) was 5 (25%), Group 3 (ProTaper Gold) was 8 (40%), and Group 4 (2Shape) was 1 (5%). The chi-square analysis showed a statistically significant difference in the frequency of dentinal cracks between the four groups in the apical section (p-value < 0.05) (Table 2).

	Present	Absent	Chi-square test	p-value
Group 1 (TruNatomy)	2 (10%)	18 (90%)	46.87	0.0001*
Group 2 (Neoendo Flex)	5 (25%)	15 (75%)		
Group 3 (ProTaper Gold)	8 (40%)	12 (60%)		
Group 4 (2Shape)	1 (5%)	19 (95%)		

TABLE 2: Intergroup comparison of the incidence of dentinal cracks (apical section)

*p-value <0.05 was considered statistically significant.

The frequency of dentinal cracks in Group 1 (TruNatomy) was 2 (10%), Group 2 (Neoendo Flex) 4 (20%), Group 3 (ProTaper Gold) 5 (25%), and Group 4 (2Shape) 3 (15%). The chi-square analysis showed a statistically significant difference in the frequency of dentinal cracks between the four groups in the middle section (p-value < 0.05) (Table 3).

	Present	Absent	Chi-square test	p-value
Group 1 (TruNatomy)	2 (10%)	18 (90%)	8.65	0.03*
Group 2 (Neoendo Flex)	4 (20%)	16 (80%)		
Group 3 (ProTaper Gold)	5 (25%)	15 (75%)		
Group 4 (2Shape)	3 (15%)	17 (85%)		

TABLE 3: Intergroup comparison of the incidence of dentinal cracks (middle section)

*p-value < 0.05 was considered statistically significant.

A significant difference in the incidence of microcracks was observed between all the file systems at the apical level except between the TruNatomy and 2Shape groups (p = 0.17) (Table 4), while no significant difference was observed between the files at the middle section except between TruNatomy and PTG (p = 0.005) and TruNatomy and Neoendo Flex (p = 0.04).

	Present	Absent	Chi-square test	p-value
Group 1 (TruNatomy)	2 (10%)	18 (90%)	1.81	0.17
Group 4 (2Shape)	1 (5%)	19 (95%)		

TABLE 4: Comparison of dentin cracks between Group 1 and Group 4 (apical section)

Discussion

Dentinal cracks can occur when the tensile stress on the root canal wall exceeds the tensile strength of the dentin [8]. These microcracks could propagate under masticatory load, during retreatment, post space preparation, or insertion, and get converted to complete cracks leading to vertical root fractures, often demanding tooth extraction [4]. Kim et al. [9] uncovered a potential link between the design characteristics of NiTi rotary instruments and the frequency of vertical root fractures and concluded that the traits of rotary file design have an impact on the amount of apical stress and strain concentration created during root canal preparation. The geometry of the cross-section, taper, pitch, and flute form are some examples of contributing factors that may be associated with the magnitude of the flaw.

The stress concentration may also be influenced by the complex root canal anatomy, the residual dentinal wall thickness, and the prepared canal diameter. At least 1 mm of sound radicular dentin should be present throughout the length of the root after all intracanal procedures. Excessive removal of the radicular dentin, especially in "danger zones," may result in strip perforation and vertical root fractures. In addition, the gradual dentinal sclerosis caused by the age-related change in the microstructure of dentin may be correlated with decreased resistance to damage initiation and propagation [3,10]. As the thickness of the dentinal wall directly relates to the tooth's resistance to lateral stresses, excessive canal preparation compromises dentinal thickness and weakens the tooth.

Dentinal microcracks were seen in all groups in the current study. In a substantial amount of the treated roots, ranging from 18% to 60% of the roots, all tapered NiTi file systems that have been evaluated so far produce microcracks [11-14].

ProTaper Gold revealed the greatest number of cracks, while TruNatomy and 2Shape presented the least amount. TruNatomy files have an off-centered parallelogram cross-sectional design, so each time the file rotates in the canal during biomechanical preparation, there is a two-point contact with the root canal wall, thereby engaging less root canal dentin. ProTaper Gold file has a unique convex triangular cross-sectional design, so it establishes three-point contact with the root canal dentinal wall. This facilitates active cutting motion, thereby removing more dentin and at the same time generating more tensile stresses.

According to Kim et al. [9], the stress produced by tapered instruments on the outer surface of dentin may reach values that are higher than the dentin's tensile strength (106 MPa), which ultimately results in the formation of dentinal cracks. According to Wilcox et al. [15], the likelihood of a root fracture rises with the amount of tooth structure lost. The incidence of crack formation and the tapering of the instruments have a significant positive correlation, according to Das et al. [16]. Radicular dentin is more frequently stressed by higher-taper rotary files, which also have a higher likelihood of thinning the remaining dentin. PTG F2 has a larger taper (0.08) compared to the other rotary files used (0.04%), hence removing more radicular dentin and generating greater stress. Bier et al. [12] found cracks in 16% of the roots instrumented with the horizontal sections of the ProTaper system, and they concluded that ProTaper rotary files damaged dentin more than other rotary files. According to Liu et al. [17], 25% of the roots instrumented with the ProTaper had cracks at the apical root surface.

The incidence of dentinal cracks was less with TruNatomy and 2Shape, which are single-file systems, than with PTG and Neoendo Flex, which are multiple-file systems. A single file can be used for both shaping and finishing the canal, rather than instrumenting the canal with a series of files, thereby simplifying the procedure and saving time. According to a study by Jyothilakshmi et al. [18], a single-file system induced fewer defects when compared to multiple-file systems. The rotation of the file in the canal places stresses on the dentin that can lead to microcracks, and this stress increases with the number of files used for biomechanical preparation.

In all the experimental groups, the apical section presented more cracks than the middle sections. This is in line with what Karatas et al. [7], Nishad and Shivamurthy [19], and Chole et al. [20] found in their studies. The root canal systems vary greatly in their cross-sectional anatomy, and root fracture susceptibility may be influenced by the canal morphology. A study conducted by Adorno et al. [11] reported the incidence of apical microcracks in 50% of mandibular premolars after canal preparation to the apical foramen, which is in accordance with the present study. The occurrence of stress due to successive instrumentation, the low capability of the thin and fragile dentin in the apical area to withstand the mechanical stress produced by direct contact with the instrument tip, and features of the files, such as taper angle, flexibility, and cross-section, may also influence the formation of cracks [21].

The possible limitations of the present in vitro study are the possibility of crack formation during sectioning and difficulty in identifying internal preexisting cracks.

Conclusions

Although the mechanism of vertical root fractures is still not completely understood, it is widely accepted that stresses on the canal wall play a critical role in the initiation of dentinal microcracks. Forces generated during the root canal treatment can be easily controlled by a discerning professional. Meanwhile, masticatory loads are recurrent and cannot be controlled. Even though dentinal cracks are caused by several factors, the most important of which are taper, cross-sectional design, and file flexibility. Preservation of dental hard tissue and maintaining the overall structural integrity of the tooth and tooth root minimize the predisposition to a vertical root fracture after root canal treatment.

Within the limitations of this in vitro study, it can be concluded that rotary NiTi instruments do cause dentinal microcracks during biomechanical preparation. ProTaper Gold and Neoendo Flex induced significantly more dentinal cracks than TruNatomy and 2Shape at 3 mm and 6 mm levels. The maximum number of dentinal defects was seen in the apical third region. According to this in vitro study, single-file systems resulted in a lesser number of cracks compared to multiple-file systems.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Acquisition, analysis, or interpretation of data: Haridarshan Singh Sidhu, Rejin Mariyam, Navjot Singh Khurana, Jagvinder Singh Mann

Critical review of the manuscript for important intellectual content: Haridarshan Singh Sidhu, Rejin Mariyam, Navjot Singh Khurana, Jagvinder Singh Mann, Sergy A, Mahesh Mohan

Concept and design: Rejin Mariyam, Navjot Singh Khurana, Jagvinder Singh Mann, Sergy A, Mahesh Mohan

Drafting of the manuscript: Rejin Mariyam

Supervision: Rejin Mariyam

Disclosures

Human subjects: Consent was obtained or waived by all participants in this study. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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Stress Distribution on Maxillary Canines Following Restoration With Different Dimensions of Metal and Fiber Posts: A Finite Element Study

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Abstract

Introduction

In recent times, finite element analysis (FEA) in the field of dentistry has been employed to assess the mechanical properties of biological materials and tissues, which are difficult to quantify directly within a living organism. Only a limited number of studies have examined the impact of post diameter and length on how stress is dispersed in a maxillary canine tooth. Hence, this in vitro investigation was conducted to analyze the distribution of stress in a maxillary canine tooth that was replaced using metal and fiber posts with different diameters (1.5 mm and 1.8 mm) and lengths (11 mm and 15 mm), applying FEA.

Materials and methods

A FEA study was performed and all models were grouped as follows: Models 1 and 5 were made of titanium (Ti) and glass fiber posts, respectively, with a diameter of 1.5 mm and a length of 15 mm with composite core and all-ceramic crown; Models 2 and 6 were made of Ti and glass fiber posts, respectively, with a diameter of 1.5 mm and a length of 11 mm with composite core and all-ceramic crown; Models 3 and 7 were made of Ti and glass fiber posts, respectively, with a diameter of 1.8 mm and a length of 15 mm with composite core and all-ceramic crown; and Models 4 and 8 were made of Ti and glass fiber posts, respectively, with a diameter of 1.8 mm and a length of 11 mm with composite core and all-ceramic crown. A force of 200 N was exerted on the ceramic crown at an angulation of 45° to the longitudinal axis of the tooth on the palatal surface above the cingulum. The failure was determined by the correlation between a larger von Mises stress estimate and an increased likelihood of failure. The resulting stresses were then contrasted with the highest possible tensile strength of the material.

Results

The study demonstrated that fiber posts with a diameter of 1.8 mm and an average length of 11 mm exhibited reduced stress levels in comparison to Ti posts. The largest stresses were seen at the cervical region of the tooth, regardless of the materials employed. There was no discernible alteration in stress when the length and diameter of the post were modified. The highest stress in the composite core was measured in Ti posts measuring 1.5 mm in diameter and 15 mm in length. The highest level of stress on dentin was noted in cases where a fiber post was used, as opposed to cases where a Ti post was used. The measured stress within the fiber post was insignificant. However, the pressures imparted to the dentin were greater and more uniformly distributed in comparison to the Ti post cases.

Conclusion

It is suggested that a composite resin core be used along with a fiber post that is larger in diameter and smaller in length, within clinical bounds, in order to lessen stress in the radicular tooth, despite the substantial coronal defect. Further clinical trials are required to assess the survival rate of these specific measurements, dimensions, and biomaterials.

Categories: Dentistry
Keywords: titanium post, stress distribution, glass fiber post, finite-element analysis, composite core

Introduction

Endodontically restored teeth that have had substantial decay of the tooth often need a post to be inserted into the root canals to support a core for the final restoration [1]. Nevertheless, research conducted both in laboratory settings and in living organisms has shown that a post does not provide additional support to teeth that have undergone endodontic treatment, even though it does enhance retention when there is no

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more than 3-4 mm of vertical clearance or approximately 25-50% of the visible portion of the tooth [2]. Recently, there have been several advancements in the development of fiber posts. Studies have shown that using a combination of fiber posts, resin, and dentin bonding strategies to restore pulpless teeth has resulted in outstanding long-term clinical outcomes [3-5]. Additionally, it offers an underpinning on which a final restoration can be anchored to the tooth [1].

In the molar area, the mean maximal biting force among humans was determined at 911 N, and in the incisal region, at 569 N. The application of forces to dental restorative materials can potentially lead to deformations caused by alterations to dimensions such as length, volume, remaining coronal tooth structure, choice of material, and material characteristics like modulus of elasticity and stress distribution [6]. Nevertheless, these indicators lack precise definitions. Traditionally, roots that are structurally challenged have been repaired using casting posts and cores, which offer the benefits of post rigidity, optimal adaptability, and strong retention. Titanium (Ti) and nickel-chromium (Ni-Cr) are examples of metallic posts. More recent materials, such as ceramics and fiber-reinforced resin, are employed due to their distinctive aesthetic traits and other advantageous characteristics [1]. The posts' physical qualities directly impact the stress distribution of the existing tooth structure. Therefore, the precise preference for postings remains a challenging decision for professionals.

Almost all post materials necessitate an enlargement in diameter to get desirable physical properties, ensuring adequate resistance against functional and parafunctional stresses while preventing post fracture. Conversely, the space for the post should be cautiously prepared, ensuring that a minimum thickness of 1 mm of the soundproof dentinal wall is left surrounding the post. When larger metal posts are utilized, they cannot form a strong connection with the root structure. This raises the chances of a root fracture during normal usage. Non-metallic posts, by their capacity to connect with dentin, result in the uniform distribution of stress throughout the root, hence enhancing tooth resistance to fracture [7].

Several authors presented recommendations regarding the ideal length of a post. According to Neagley, a post must be at least 8 mm long [8]. A minimum crown post length ratio of 1:1 was proposed. Various methods have been developed for measuring and analyzing stress, including the strain gauge technique, the loading test, and the photoelastic method. Nevertheless, these solutions possess their own drawbacks. These procedures are analogous, two-dimensional, and challenging to replicate. Creating a reliable indicator of stress distribution in root systems has proven challenging when relying exclusively on experimental and clinical observation. The finite element method (FEM) is a mathematical technique that offers a flexible approach to analyzing stress distributions in complicated systems. The benefits of this approach include a closer approximation to natural settings, lower experimentation costs, prevention of damaging testing, high reproducibility and accuracy of outcomes, and time savings. This technique is highly valuable for assessing the mechanical properties of biological materials and human tissues that are difficult to evaluate directly in living organisms [9]. This technique involves representing a physical structure as a collection of a limited number of pieces. A general approximation solution to the original problem is determined [10].

The impact of post length and diameter on roots' ability to withstand fracture is still up for debate, despite earlier research. Therefore, a three-dimensional (3D) finite element analysis (FEA) was performed on the maxillary canine tooth to assess and contrast the pattern of stress when a load of 200 N is imposed following the insertion of Ti and fiber posts with diameters of 1.5 mm and 1.8 mm and lengths of 15 mm and 11 mm [7], where the load of 200 N was used to simulate the typical biting or chewing forces that a maxillary canine tooth experiences during normal use.

Materials And Methods

This was an FEA study conducted at Royal Dental College, Kerala, India. The construction of the FEM comprised several steps:

Creating a geometric representation of a typical upper canine tooth

Modeling is the initial stage of FEA. A mathematical FEA model was developed to analyze sound extracted from human maxillary canines. The preciseness of the model directly impacts the level of accuracy of the outcomes of the analysis. A tooth of approximately 26 mm in length, with a crown height of 10 mm and a root length of 16 mm, was chosen. The tooth had a cone beam computed tomography (CBCT) scan by Carestream Dental LLC (Atlanta, Georgia, United States), 2 mA, 70 kV, and a scan time of 17.5 seconds. The slice interval and slice thickness were both 0.640 mm. Using 3D digital dentofacial diagnostic and imaging technology in Kerala, the various facets of the tooth were observed with precision. The CT scan visuals were acquired in the DICOM format and utilized as input in the Mimics software Version 8.11 (Materialise, Leuven, Belgium). Figure *1* exhibits the utilization of the software for converting the CBCT scan into a 3D geometric framework.

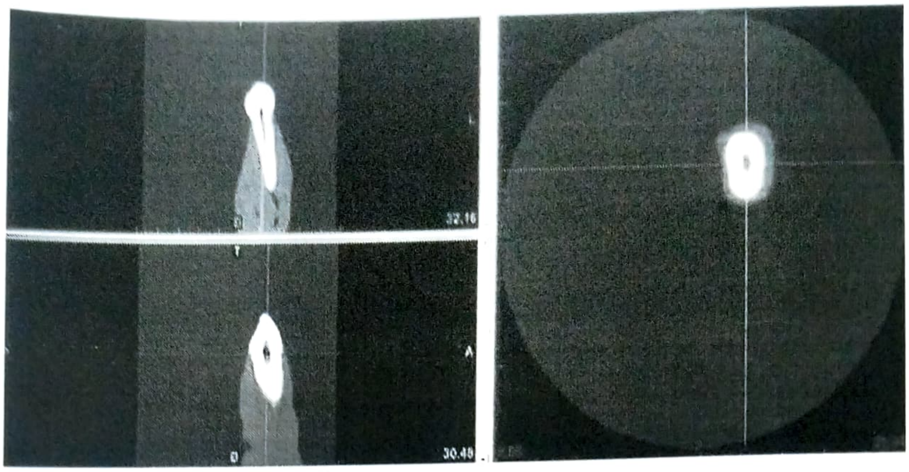

FIGURE 1: CBCT scans for the FEA

CBCT, cone beam computed tomography; FEA, finite element analysis

Mimics is a software specifically designed for medical purposes that enables the visualization and segmentation of CT and MRI scans. The investigation involved exporting data from the Mimics program, which consisted of cloud data points and lines that are in stereolithography format. This data was then integrated into RapidForm software (Inus Technology, Inc., Seoul, South Korea) to transform the cloud data points into surfaces, including points, lines, and surfaces (Figure 2).

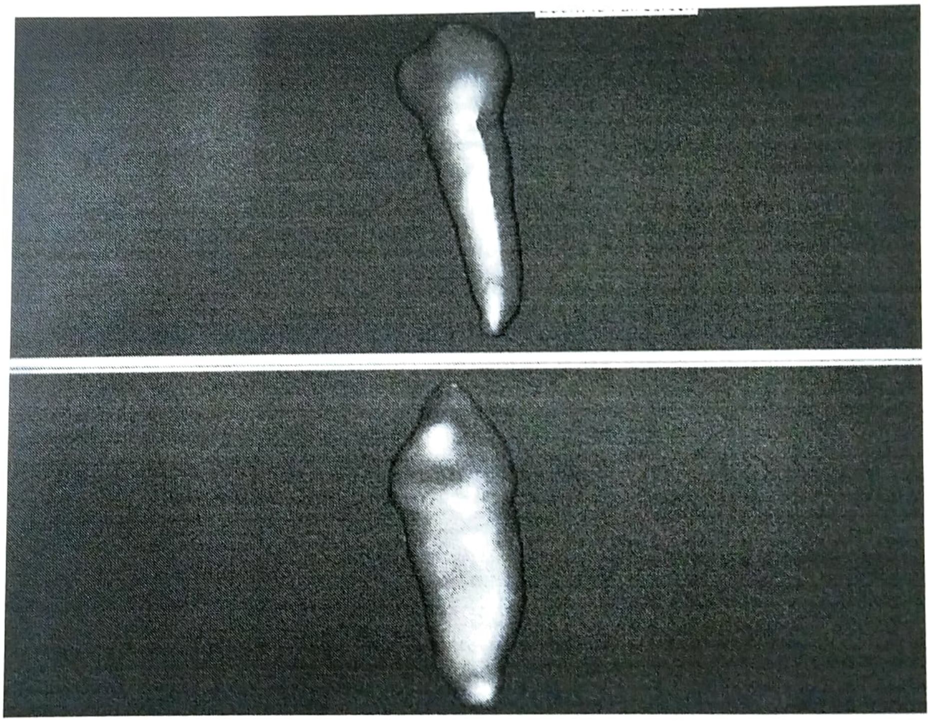

FIGURE 2: STL image creation in the software

STL, stereolithography

Using a geometric model (GM) to construct a FEM

The GM was transformed into a FEM employing HYPERMESH software Version 13.0 (Altair, Troy, Michigan, United States). The tooth's GM was put into the meshing software "Hypermesh." The Hypermesh program, namely the Altair HyperWorks Version 13.0, was utilized to transform a GM into a FEM. This software offers the benefits of enhancing product performance, automating design procedures, and increasing profitability in a versatile and adaptable setting. The individual components in Hypermesh, such as teeth, periodontal ligament, gutta-percha, post, core, root, and crown, were subsequently divided into smaller elements (meshing) and put together. Hypermesh offers advanced automation capabilities that enable the optimization of meshes based on specific quality standards, modification of preexisting meshes using morphing techniques, and creation of mid-surfaces from models with different thicknesses. The FEM, also known as meshed models, was comprised of 3D tetrahedral elements with four nodes each. A GM consists solely of lines, surfaces, and volumes. A FEM consists of nodes and elements (Figure 3).

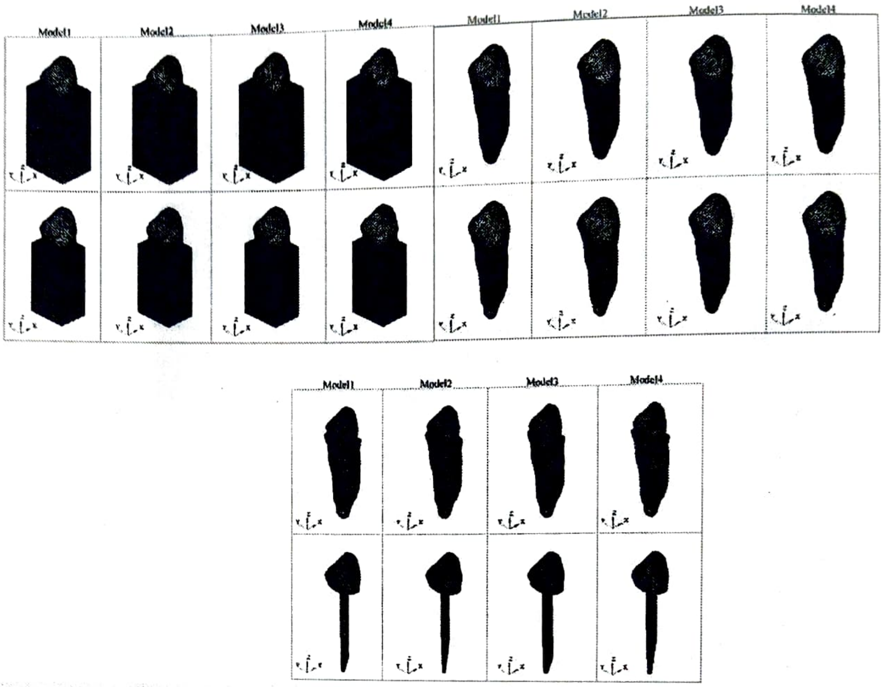

FIGURE 3: FEMs created for the study

FEM, finite element method

A total of eight experimental models were developed that portrayed different components of the structure, including the gutta-percha, post, core, root, and crown. The periodontal ligament was shown as a layer with a thickness of 0.3 mm surrounding the surface of the root. The cement layer between the post and the dentin was insufficiently thick to be accurately represented in the finite element simulation. However, the cement was considered a component of the dentin due to the comparable mechanical properties shared by both materials. The lack of a cement layer in the simulation was not anticipated to result in any substantial errors. This study contrasted two distinct categories of posts. These are glass fiber posts and Ti metal posts. The study examined two post diameter architectures: 1.5 mm and 1.8 mm. The study evaluated two post length configurations: one with a length of 15 mm (12 mm in the root, 3 mm coronal, and 4 mm remaining gutta-percha) and another with a length of 11 mm (8 mm in the root, 3 mm coronal, and 8 mm remaining gutta-percha). The models were categorized and further organized into subgroups as outlined below: Models 1 and 5 were constructed using Ti and glass fiber posts, with a diameter of 1.5 mm and a length of 15 mm. They also had a composite core and an all-ceramic crown. Models 2 and 6 were similar, but with a length of 11 mm. Models 3 and 7 had a larger diameter of 1.8 mm while still maintaining a length of 15 mm. Models 4 and 8 had the same diameter but a shorter length of 11 mm (Figure 4).

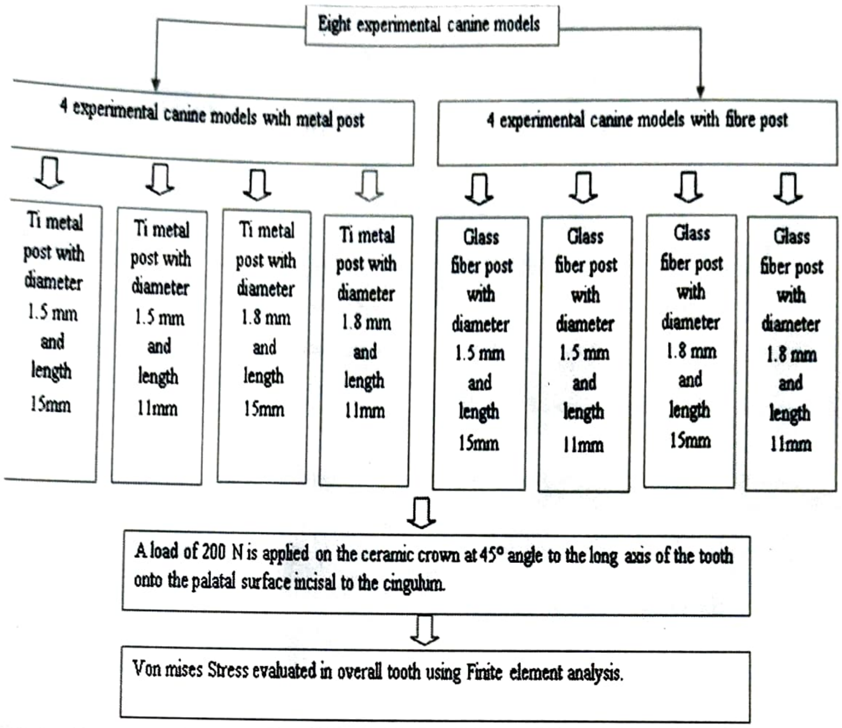

FIGURE 4: Flow chart of the methodology and grouping

Ti, titanium

Determining the characteristics of the material

The elements have been allocated with values for modulus of elasticity and Poisson's ratio. Acquiring accurate parameters can be a challenging endeavor, requiring considerable estimation when there is limited information available from testing materials or literature. The FEM required accurate assignment of material attributes to accurately simulate the behavior of the material under study. By entering a certain set of material parameters into the finite element program, one can easily receive a corresponding set of numerical outputs. The position, size, and trajectory of force delivery can be readily adjusted to replicate clinical scenarios. The study was based on a few specific suppositions. The assumption was made that all the materials in the model were homogeneous and isotropic. The cement layer was considered to be a component of the dentin due to the same mechanical attributes of dentin and cement.

Establishing the boundary characteristics

The models were meshed using first-order tetrahedral elements, with each node having three degrees of freedom. This led to a total of 67,278 nodes and 357,333 elements, each around 0.3 mm in dimension. The outermost nodes of the alveolar bone were immobilized in all orientations constituting the boundary conditions.

Force application

A 200 N load was exerted on the ceramic crown at a 45° inclination relative to the long axis of the tooth, namely on the palatal surface above the cingulum. The occlusal load of typical magnitude was only taken into account when static loading was given to the tooth. It was divided into vertical (y-axis) and horizontal (x-axis) components. The von Mises stress was used to compute the maximum stresses in the tooth structure and post.

Implementation of the analysis and subsequent interpretation of the findings

The ANSYS software Version 12.1 (Ansys, Inc., Canonsburg, Pennsylvania, United States) was utilized to conduct a linear static analysis, and interpretations of the applied load characteristics were made. ANSYS is a popular FEA code utilized in computer-aided engineering. It enables the creation of computer models for structures, machinery parts, or systems. These models can be subjected to operational loads and standards of design, allowing for the examination of physical responses such as stress values, temperature distributions, pressure, and displacement. The failure was determined by the correlation between a larger von Mises stress value and an increased likelihood of failure. The resulting stresses were then contrasted with the ultimate tensile strength of the material [9]. In a similar vein, structures were noted to shift when forces were surpassed. The pressures and displacements were visualized through a range of different colors. The color red indicates the highest level of stress, whereas dark blue represents the lowest level of stress. von Mises stress is the criterion employed to assess the structure from a stress perspective. The study involved stress analysis, which was conducted employing the equivalent von Mises stress measured in megapascal (MPa).

Results

The deflection of the teeth appeared nearly the same in all four situations. However, the deflection was significantly greater for a lengthier post. Based on the simulation findings, the greatest deflection of approximately 0.126 mm was seen at the crown region for the given loads being applied and boundary parameters. The FEM of von Mises stress in the crown revealed that the load application area experiences the most stress. The FEM of von Mises stress in the core revealed that the highest stress was located on the palatal side at the center. The FEA of von Mises stress in the Ti post revealed that the highest stress was found in the upper section. The FEA of von Mises stress in the periodontal ligament revealed that the highest stress was found in the cervical region. The FEA of von Mises stress in the cortical bone indicated that the highest stress in the cortical bone was detected near the fixation location, and it remained constant in all cases.

The deflection of the teeth remained nearly uniform in all four situations, except when a longer post was used, where it exhibited a significantly greater deflection. Based on the simulation findings, the highest deflection was found at the crown part, with a value of approximately 0.126 mm, under the given loads being applied and boundary parameters. The FEA of von Mises stress in the crown demonstrated that the load application zone experiences the highest level of stress. The FEA of von Mises stress in the core reveals that the highest stress was seen on the palatal side at the center. The FEA of von Mises stress in the fiber post revealed that the highest stress was seen in the upper section, and that of dentine was revealed to be seen in specific areas. The FEA of von Mises stress in the periodontal ligament revealed that the highest stress occurred in the cervical region. The FEA of von Mises stress in the spongy bone indicated that the highest level of stress was found in the apical area. Table *1* presents the von Mises stress distribution in various sections of Ti and fiber posts.

Part	Ti post				Fiber post			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Composite core	49.5	47.5	49.1	48.4	48.8	46.9	48.3	47.5
Post	43.3	42.6	38.9	37.4	28.1	27.5	26.2	25.8
Dentine	13	13.1	12.8	12.8	13.6	13.5	13.6	13.6
Ceramic crown	200.5	200.4	200.5	200.4	200.4	200.3	200.4	200.3
Periodontal ligament	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
Spongy bone	3.8	3.7	3.8	3.7	3.7	3.7	3.7	3.7
Cortical bone	31.7	31.7	31.7	31.7	31.7	31.7	31.7	31.7

TABLE 1: von Mises stress in different parts of Ti and fiber post

Ti, titanium

The highest level of stress in the composite core was recorded in Model 1 (Figures 5,6).

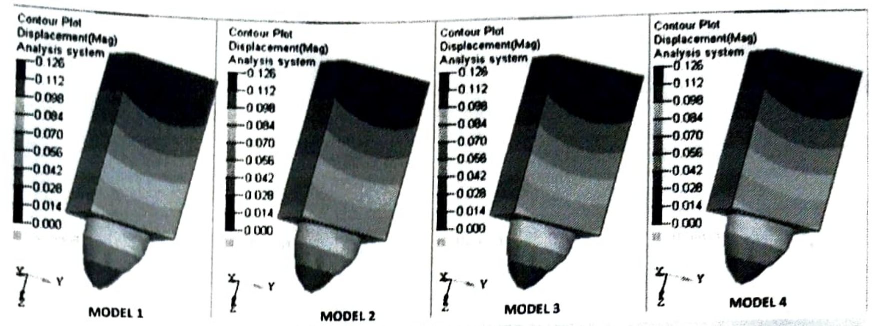

FIGURE 5: Heat map of the different models

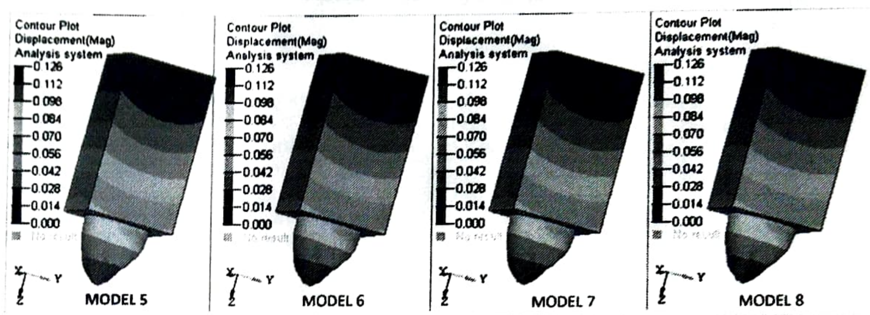

FIGURE 6: Heat map of the Models used

The stress in the core with the Ti post was greater than that in the core with the fiber post. A core reinforced with a fiber post measuring 1.5 mm in diameter and 11 mm in length exhibited lower levels of stress in comparison to other scenarios. Therefore, the fiber post is superior in comparison to the Ti post. In contrast to the stress fluctuations in the composite core of each Ti and fiber post model, the highest level of stress carried through the dentin can be detected in cases using fiber posts as opposed to Ti posts. The transmission of stresses to dentine was limited when using a Ti post with a diameter of 1.8 mm. There was no noticeable change in stress levels when the length of the post was altered.

The design with a diameter of 1.5 mm and a length of 15 mm showed the highest level of stress in the Ti post. The lowest possible stress was seen when the diameter was 1.8 mm and the length was 11 mm. The fiber post design with a diameter of 1.5 mm and a length of 15 mm exhibited the highest level of stress. The lowest level of tension was seen when the diameter was 1.8 mm and the length was 11 mm. The stress levels in the Ti post were greater than those in the fiber post. However, the difference in post material stress fluctuation for various lengths was not statistically significant.

Discussion

Only a limited number of studies have examined the impact of both post diameter and length on how stresses are distributed in a maxillary canine tooth. Thus, this experiment was conducted to analyze the pattern of distribution of stress in a tooth that was restored using metal and fiber posts with different diameters (1.5 and 1.8 mm) and lengths (11 mm and 15 mm) using FEA. A parallel post was used for this study due to its uniform size and diameter across all examined lengths. The width of the canal opening of the maxillary canine, as reported in previous research [11,12], ranges from 1.47 to 1.78 mm. Therefore, the diameter of the posts in this investigation was chosen to be 1.5 mm and 1.8 mm.

FEA is the preferred method for obtaining an optically realistic investigation that includes comprehensive dental anatomy and a computational approach. In this study, the periodontal ligament and alveolar bone were modeled, emulating clinical conditions. The periodontal ligament has a lower modulus of elasticity, which permits the tooth to reach its lowest point and facilitates its motion. Due to its similar physical qualities to dentin, cementum, which is a thin layer, was deemed superfluous to be classified as a distinct layer from dentin. By employing FEA, it is possible to correctly analyze the stress caused by evaluating the areas of stress concentration. It is more efficient as it avoids the time spent on standardization concerns or on processing several samples, as is the case with mechanical tests. Due to these benefits, this approach has been employed to examine the mechanical properties of teeth that have had endodontic treatment and have been exposed to various procedures and restorations [9].

In 1972, Helfer et al. contended that the loss of water (10%) in teeth without pulp could have an impact on their characteristics [15]. Nevertheless, research juxtaposing certain characteristics, such as microhardness, modulus of elasticity, and tensile strengths, in teeth with vital pulp and teeth without pulp observed that these characteristics had minimal impact on the ability of the teeth to resist fractures, despite observing some alterations in relative humidity and characteristics [14-16]. Due to structural alterations in the dentin that resulted in a reduction of water and collagen cross-linking following root canal therapy, endodontically treated teeth were once thought to be more susceptible to fracture [17]. It is well known that elevated cuspal deflection during function is an indication of the decline of structural integrity related to access preparation, and this increases the risk of fractures. The presence of anterior and canine guidance enables the prompt disengagement of molars and premolars during lateral or protrusive actions, such as mastication [18]. During laterotrusion, the tip of the lower canine contacts the mesial groove of the upper canine [19]. However, much research has not been noticed in the literature about stress distribution in canine teeth that are endodontically treated and reconstructed using post and core. Therefore, this tooth was chosen for the investigation.

Post and core restorations are intricate systems composed of multiple components. The degree of stress distribution within the framework is multiaxial, inconsistent, and influenced by the strength and direction of external forces applied [1]. A tooth that has been rebuilt with a fiber post exhibits a uniform stress distribution, resembling that of a natural tooth. Conversely, the metal post approach caused focused pressures that impacted both the connection between the post and cement, and this, in turn, resulted in tooth fracture [20]. Ti in its pure form exhibits excellent biocompatibility, corrosion resistance, and low heat conductivity. However, it is much less stiff than stainless steel [21]. In their study, Mitsui et al. [22] examined the fracture durability of bovine teeth that were replaced using five distinct intraradicular post frameworks: cast metal posts, Ti posts, glass fiber posts, carbon fiber posts, and zirconium posts. The Ti posts had a greater average fracture resistance score in comparison to glass fiber and zirconium posts and demonstrated comparable results to carbon fiber posts. The conclusion drawn by the authors is that Ti and carbon fiber posts are the most appropriate choices. This study contradicts our findings.

Multiple contributors provide suggestions regarding the length of posts. According to a review article by Goodacre and Spolnik [23], the post length should ideally be three-quarters of the total length of the root canal, or at the very least, the length of the crown. It is advised that a remaining 4-5 mm of gutta-percha should be present at the apex to ensure a sufficient seal. Sorensen and Martinoff [24] found a 97% success rate in a retrospective investigation when the length of the post was equal to or greater than the height of the crown. As per the findings of Neagley, a post must have a minimum length of 8 mm [8]. Research has demonstrated that forces tend to accumulate at the highest point of the bone during the process of chewing. For teeth that have metal posts, forces likewise tend to be concentrated near the tip of the post. Thus, it is essential for a post to consistently protrude apically beyond the crest of the bone [25]. A recent study conducted by Abramovitz et al. [26] has shown that a 3-mm layer of gutta-percha does not reliably seal the apex. As a result, it is suggested to use a layer of 4-5 mm instead. Based on these factors, the post lengths of 11 mm and 15 mm were chosen for this study. To maximize the benefits of increased bonding surface between the post and tooth structure, and additionally, between the post and core material, it is advisable to utilize larger sizes of fiber posts. By employing this method, it is possible to enhance the cohesion and durability of the central material [7].

Irrespective of the content of the post, when the total length of the post increased, the overall displacement decreased [27]. Our findings align with those of Cailleteau et al. [28], who observed a modification in the flexure resistance of the tooth structure when the post was introduced into the root canal. The stress distribution shifted from the coronal region to the apical region of the root. The magnitude of the tension was contingent upon the length of the post. The fiber post group exhibited a greater overall displacement compared to the metal post groups. This could be attributed to the fiber post having a significantly lower elastic modulus compared to the metal post. Consequently, the group using fiber posts exhibited more elasticity and a bigger overall displacement.

Additionally, the direction in which force was applied to the canine teeth was derived from earlier research [20,29]. Model 1 exhibited the highest level of stress in the composite core, as found in this investigation. The stress in the core with the Ti post was greater than that in the core with the fiber post. A core placed with fiber posts measuring 1.5 mm in diameter and 11 mm in length exhibits lower levels of stress when viewed alongside alternative scenarios. The fiber post exhibited superior performance in comparison to the Ti post. Furthermore, the relationship between the low elasticity modulus of the glass fiber post and ceramic, as well as the bonding between ceramic, composite resin core, and resin cement, led to the selection of all-ceramic crowns for this investigation. By utilizing a fiber post, these characteristics produce a flexible, sophisticated restorative system with mechanical qualities comparable to healthy teeth.

According to this study, the stress transferred to dentin was negligible when using a Ti post with a diameter of 1.8 mm. This could be because the modulus of elasticity of the fiber post is similar to that of dentin, which is approximately 20 GPa. Additionally, the fiber post is five to 10 times more flexible than high-modulus metal posts. This flexibility enables the post to effectively absorb stress and avert root fractures. The fiber post exhibits superior stress distribution to dentin compared to the metal post. Although Ti posts induced stress concentration within the post itself, they also increased the likelihood of root breakage. Metal posts, because of their inflexibility and rigidity characteristics, transmit forces in a linear direction, exerting a wedging impact on the tooth structure, akin to a metal wedge on a wooden object [3]. There was no substantial fluctuation in stress seen in dentin when altering the length of the post, but it was relatively lower for shorter posts. The investigation, done by Pegoretti et al., found that glass fiber posts used to replace teeth resulted in a lower concentration of stress within the root compared to metal and carbon fiber posts. When there is a significant variation in Young's modulus between the dentin and the posts, the stress distribution on the tooth surface becomes less uniform, resulting in the formation of stress concentration zones on the dentin [30].

The FEA is a precise numerical technique used in stress analysis, specifically in dental biomechanics [9]. It allows for the determination of an approximate overall solution to the original problem [10]. A set of concurrent formulas is generated and resolved to determine the expected stress distributions in each component across a structure. The variables can be controlled with the utmost accuracy using computer technology, thereby removing any variance caused by sampling errors. To carry out this FEM analysis, the values for Poisson's ratio and Young's modulus of elasticity for all components were obtained from earlier research [1,9]. Performing FEM analysis many times will consistently produce identical results with 100% certainty. Hence, it is unequivocal that the outcomes are consistently influenced by modifying the variables rather than by random occurrences. Hence, traditional inferential statistical analysis is typically excluded from FEA [9].

Currently, some constraints must be acknowledged with respect to the current investigation. It was believed that the structures and materials employed in this investigation were homogeneous, isotropic, and linearly elastic. Consequently, the computational modeling differed from the genuine tooth frame and its supporting tissues [9]. Root fractures often occur owing to dynamic stress, which can culminate in a fatigue cycle in clinical situations distinct from static loading. Additional research is necessary to simulate the susceptibility to fracture and the effects of thermal and mechanical cycle loads to precisely predict the stress distribution in teeth that have undergone endodontic treatment. The research should also consider the impact of various restorative materials on the strength of the teeth, whether they are compromised or not.

Conclusions

The composite core exhibited the highest level of stress on Ti posts measuring 1.5 mm in diameter and 15 mm in length. Fiber posts with a diameter of 1.8 mm and a length of 11 mm exhibited lower levels of stress in the cervical region in comparison to Ti posts. Maximum strains happened in the tooth's cervical region regardless of the materials employed. There was no noticeable alteration in stress when the length and diameter of the post were modified. The highest level of stress absorbed by dentin was detected in cases where a fiber post was used, as opposed to cases where a Ti post was used. The fiber post showed minimal observed stresses; however, stresses transferred to the dentin were greater, which were distributed equally in comparison with Ti post cases. To alleviate stress in the remaining radicular tooth with a significant coronal defect, it is advisable to use a composite resin core along with a fiber post that has a wide diameter and shortened length while staying within the therapeutic stipulations.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Mahesh Mohan, Lubna Mohammad, Nasarudheen Cholayil, Saumya Vats, Mohammed Salman Kuttikkodan, John Kodumbilayiparambil Anto

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Supervision: Mahesh Mohan

Disclosures

Human subjects: All authors have confirmed that this study did not involve human participants or tissue.
Animal subjects: All authors have confirmed that this study did not involve animal subjects or tissue.
Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the

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Stress Distribution on Maxillary Canines Following Restoration With Different Dimensions of Metal and Fiber Posts: A Finite Element Study

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Abstract

Introduction

In recent times, finite element analysis (FEA) in the field of dentistry has been employed to assess the mechanical properties of biological materials and tissues, which are difficult to quantify directly within a living organism. Only a limited number of studies have examined the impact of post diameter and length on how stress is dispersed in a maxillary canine tooth. Hence, this in vitro investigation was conducted to analyze the distribution of stress in a maxillary canine tooth that was replaced using metal and fiber posts with different diameters (1.5 mm and 1.8 mm) and lengths (11 mm and 15 mm), applying FEA.

Materials and methods

A FEA study was performed and all models were grouped as follows: Models 1 and 5 were made of titanium (Ti) and glass fiber posts, respectively, with a diameter of 1.5 mm and a length of 15 mm with composite core and all-ceramic crown; Models 2 and 6 were made of Ti and glass fiber posts, respectively, with a diameter of 1.5 mm and a length of 11 mm with composite core and all-ceramic crown; Models 3 and 7 were made of Ti and glass fiber posts, respectively, with a diameter of 1.8 mm and a length of 15 mm with composite core and all-ceramic crown; and Models 4 and 8 were made of Ti and glass fiber posts, respectively, with a diameter of 1.8 mm and a length of 11 mm with composite core and all-ceramic crown. A force of 200 N was exerted on the ceramic crown at an angulation of 45° to the longitudinal axis of the tooth on the palatal surface above the cingulum. The failure was determined by the correlation between a larger von Mises stress estimate and an increased likelihood of failure. The resulting stresses were then contrasted with the highest possible tensile strength of the material.

Results

The study demonstrated that fiber posts with a diameter of 1.8 mm and an average length of 11 mm exhibited reduced stress levels in comparison to Ti posts. The largest stresses were seen at the cervical region of the tooth, regardless of the materials employed. There was no discernible alteration in stress when the length and diameter of the post were modified. The highest stress in the composite core was measured in Ti posts measuring 1.5 mm in diameter and 15 mm in length. The highest level of stress on dentin was noted in cases where a fiber post was used, as opposed to cases where a Ti post was used. The measured stress within the fiber post was insignificant. However, the pressures imparted to the dentin were greater and more uniformly distributed in comparison to the Ti post cases.

Conclusion

It is suggested that a composite resin core be used along with a fiber post that is larger in diameter and smaller in length, within clinical bounds, in order to lessen stress in the radicular tooth, despite the substantial coronal defect. Further clinical trials are required to assess the survival rate of these specific measurements, dimensions, and biomaterials.

Categories: Dentistry
Keywords: titanium post, stress distribution, glass fiber post, finite-element analysis, composite core

Introduction

Endodontically restored teeth that have had substantial decay of the tooth often need a post to be inserted into the root canals to support a core for the final restoration [1]. Nevertheless, research conducted both in laboratory settings and in living organisms has shown that a post does not provide additional support to teeth that have undergone endodontic treatment, even though it does enhance retention when there is no

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more than 3-4 mm of vertical clearance or approximately 25-50% of the visible portion of the tooth [2]. Recently, there have been several advancements in the development of fiber posts. Studies have shown that using a combination of fiber posts, resin, and dentin bonding strategies to restore pulpless teeth has resulted in outstanding long-term clinical outcomes [3-5]. Additionally, it offers an underpinning on which a final restoration can be anchored to the tooth [1].

In the molar area, the mean maximal biting force among humans was determined at 911 N, and in the incisal region, at 569 N. The application of forces to dental restorative materials can potentially lead to deformations caused by alterations to dimensions such as length, volume, remaining coronal tooth structure, choice of material, and material characteristics like modulus of elasticity and stress distribution [6]. Nevertheless, these indicators lack precise definitions. Traditionally, roots that are structurally challenged have been repaired using casting posts and cores, which offer the benefits of post rigidity, optimal adaptability, and strong retention. Titanium (Ti) and nickel-chromium (Ni-Cr) are examples of metallic posts. More recent materials, such as ceramics and fiber-reinforced resin, are employed due to their distinctive aesthetic traits and other advantageous characteristics [1]. The posts' physical qualities directly impact the stress distribution of the existing tooth structure. Therefore, the precise preference for postings remains a challenging decision for professionals.

Almost all post materials necessitate an enlargement in diameter to get desirable physical properties, ensuring adequate resistance against functional and parafunctional stresses while preventing post fracture. Conversely, the space for the post should be cautiously prepared, ensuring that a minimum thickness of 1 mm of the soundproof dentinal wall is left surrounding the post. When larger metal posts are utilized, they cannot form a strong connection with the root structure. This raises the chances of a root fracture during normal usage. Non-metallic posts, by their capacity to connect with dentin, result in the uniform distribution of stress throughout the root, hence enhancing tooth resistance to fracture [7].

Several authors presented recommendations regarding the ideal length of a post. According to Neagley, a post must be at least 8 mm long [8]. A minimum crown post length ratio of 1:1 was proposed. Various methods have been developed for measuring and analyzing stress, including the strain gauge technique, the loading test, and the photoelastic method. Nevertheless, these solutions possess their own drawbacks. These procedures are analogous, two-dimensional, and challenging to replicate. Creating a reliable indicator of stress distribution in root systems has proven challenging when relying exclusively on experimental and clinical observation. The finite element method (FEM) is a mathematical technique that offers a flexible approach to analyzing stress distributions in complicated systems. The benefits of this approach include a closer approximation to natural settings, lower experimentation costs, prevention of damaging testing, high reproducibility and accuracy of outcomes, and time savings. This technique is highly valuable for assessing the mechanical properties of biological materials and human tissues that are difficult to evaluate directly in living organisms [9]. This technique involves representing a physical structure as a collection of a limited number of pieces. A general approximation solution to the original problem is determined [10].

The impact of post length and diameter on roots' ability to withstand fracture is still up for debate, despite earlier research. Therefore, a three-dimensional (3D) finite element analysis (FEA) was performed on the maxillary canine tooth to assess and contrast the pattern of stress when a load of 200 N is imposed following the insertion of Ti and fiber posts with diameters of 1.5 mm and 1.8 mm and lengths of 15 mm and 11 mm [7], where the load of 200 N was used to simulate the typical biting or chewing forces that a maxillary canine tooth experiences during normal use.

Materials And Methods

This was an FEA study conducted at Royal Dental College, Kerala, India. The construction of the FEM comprised several steps:

Creating a geometric representation of a typical upper canine tooth

Modeling is the initial stage of FEA. A mathematical FEA model was developed to analyze sound extracted from human maxillary canines. The preciseness of the model directly impacts the level of accuracy of the outcomes of the analysis. A tooth of approximately 26 mm in length, with a crown height of 10 mm and a root length of 16 mm, was chosen. The tooth had a cone beam computed tomography (CBCT) scan by Carestream Dental LLC (Atlanta, Georgia, United States), 2 mA, 70 kV, and a scan time of 17.5 seconds. The slice interval and slice thickness were both 0.640 mm. Using 3D digital dentofacial diagnostic and imaging technology in Kerala, the various facets of the tooth were observed with precision. The CT scan visuals were acquired in the DICOM format and utilized as input in the Mimics software Version 8.11 (Materialise, Leuven, Belgium). Figure *1* exhibits the utilization of the software for converting the CBCT scan into a 3D geometric framework.

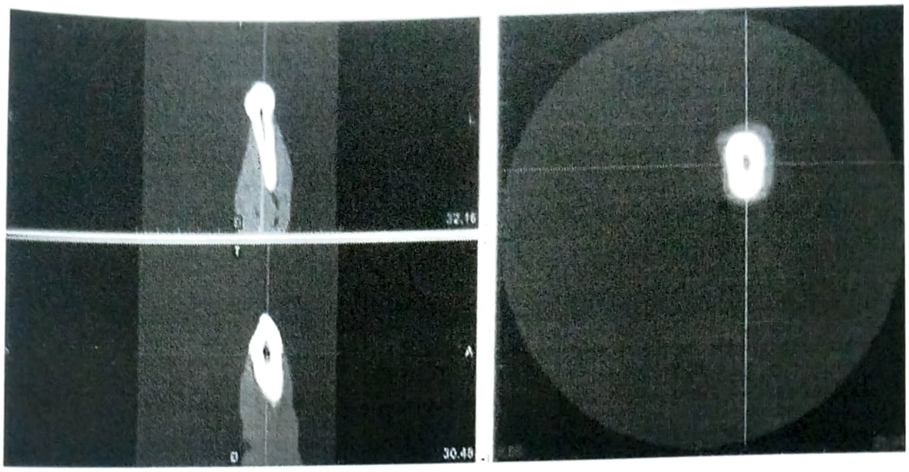

FIGURE 1: CBCT scans for the FEA

CBCT, cone beam computed tomography; FEA, finite element analysis

Mimics is a software specifically designed for medical purposes that enables the visualization and segmentation of CT and MRI scans. The investigation involved exporting data from the Mimics program, which consisted of cloud data points and lines that are in stereolithography format. This data was then integrated into RapidForm software (Inus Technology, Inc., Seoul, South Korea) to transform the cloud data points into surfaces, including points, lines, and surfaces (Figure 2).

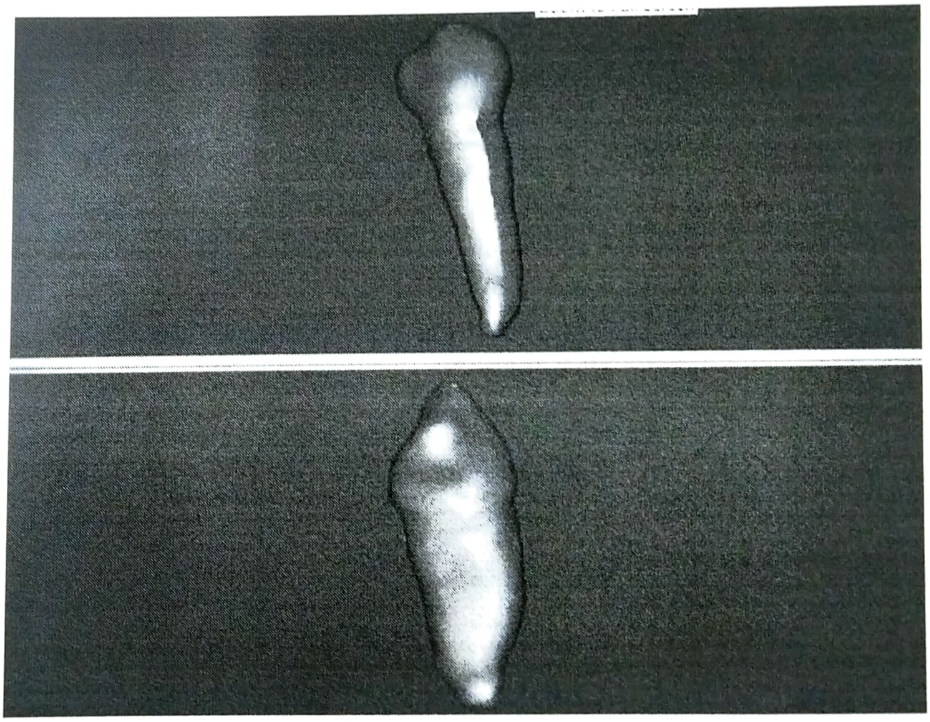

FIGURE 2: STL image creation in the software

STL, stereolithography

Using a geometric model (GM) to construct a FEM

The GM was transformed into a FEM employing HYPERMESH software Version 13.0 (Altair, Troy, Michigan, United States). The tooth's GM was put into the meshing software "Hypermesh." The Hypermesh program, namely the Altair HyperWorks Version 13.0, was utilized to transform a GM into a FEM. This software offers the benefits of enhancing product performance, automating design procedures, and increasing profitability in a versatile and adaptable setting. The individual components in Hypermesh, such as teeth, periodontal ligament, gutta-percha, post, core, root, and crown, were subsequently divided into smaller elements (meshing) and put together. Hypermesh offers advanced automation capabilities that enable the optimization of meshes based on specific quality standards, modification of preexisting meshes using morphing techniques, and creation of mid-surfaces from models with different thicknesses. The FEM, also known as meshed models, was comprised of 3D tetrahedral elements with four nodes each. A GM consists solely of lines, surfaces, and volumes. A FEM consists of nodes and elements (Figure 3).

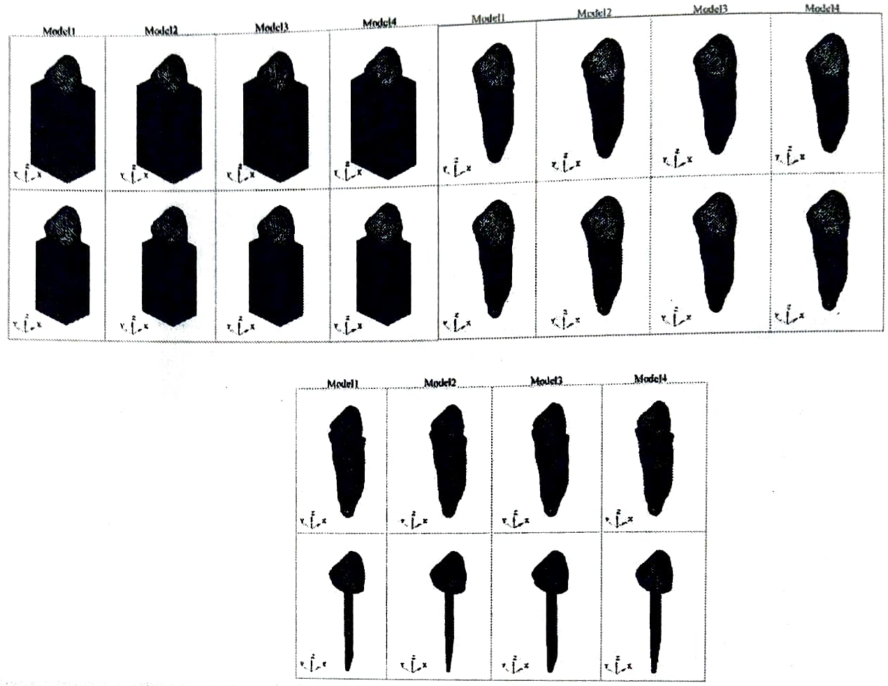

FIGURE 3: FEMs created for the study

FEM, finite element method

A total of eight experimental models were developed that portrayed different components of the structure, including the gutta-percha, post, core, root, and crown. The periodontal ligament was shown as a layer with a thickness of 0.3 mm surrounding the surface of the root. The cement layer between the post and the dentin was insufficiently thick to be accurately represented in the finite element simulation. However, the cement was considered a component of the dentin due to the comparable mechanical properties shared by both materials. The lack of a cement layer in the simulation was not anticipated to result in any substantial errors. This study contrasted two distinct categories of posts. These are glass fiber posts and Ti metal posts. The study examined two post diameter architectures: 1.5 mm and 1.8 mm. The study evaluated two post length configurations: one with a length of 15 mm (12 mm in the root, 3 mm coronal, and 4 mm remaining gutta-percha) and another with a length of 11 mm (8 mm in the root, 3 mm coronal, and 8 mm remaining gutta-percha). The models were categorized and further organized into subgroups as outlined below: Models 1 and 5 were constructed using Ti and glass fiber posts, with a diameter of 1.5 mm and a length of 15 mm. They also had a composite core and an all-ceramic crown. Models 2 and 6 were similar, but with a length of 11 mm. Models 3 and 7 had a larger diameter of 1.8 mm while still maintaining a length of 15 mm. Models 4 and 8 had the same diameter but a shorter length of 11 mm (Figure 4).

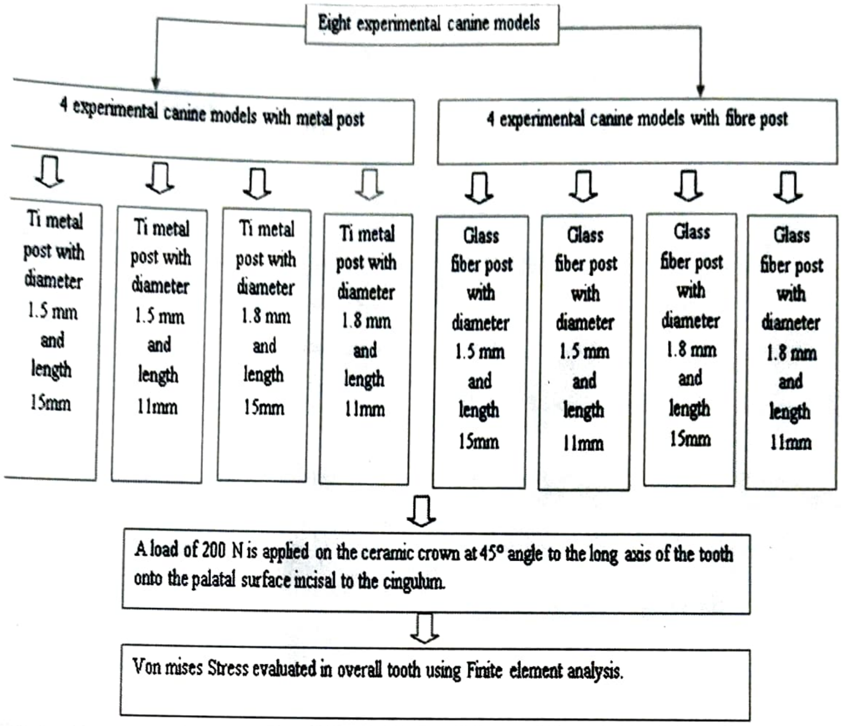

FIGURE 4: Flow chart of the methodology and grouping

Ti, titanium

Determining the characteristics of the material

The elements have been allocated with values for modulus of elasticity and Poisson's ratio. Acquiring accurate parameters can be a challenging endeavor, requiring considerable estimation when there is limited information available from testing materials or literature. The FEM required accurate assignment of material attributes to accurately simulate the behavior of the material under study. By entering a certain set of material parameters into the finite element program, one can easily receive a corresponding set of numerical outputs. The position, size, and trajectory of force delivery can be readily adjusted to replicate clinical scenarios. The study was based on a few specific suppositions. The assumption was made that all the materials in the model were homogeneous and isotropic. The cement layer was considered to be a component of the dentin due to the same mechanical attributes of dentin and cement.

Establishing the boundary characteristics

The models were meshed using first-order tetrahedral elements, with each node having three degrees of freedom. This led to a total of 67,278 nodes and 357,333 elements, each around 0.3 mm in dimension. The outermost nodes of the alveolar bone were immobilized in all orientations constituting the boundary conditions.

Force application

A 200 N load was exerted on the ceramic crown at a 45° inclination relative to the long axis of the tooth, namely on the palatal surface above the cingulum. The occlusal load of typical magnitude was only taken into account when static loading was given to the tooth. It was divided into vertical (y-axis) and horizontal (x-axis) components. The von Mises stress was used to compute the maximum stresses in the tooth structure and post.

Implementation of the analysis and subsequent interpretation of the findings

The ANSYS software Version 12.1 (Ansys, Inc., Canonsburg, Pennsylvania, United States) was utilized to conduct a linear static analysis, and interpretations of the applied load characteristics were made. ANSYS is a popular FEA code utilized in computer-aided engineering. It enables the creation of computer models for structures, machinery parts, or systems. These models can be subjected to operational loads and standards of design, allowing for the examination of physical responses such as stress values, temperature distributions, pressure, and displacement. The failure was determined by the correlation between a larger von Mises stress value and an increased likelihood of failure. The resulting stresses were then contrasted with the ultimate tensile strength of the material [9]. In a similar vein, structures were noted to shift when forces were surpassed. The pressures and displacements were visualized through a range of different colors. The color red indicates the highest level of stress, whereas dark blue represents the lowest level of stress. von Mises stress is the criterion employed to assess the structure from a stress perspective. The study involved stress analysis, which was conducted employing the equivalent von Mises stress measured in megapascal (MPa).

Results

The deflection of the teeth appeared nearly the same in all four situations. However, the deflection was significantly greater for a lengthier post. Based on the simulation findings, the greatest deflection of approximately 0.126 mm was seen at the crown region for the given loads being applied and boundary parameters. The FEM of von Mises stress in the crown revealed that the load application area experiences the most stress. The FEM of von Mises stress in the core revealed that the highest stress was located on the palatal side at the center. The FEA of von Mises stress in the Ti post revealed that the highest stress was found in the upper section. The FEA of von Mises stress in the periodontal ligament revealed that the highest stress was found in the cervical region. The FEA of von Mises stress in the cortical bone indicated that the highest stress in the cortical bone was detected near the fixation location, and it remained constant in all cases.

The deflection of the teeth remained nearly uniform in all four situations, except when a longer post was used, where it exhibited a significantly greater deflection. Based on the simulation findings, the highest deflection was found at the crown part, with a value of approximately 0.126 mm, under the given loads being applied and boundary parameters. The FEA of von Mises stress in the crown demonstrated that the load application zone experiences the highest level of stress. The FEA of von Mises stress in the core reveals that the highest stress was seen on the palatal side at the center. The FEA of von Mises stress in the fiber post revealed that the highest stress was seen in the upper section, and that of dentine was revealed to be seen in specific areas. The FEA of von Mises stress in the periodontal ligament revealed that the highest stress occurred in the cervical region. The FEA of von Mises stress in the spongy bone indicated that the highest level of stress was found in the apical area. Table *1* presents the von Mises stress distribution in various sections of Ti and fiber posts.

Part	Ti post				Fiber post			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Composite core	49.5	47.5	49.1	48.4	48.8	46.9	48.3	47.5
Post	43.3	42.6	38.9	37.4	28.1	27.5	26.2	25.8
Dentine	13	13.1	12.8	12.8	13.6	13.5	13.6	13.6
Ceramic crown	200.5	200.4	200.5	200.4	200.4	200.3	200.4	200.3
Periodontal ligament	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
Spongy bone	3.8	3.7	3.8	3.7	3.7	3.7	3.7	3.7
Cortical bone	31.7	31.7	31.7	31.7	31.7	31.7	31.7	31.7

TABLE 1: von Mises stress in different parts of Ti and fiber post

Ti, titanium

The highest level of stress in the composite core was recorded in Model 1 (Figures 5,6).

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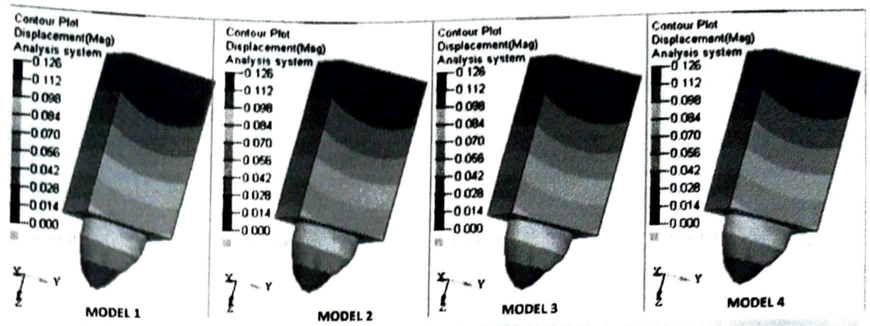

FIGURE 5: Heat map of the different models

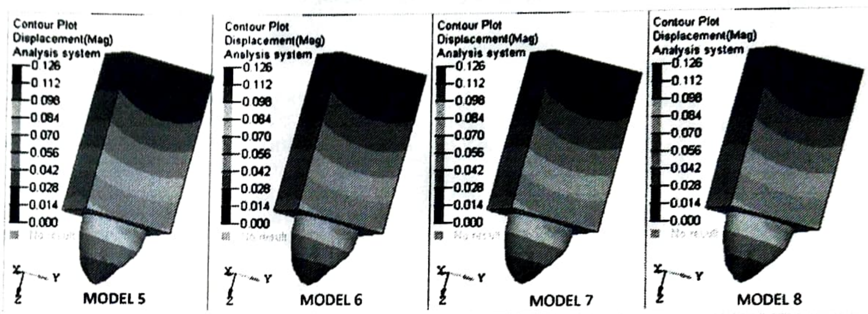

FIGURE 6: Heat map of the Models used

The stress in the core with the Ti post was greater than that in the core with the fiber post. A core reinforced with a fiber post measuring 1.5 mm in diameter and 11 mm in length exhibited lower levels of stress in comparison to other scenarios. Therefore, the fiber post is superior in comparison to the Ti post. In contrast to the stress fluctuations in the composite core of each Ti and fiber post model, the highest level of stress carried through the dentin can be detected in cases using fiber posts as opposed to Ti posts. The transmission of stresses to dentine was limited when using a Ti post with a diameter of 1.8 mm. There was no noticeable change in stress levels when the length of the post was altered.

The design with a diameter of 1.5 mm and a length of 15 mm showed the highest level of stress in the Ti post. The lowest possible stress was seen when the diameter was 1.8 mm and the length was 11 mm. The fiber post design with a diameter of 1.5 mm and a length of 15 mm exhibited the highest level of stress. The lowest level of tension was seen when the diameter was 1.8 mm and the length was 11 mm. The stress levels in the Ti post were greater than those in the fiber post. However, the difference in post material stress fluctuation for various lengths was not statistically significant.

Discussion

Only a limited number of studies have examined the impact of both post diameter and length on how stresses are distributed in a maxillary canine tooth. Thus, this experiment was conducted to analyze the pattern of distribution of stress in a tooth that was restored using metal and fiber posts with different diameters (1.5 and 1.8 mm) and lengths (11 mm and 15 mm) using FEA. A parallel post was used for this study due to its uniform size and diameter across all examined lengths. The width of the canal opening of the maxillary canine, as reported in previous research [11,12], ranges from 1.47 to 1.78 mm. Therefore, the diameter of the posts in this investigation was chosen to be 1.5 mm and 1.8 mm.

FEA is the preferred method for obtaining an optically realistic investigation that includes comprehensive dental anatomy and a computational approach. In this study, the periodontal ligament and alveolar bone were modeled, emulating clinical conditions. The periodontal ligament has a lower modulus of elasticity, which permits the tooth to reach its lowest point and facilitates its motion. Due to its similar physical qualities to dentin, cementum, which is a thin layer, was deemed superfluous to be classified as a distinct layer from dentin. By employing FEA, it is possible to correctly analyze the stress caused by evaluating the areas of stress concentration. It is more efficient as it avoids the time spent on standardization concerns or on processing several samples, as is the case with mechanical tests. Due to these benefits, this approach has been employed to examine the mechanical properties of teeth that have had endodontic treatment and have been exposed to various procedures and restorations [9].

In 1972, Helfer et al. contended that the loss of water (10%) in teeth without pulp could have an impact on their characteristics [15]. Nevertheless, research juxtaposing certain characteristics, such as microhardness, modulus of elasticity, and tensile strengths, in teeth with vital pulp and teeth without pulp observed that these characteristics had minimal impact on the ability of the teeth to resist fractures, despite observing some alterations in relative humidity and characteristics [14-16]. Due to structural alterations in the dentin that resulted in a reduction of water and collagen cross-linking following root canal therapy, endodontically treated teeth were once thought to be more susceptible to fracture [17]. It is well known that elevated cuspal deflection during function is an indication of the decline of structural integrity related to access preparation, and this increases the risk of fractures. The presence of anterior and canine guidance enables the prompt disengagement of molars and premolars during lateral or protrusive actions, such as mastication [18]. During laterotrusion, the tip of the lower canine contacts the mesial groove of the upper canine [19]. However, much research has not been noticed in the literature about stress distribution in canine teeth that are endodontically treated and reconstructed using post and core. Therefore, this tooth was chosen for the investigation.

Post and core restorations are intricate systems composed of multiple components. The degree of stress distribution within the framework is multiaxial, inconsistent, and influenced by the strength and direction of external forces applied [1]. A tooth that has been rebuilt with a fiber post exhibits a uniform stress distribution, resembling that of a natural tooth. Conversely, the metal post approach caused focused pressures that impacted both the connection between the post and cement, and this, in turn, resulted in tooth fracture [20]. Ti in its pure form exhibits excellent biocompatibility, corrosion resistance, and low heat conductivity. However, it is much less stiff than stainless steel [21]. In their study, Mitsui et al. [22] examined the fracture durability of bovine teeth that were replaced using five distinct intraradicular post frameworks: cast metal posts, Ti posts, glass fiber posts, carbon fiber posts, and zirconium posts. The Ti posts had a greater average fracture resistance score in comparison to glass fiber and zirconium posts and demonstrated comparable results to carbon fiber posts. The conclusion drawn by the authors is that Ti and carbon fiber posts are the most appropriate choices. This study contradicts our findings.

Multiple contributors provide suggestions regarding the length of posts. According to a review article by Goodacre and Spolnik [23], the post length should ideally be three-quarters of the total length of the root canal, or at the very least, the length of the crown. It is advised that a remaining 4-5 mm of gutta-percha should be present at the apex to ensure a sufficient seal. Sorensen and Martinoff [24] found a 97% success rate in a retrospective investigation when the length of the post was equal to or greater than the height of the crown. As per the findings of Neagley, a post must have a minimum length of 8 mm [8]. Research has demonstrated that forces tend to accumulate at the highest point of the bone during the process of chewing. For teeth that have metal posts, forces likewise tend to be concentrated near the tip of the post. Thus, it is essential for a post to consistently protrude apically beyond the crest of the bone [25]. A recent study conducted by Abramovitz et al. [26] has shown that a 3-mm layer of gutta-percha does not reliably seal the apex. As a result, it is suggested to use a layer of 4-5 mm instead. Based on these factors, the post lengths of 11 mm and 15 mm were chosen for this study. To maximize the benefits of increased bonding surface between the post and tooth structure, and additionally, between the post and core material, it is advisable to utilize larger sizes of fiber posts. By employing this method, it is possible to enhance the cohesion and durability of the central material [7].

Irrespective of the content of the post, when the total length of the post increased, the overall displacement decreased [27]. Our findings align with those of Cailleteau et al. [28], who observed a modification in the flexure resistance of the tooth structure when the post was introduced into the root canal. The stress distribution shifted from the coronal region to the apical region of the root. The magnitude of the tension was contingent upon the length of the post. The fiber post group exhibited a greater overall displacement compared to the metal post groups. This could be attributed to the fiber post having a significantly lower elastic modulus compared to the metal post. Consequently, the group using fiber posts exhibited more elasticity and a bigger overall displacement.

Additionally, the direction in which force was applied to the canine teeth was derived from earlier research [20,29]. Model 1 exhibited the highest level of stress in the composite core, as found in this investigation. The stress in the core with the Ti post was greater than that in the core with the fiber post. A core placed with fiber posts measuring 1.5 mm in diameter and 11 mm in length exhibits lower levels of stress when viewed alongside alternative scenarios. The fiber post exhibited superior performance in comparison to the Ti post. Furthermore, the relationship between the low elasticity modulus of the glass fiber post and ceramic, as well as the bonding between ceramic, composite resin core, and resin cement, led to the selection of all-ceramic crowns for this investigation. By utilizing a fiber post, these characteristics produce a flexible, sophisticated restorative system with mechanical qualities comparable to healthy teeth.

According to this study, the stress transferred to dentin was negligible when using a Ti post with a diameter of 1.8 mm. This could be because the modulus of elasticity of the fiber post is similar to that of dentin, which is approximately 20 GPa. Additionally, the fiber post is five to 10 times more flexible than high-modulus metal posts. This flexibility enables the post to effectively absorb stress and avert root fractures. The fiber post exhibits superior stress distribution to dentin compared to the metal post. Although Ti posts induced stress concentration within the post itself, they also increased the likelihood of root breakage. Metal posts, because of their inflexibility and rigidity characteristics, transmit forces in a linear direction, exerting a wedging impact on the tooth structure, akin to a metal wedge on a wooden object [3]. There was no substantial fluctuation in stress seen in dentin when altering the length of the post, but it was relatively lower for shorter posts. The investigation, done by Pegoretti et al., found that glass fiber posts used to replace teeth resulted in a lower concentration of stress within the root compared to metal and carbon fiber posts. When there is a significant variation in Young's modulus between the dentin and the posts, the stress distribution on the tooth surface becomes less uniform, resulting in the formation of stress concentration zones on the dentin [30].

The FEA is a precise numerical technique used in stress analysis, specifically in dental biomechanics [9]. It allows for the determination of an approximate overall solution to the original problem [10]. A set of concurrent formulas is generated and resolved to determine the expected stress distributions in each component across a structure. The variables can be controlled with the utmost accuracy using computer technology, thereby removing any variance caused by sampling errors. To carry out this FEM analysis, the values for Poisson's ratio and Young's modulus of elasticity for all components were obtained from earlier research [1,9]. Performing FEM analysis many times will consistently produce identical results with 100% certainty. Hence, it is unequivocal that the outcomes are consistently influenced by modifying the variables rather than by random occurrences. Hence, traditional inferential statistical analysis is typically excluded from FEA [9].

Currently, some constraints must be acknowledged with respect to the current investigation. It was believed that the structures and materials employed in this investigation were homogeneous, isotropic, and linearly elastic. Consequently, the computational modeling differed from the genuine tooth frame and its supporting tissues [9]. Root fractures often occur owing to dynamic stress, which can culminate in a fatigue cycle in clinical situations distinct from static loading. Additional research is necessary to simulate the susceptibility to fracture and the effects of thermal and mechanical cycle loads to precisely predict the stress distribution in teeth that have undergone endodontic treatment. The research should also consider the impact of various restorative materials on the strength of the teeth, whether they are compromised or not.

Conclusions

The composite core exhibited the highest level of stress on Ti posts measuring 1.5 mm in diameter and 15 mm in length. Fiber posts with a diameter of 1.8 mm and a length of 11 mm exhibited lower levels of stress in the cervical region in comparison to Ti posts. Maximum strains happened in the tooth's cervical region regardless of the materials employed. There was no noticeable alteration in stress when the length and diameter of the post were modified. The highest level of stress absorbed by dentin was detected in cases where a fiber post was used, as opposed to cases where a Ti post was used. The fiber post showed minimal observed stresses; however, stresses transferred to the dentin were greater, which were distributed equally in comparison with Ti post cases. To alleviate stress in the remaining radicular tooth with a significant coronal defect, it is advisable to use a composite resin core along with a fiber post that has a wide diameter and shortened length while staying within the therapeutic stipulations.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

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Effects of Irrigants on Pulp Stem Cells: A Systematic Review

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ABSTRACT

Endodontic intervention in necrotic immature permanent teeth is usually a clinical challenge. With appropriate case selection, regenerative treatment can be effective, providing a desirable outcome. However, there is still no consensus on the optimal methods to achieve predictable clinical outcome. To ensure a successful regenerative procedure, it is essential to investigate the appropriate disinfection protocols and the use of biocompatible molecules in order to control the release of growth factors and the differentiation of stem cells. This systematic review summarizes the present knowledge regarding the effect of intracanal irrigants on the dental derived stem cells fate in regenerative endodontic procedures.

Keywords: Chlorhexidine; Growth factors; Intracanal irrigants; NaOCl; Regenerative endodontics

INTRODUCTION

Regenerative endodontic procedures (REP) have emerged as an alternative treatment modality for nonessential immature permanent teeth previously treated with apexification. REPs aim to promote normal pulp function by regenerating the pulp-dentin complex for which optimal disinfection of the root canal system is a mandatory call to achieve favorable results in REPs.[1] However, recent regenerative endodontic research indicates that commonly used root canal disinfectants may have direct or indirect effects on stem cells. Several clinical approaches have recently been proposed to preserve and stimulate dental stem cells and mostly focused on chemical disinfection of the root canal system with a combination of sodium hypochlorite (NaOCl) and chlorhexidine (CHX).[2,3] These irrigants are used for their known bacteriocidal and bacteriostatic effects. Unfortunately, there is no standard treatment protocol for the use of different irrigation solutions during disinfection of the root canal. Treatment protocols are implemented without adequate information about the effect of disinfection methods on stem cell viability. These materials can be cytotoxic to stem cells as they have been reported to be cytotoxic to periodontal ligament stem cells, cultured fibroblasts, and human deciduous teeth stem cells.[4] However, in addition to the better known antimicrobial properties, there is a need to evaluate the effect of each chemical agent used in regenerative procedures on stem cell of apical papilla. The purpose of this review was to comprehensively cover the disinfectants commonly used in regenerative endodontics and their role in stem cell fate.

2. MATERIALS AND METHODS

2.1. Protocol and registration

This work followed the recommendations of the Preferred Reporting Units of Systematic Reviews and Meta-Analyses (PRISMA)[5] statement and was performed according to current recommendations for endodontic systematic reviews and meta-analyses.[6] The systematic review protocol was previously registered in the Prospective Register of Systematic Reviews (PROSPERO) under registration number CRD42021255271.

2.2. Eligibility Criteria

The PICO method (Participant, Intervention, Comparison and Outcome) was used to develop the research question: "What is the effect of different irrigation agents, their concentration, irrigation protocol and irrigation techniques on the survival of the pulp stem cells? ", where (P): patients under 30 years old, traumatized necrotic immature permanent incisors with or without periapical radiolucency, (I): different irrigation methods for pulp revascularization, including irrigants such as sodium hypochlorite in different concentrations, chlorhexidine and EDTA. Another intervention was irrigation techniques used in the treatment of traumatic necrotic immature permanent incisors, (C) Effects of normal saline on pulp stem cells (O): survival, clinical and radiographic success. pulpal revascularization in the treatment of necrotic immature permanent traumatized incisors.

2.3. Outcome measures

The primary outcomes were survival, clinical and radiographic. Survival was defined as a tooth remaining in the oral cavity after follow-up. Clinical success was achieved with absence of clinical sign and symptoms (i.e, tenderness on percussion or palpation, swelling or fistulas, or spontaneous pain). Radiographical success was achieved if the size of the periapical area decreased and side effects such as root resorption and ankylosis were absent or did not increase after follow-up. Secondary outcomes were: sustained root development, pulp viability and crown color, . where sustained root development had 3 aspects: increased root length, increased root width and decreased tip diameter.

2.4. Study selection criteria

Inclusion criteria were randomized clinical trials, retrospective/prospective cohort studies and case-control studies. This review included only studies with a follow-up of at least 12 months and studies with at least 10 cases. Only articles that investigated pulpal revascularization techniques (RET) or compared RET with other techniques (i.e, apexification) in traumatized necrotic immature teeth were included. Studies were not restricted by language or year of publication.

2.5. Databases and search strategy

The database search, study selection, and data extraction were performed by two independent researchers (M.S.; I.A.). If there were differences between them, a third author (V.F.L.) was consulted. A systematic expanded electronic search was conducted in PubMed, Web of Science, Scopus, and Embase on June 16, 2021. The search was conducted using the Boolean operators AND and OR to combine terms and develop a search strategy. Search terms were constructed as follows: (regenerative endodontics or regenerative* or endodontic regeneration or regenerative endodontics or regenerative access or pulp revascularization or revascularization* or resuscitation* or loose tips or immature teeth) AND (necrosis) (non-essential AND tooth *) OR pulpless) AND (dental trauma* OR traumatic* OR traumatic* OR tooth In addition, the reference lists of all selected articles were examined for further studies.

2.6. Study selection process

All study titles and abstracts were independently assessed by two reviewers (M.S. and I.A.). If screening of the abstract did not provide sufficient information, the entire article was reviewed before a final decision was made. Two researchers also extracted all data on relevant variables. An investigator not involved in the selection process (J.M.M.C.) performed the following meta-analysis.

2.7. Unpacking the data

The variables extracted from each article were: author and year of publication, study type, sample size, number of groups, demographic variables (sex and age), follow-up in months, loss to follow-up, type of trauma, irrigation agents used and their concentrations, root canal dressing, duration of root canal dressing in weeks, type of frame with or without matrix, type of crown density, survival rate, success rate, failure, changes in root length and width, changes in apical diameter, adverse events or effects and crown and tooth

2.8. Methodological Quality Assessment

Two researchers assessed the risk of bias in all selected studies (M.S. and J.M.M.-C.) using a Cochrane risk-of-bias tool, RoB 2.0, to evaluate randomized clinical trials and the ONS (Newcastle–Ottawa scale) to evaluate non-randomized studies, including case-control and cohort studies. The NOS includes 8 items with a potential score of 9. Three main domains are considered: patient selection, comparability of the study groups, and results or outcomes. Articles were classified as being of 'high', 'moderate', or 'low quality', where high-quality articles scored more than 6 points. The Cochrane RoB 2.0 methodology assessment consists of five domains that evaluate: the randomization process, deviations from intended interventions, missing outcome data, outcome measurement, and selection of reported outcomes. Producing three levels of bias: 'low risk of bias', 'some concerns', or 'high risk of bias'.

2.9. Quantitative Synthesis-Meta-Analysis

All studies included in the meta-analysis were combined using a random-effects model. The estimated effect size was the event rate, odd ratios, means, and different means. The 95% confidence intervals were calculated for all estimated variables. Heterogeneity among the combined studies was assessed using a Q test (p-value < 0.05) and quantified with the I2, considering slight heterogeneity if it was 25–50%, moderate if 50–75%, and high heterogeneity if > 75%. Statistical significance was tested using a Z test (p-value < 0.05). The meta-analysis has been represented with a forest plot, and the publication bias was assessed using an Egger's test that indicates the existence of possible publication bias when the p-value is less than 0.05 (indicating significant asymmetry).

3.1. Study Selection

The search identified a total of 322 initial results, of which 139 were retrieved from PubMed, 50 from Scopus, 85 from Web of Science, 45 from Embase. Duplicates were manually removed using Mendeley reference management software, leaving a total of 199 studies. After screening the title and abstract, 190 articles were excluded. A total of 9 studies were eligible for full-text reading and all were selected for qualitative and quantitative synthesis. (Figure 1)

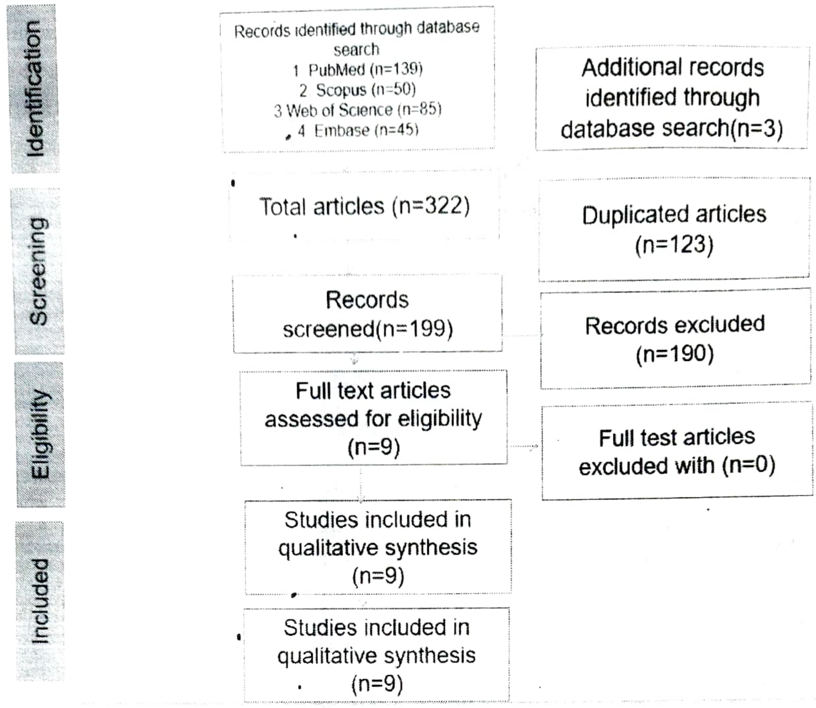

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram.

DISCUSSION

Successful endodontic treatment depends on effective mechanical and chemical cleaning of the root canal system. Mechanical instrumentation of canals infected with immature roots is contraindicated due to fragile, underdeveloped tooth walls. Thus, chemical cleaning is the most important disinfection technique in regenerative endodontic treatment.[7] Previous studies[8,9] have shown that apical papilla stem cells are essential for regenerative endodontics and their preservation should be a priority for clinicians. Martin *et al*[10] reported that different concentrations of NaOCl can affect the survival rate of stem cells and recommended a NaOCl concentration of 1.5-3% during RET. The studies included in this systematic review used different concentrations of NaOCl: 0.5%, 1%, 1.5%, 2%, 2.5%, 5% and 6%; therefore, lower or higher NaOCl concentrations may have negatively affected the RET result.[11-16]

Several studies[17,18] have recommended the use of ethylenediaminetetraacetic acid (EDTA) at the second RET follow-up visit because it reduces the unwanted effects of NaOCl on stem cell viability and releases growth factors. Although another study by Farhad Mollashah *et al*[19] showed that EDTA had greater cytotoxicity than NaOCl and CHX had less cytotoxicity than NaOCl or EDTA on survival of human apical papillary stem cells. In addition, a recent systematic review[20] reported that there were no unsuccessful cases in which EDTA was not used as an irrigation solution during RET procedures. Two of the studies[21,22] included in this review did not use EDTA irrigation and still had similar results to the other included studies. Further studies on the use of EDTA in RET are needed to better understand its effect on such treatments.

EDTA stimulates the release of these growth factors from dentin and increases their bioavailability. In addition, EDTA removes the smear layer and disinfects dentin, thus improving stem cell attachment. Regardless of the effect of EDTA on the release of bioactive molecules, apical extrusion of EDTA not only causes periapical decalcification of bone, but can also impair neuroimmune regulation even at very low concentrations. Also, leakage of EDTA into periapical tissues can inhibit macrophage function and reduce periapical

inflammatory responses. Despite the beneficial use of EDTA in clinical regenerative endodontic therapy, EDTA had direct negative effects on cell proliferation, cell migration and osteogenic differentiation *in vitro* in stem cell of apical papilla.[23,24,25]
In contrast to EDTA, NaOCl inhibited the differentiation of humen deciduous teeth stem cells and pulp stem cells into pre-odontoblast cells *in vitro* and *in vivo studies*.[26] NaOCl denatures dentin-derived growth factors and inhibits their effects on the differentiation and proliferation of mesenchymal stem cells.[27]
Yasuda *et al*[28] showed that the cytotoxicity of MTAD against MC3T3-E1 osteoblast-like cells and periodontal ligament cells was lower than 5.25% NaOCl, 17% EDTA and 0.12% CHX. The cytotoxicity of these materials was evaluated in L929 fibroblasts for 24 h. In the study by Zhang *et al*[29], MTAD showed lower cytotoxicity than 5.25% NaOCl and EDTA and higher cytotoxicity than 2.63%, 1.31% and 0.66% NaOCl. Ring *et al*[30] showed that the cytotoxicity of NaOCl/MTAD was slightly lower than that of NaOCl and NaOCl/EDTA. This indicated higher biocompatibility of MTAD than NaOCl. Another study also confirmed the cytotoxicity of 17% EDTA even at 0.1% dilution. The difference in results was due to the difference in sensitivity of the cell lines used or the experimental conditions, such as the use of different material concentrations and different evaluation times. Conversely, Ghandi *et al*[31] reported that MTAD irrigation had no advantage over saline and did not induce fibroblast adhesion. According to the results of previous studies and the present findings, MTAD should not be chosen as irrigation for revascularization procedures, because it has not been confirmed to have a positive effect on the attachment of stem cells of apical papilla to dentin.
QMix is a mixture of polyaminocarboxylic acid, salt, antimicrobial bisbiguanide, calcium chelating agent and surfactant. It has antimicrobial properties and substance, but cannot dissolve tissue. In several studies, the cytotoxic effect of QMix was found to be very similar to 5.25% NaOCl and greater than 2% CHX.[32,33] In a study by Chandrasekhar *et al*[34], QMix showed less cytotoxicity than 3% NaOCl, 2% CHX, and 17 TA in rat subcutaneous tissues. CHX had the lowest 'cytotoxicity after sterile saline. The cytotoxicity of CHX, unlike MTAD, EDTA, QMix and NaOCl, did not change significantly over time. In a previous study, 2% CHX showed residual antibacterial activity and was more potent than 5.25% NaOCl in this regard. In addition, it showed lower cytotoxicity compared to 5.25% NaOCl. Bajram *et al*[35] in a study, 2% CHX had greater cytotoxicity to rat periodontal ligament fibroblasts than MTAD and NaOCl. The results of an *in vitro* study on the cytotoxicity of CHX against human gingival cells showed that the toxic power of CHX depends on the composition of the exposure medium, the exposure dose, and the length of exposure. Chlorhexidine does not appear to have long-term toxic effects on host tissues, but it can cause an inflammatory response in these tissues.

CONCLUSION

Chlorhexidine had the lowest cytotoxicity compared to EDTA, MTAD, QMix and NaOCl, and its cytotoxicity did not change over time, compared to other solutions. These findings highlight that even commonly used endodontic irrigants have a profound effect on stem cell survival and differentiation capacity. Thus, besides adequate disinfection, it is crucial to create a microenvironment in root canals that will promote the survival/proliferation and differentiation of stem cells. These results can provide a key for choosing the irrigating solution in cases of pulp regeneration.

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ORIGINAL RESEARCH

Evaluation of the Effect of Parental Smoking on Gingival Melanin Pigmentation in Children

Ashish Anand[1], Tinesh Raja[2], Vabool Thakur[3], Nidhi Agarwal[4]

Abstract

Background: The presence of melanin pigmentation of the gingiva has unfavorable effects on esthetics in children. Although there are several local and systemic factors that cause melanin pigmentation, they may also be induced by the stimulation of melanocytes by stimuli present in tobacco smoke.

Aim: The aim of the study was to correlate the effect of parental smoking on the pigmentation of gingiva in children of Modinagar, Uttar Pradesh, India.

Materials and methods: The study was a cross-sectional observational study. The study sample was formed by all children between 8 and 14 years of age. Only medically compromised children were excluded from the study. The children were examined for the presence of gingival melanin pigmentation. The status was recorded as present or absent. Determination of the smoking status of family members was done by a self-formulated questionnaire.

Results: The presence of pigmentation was seen in 114 (82%) children, whereas pigmentation was absent in 26 (18%) children. Out of the total sample of 140 children, 95 had one or more family members who were smoking. The Chi-squared test performed to form an association between pigmentation and the type of tobacco used revealed high significance ($p = 0.00$) for the father who smokes bidi.

Conclusion: There is a correlation between parental smoking and melanin pigmentation in the gingiva of children, and the correlation is very high when the father is a smoker, especially when he smokes bidi.

Keywords: Gingival pigmentation, Melanin pigmentation, Parental smoking.

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Introduction

Smoker's melanosis is a recognized phenomenon in smokers in which there is an increase in gingival melanin pigmentation.[1] Nicotine, cotinine, and other volatile chemicals, including acetaldehyde and acrolein, build as a result of long-term smoking exposure.[2] The inhalation of tobacco smoke in the air, known as passive smoking, secondhand smoke, or environmental tobacco smoke (ETS), consists of 15–20% mainstream smoke (smoke exhaled by the smoker) and 80–85% sidestream smoke (smoke from the burning tip of a cigarette).[3]

Research shows that the maximum frequency of oral pigmentation is seen in Indians (89%). The incidence of smoking in the Indian population has been found to be 47% in men and 14% in women.[4] Due to the lack of stringent "smoke-free" rules in India, children who have a smoker in the household are more likely to develop gingival pigmentation.[5]

The presence of melanin pigmentation in gingiva has unfavorable effects on esthetics. Individuals complain about an unhealthy, dirty, and dark appearance of the gingiva, the mismatch of gingival color with that of skin or teeth, and lowered self-esteem.

The literature contains very few studies assessing smoking's impact on gingival pigmentation. Therefore, the purpose of this study is to determine how parental smoking affects the gingival pigmentation of children in Modinagar, Uttar Pradesh, India (Table 1).

Materials and Methods

The study was a cross-sectional observational study. The ethical clearance was obtained from the ethical committee of the Institute of Dental Studies & Technologies, Ghaziabad, Uttar Pradesh, India. Informed consent was obtained from the parents before the commencement of the study. At 80% ($1 - \beta$) power of the investigation, 140 was the minimum suggested sample size to detect the statistical significance of 5% ($\alpha = 0.05$) and effect size (f) 0.39 using G*Power 3.1.

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Conflict of interest: None

Table 1: Association between pigmentation and individual smoking (father, mother, or associated family member)

		Father	*Mother*	*Associated family member*
PP	Smoking	58	19	39
	Nonsmoking	56	95	75
PA	Smoking	18	0	24
	Nonsmoking	8	25	19

PP, pigmentation present; PA, pigmentation absent

The study sample was formed by all children between 8 and 14 years of age reporting to the outpatient department of the dental college and associated hospital. The study excluded children who were medically compromised. The children underwent examinations to check for gingival melanin pigmentation. The status was noted either as present or absent.

Evaluation of Gingival Pigmentation

If single pigmentation units or the creation of a continuous ribbon extending from two adjacent units were seen, the pigmentation was considered to be present. The pigmentation was marked absent in cases where there was no pigmentation.

Evaluation of Smoking Status

Family members' smoking status was ascertained using a self-created questionnaire. The questionnaire's reliability, as determined by Cronbach's α, was 0.82, and its face validity was 0.73. When at least one family member smoked once a day at home in the child's presence during the previous 6 months, the child was considered to be a part of the smoker family. Face-to-face interviews of the father, mother, and grandparents, if living together, were carried out by a single examiner.

Results

Out of the 140 children, 56 (40.3%) were girls, and 84 (59.7%) were boys, with a mean age of 11.13 years.

The presence of pigmentation was seen in 114 (82%) children, whereas pigmentation was absent in 26 (18%) children.

Out of the total sample of 140 children, 95 had one or more family members who were smoking.

Among the pigmentation present (PP) group, 58 fathers, 19 mothers, and 39 associated family members were found to be smokers.

Among the pigmentation absent (PA) group, 18 fathers and 24 associated family members were found to be smokers. None of the mothers were found to be smokers in the group.

An association between pigmentation and combined smoking was made, and the result showed high significance ($p = 0.05$) when at least one member of the family had a smoking habit. The odds ratio was found to be 3.167 (Fig. 1).

The Chi-squared test performed to form an association between pigmentation and the type of tobacco used revealed high significance ($p = 0.00$) for the father who smokes bidi (Fig. 2).

Discussion

Pigmentation of the gingiva may be due to a physiological or pathological cause. The level of melanin pigmentation can change depending on a person's age, gender, skin tone, race, lifestyle, and a few other environmental variables.[6]

Children whose parents smoked had higher levels of pigmentation than children whose parents did not smoke.

There are primarily two ways that stimulatory compounds from passive smoking get to the melanocytes[7]:

- By inhaling the smoke, nicotine and its byproducts cause an increase in the activity of melanocytes.
- Dissolving in the saliva affects the oral epithelium.

In the present study, 40.3% of girls and 59.7% of boys had pigmentation, which shows a slight predilection of gingival melanin pigmentation in boys.

Hanioka et al. conducted a case–control study in the Japanese population and found that children with gingival pigmentation had

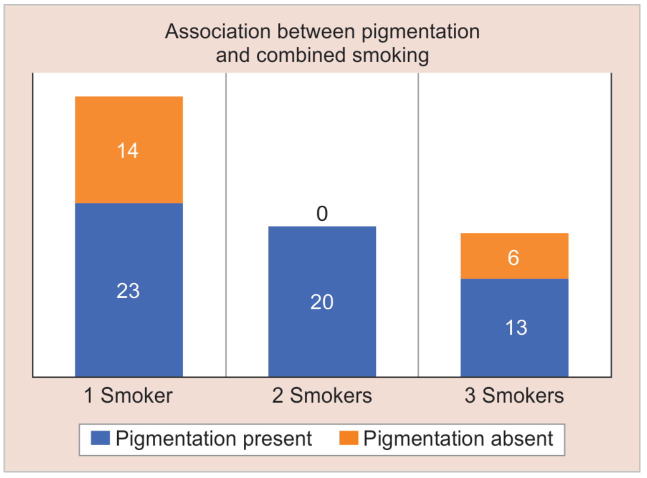

Fig. 1: Association between pigmentation and combined smoking

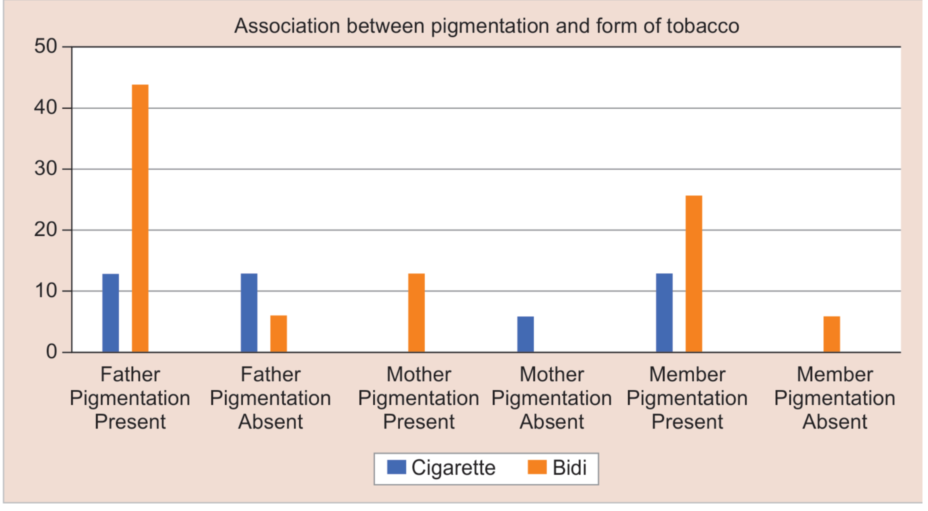

Fig. 2: Association between pigmentation and form of tobacco use

a higher percentage of parental smoking (70–71%) than children without pigmentation (35%).[8]

In Turkey, Boyaci et al. assessed the levels of nicotine metabolite in children's blood and urine and discovered a strong link between gingival pigmentation and passive smoking.[9]

The precise amount of time that smoking parents and their children spent together was not accessible for this study's data. Nonetheless, the majority of parents smoked 6 to 10 cigarettes a day, making them moderate to heavy smokers; as a result, it's possible that their children were exposed to passive smoke.

In the present study, along with the impact of the smoking habit of the father, the habits of the mother and other family members (i.e., grandparents and other relatives in the case of a joint family) were also included, although a significant association was not found.

Additionally, the present study also assessed whether the type of tobacco consumption, such as cigarettes, bidis, and other products, also had any association with pigmentation. It was observed that parental bidi smoking had a greater association with gingival pigmentation than other forms of tobacco products. Bidi contains more particulate matter as they do not have filters, along with a higher amount of nicotine, compared to cigarettes.

Parents' smoking had a discernible effect on their children's gingival pigmentation, although it was unclear how much more melanin was formed as a result. A stronger correlation between melanin pigmentation in human gingiva and passive smoking could be established by conducting additional investigations utilizing quantitative analysis regarding the effects of ETS and gingival pigmentation. Even while it is suggestive of parental smoking, the higher pigmentation in participants exposed to ETS from smoker parents is not conclusive.

Conclusion

Our cross-sectional study's findings lead us to the conclusion that there is a link between parental smoking and melanin pigmentation in children's gingiva, and that association is strongest when the father smokes, particularly when he smokes bidi.

Clinical Significance

The study emphasizes the harm passive smoking causes to youngsters, and further research may be done to understand the various harmful impacts of smoking. This study will be useful in creating awareness and counseling to adults regarding the ill effects of smoking with regard to the impact on children.

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ORIGINAL RESEARCH

A Comparative Evaluation of Nanosilver Fluoride, Chlorhexidine, and Sodium Fluoride When Used as a Varnish on *Streptococcus mutans* Levels in Children with Caries

Tinesh Raja[1], Nidhi Agarwal[2], Zohra Jabin[3], Ashish Anand[4], Nandita Waikhom[5], Vabool Thakur[6]

Abstract

Aim: The purpose of the present study is to evaluate the effect of nanosilver fluoride (NSF), chlorhexidine (CHX), and sodium fluoride (NaF) when used as a varnish on *Streptococcus mutans* levels in children with dental caries.

Study design: A total of 120 children (age range 8–12 years) with incipient caries were randomly assigned to four groups ($n = 30$): group I—NSF varnish, group II—CHX varnish, group III—NaF varnish, and group IV—control. Varnish application at baseline was performed once. To assess the levels of *S. mutans* using the culture method [colony-forming units (CFUs)] and optical density (OD), plaque and samples were taken at baseline (T0), 1 month (T1), and 3 months (T3). Additionally, the oral hygiene index-simplified (OHI-S) was noted for clinical assessment.

Results: By the end of 3 months, a statistically significant reduction in plaque CFU and salivary CFU was found in group II. At the conclusion of the 3 months, group I had the greatest decrease in OHI-S. After 3 months, the plaque CFU score did not differ significantly across groups I, II, and III. However, a statistically significant difference in OD values (p-value of 0.00) was discovered between group I and all other groups.

Conclusion: Children with early caries can effectively lower their *S. mutans* count by using NSF varnish.

Keywords: Chlorhexidine, Incipient caries, Nanosilver fluoride, Sodium fluoride, *Streptococcus mutans*, Varnish.

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Introduction

Dental caries remains the most common dental illness globally and is regarded a serious global health concern. According to the World Health Organization's 2003 oral health report, periodontal diseases and dental caries are pandemic ailments that affect the entire community, irrespective of age, gender, or socioeconomic status.[1] As preventive measures and community oral health care services are more challenging to access in developing nations like India, the issue is more concerning there. According to the 2002–2003 National Oral Health Survey, the decayed, missing, filled teeth (DMFT) index score for Indian children was approximately 2, and the prevalence of caries increased with age, rising from 51.9 to 63.1% in the 5–15-year-old age-group, respectively.[2]

Minimally invasive techniques to halt the progression of dental caries are replacing more traditional methods of treating the condition, which involves surgically removing the damaged dental tissue and then placing an appropriate restorative material. Remineralization aims to prevent dental cavities by comprehensively protecting the patient in the long run by intervening as soon as possible.

Sodium fluoride (NaF) varnish is one of the oldest and most widely used varnishes. It is professionally applied to the tooth surface, with four applications annually at weekly intervals to provide antimicrobial and anticary activity.[3] A cationic bisbiguanide with a broad antimicrobial range is chlorhexidine (CHX). In dentistry, it is widely used in a variety of forms, including dentifrices (0.4%), gels (1%), solutions (0.12 and 0.2%), and varnishes (1, 10, 20, and 35%). Compared to other applied agent forms, it has been proposed that the varnish form of CHX administration leads to a sustained reduction of *S. mutans*.[4]

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However, with advancements in technology, an innovative approach has been made to combat the high incidence of dental caries—the use of nanotechnology in dentistry. Silver nanoparticles, one of many types of nanomaterials, have demonstrated significant promise for use in biological applications. Many of the antibacterial effects of nanomaterials stem from the release of silver ions, which can pass through the cell wall of bacteria and cause both direct and indirect lipid peroxidation, damaging the cell membrane, halting deoxyribonucleic acid (DNA) replication, and affecting both respiratory protein restoration and inhibition.[5]

Thus, the objective of the current study was to discover how to varnish applications of NaF, CHX, and nanosilver fluoride (NSF) altered the levels of *S. mutans* in children with dental caries.

Materials and Methods

The study followed the Consolidated Standards of Reporting Trials (CONSORT) 2010 standards and was a randomized, triple-blinded clinical controlled trial (Fig. 1).

For every group (NSF, CHX, NaF, and control), a minimum sample size of 27 was advised, taking into account a power of 80% (1-β), with a 95% confidence interval and an effect size (*f*) of 0.39 using G*Power 3.1. An overall suggested sample size of 109 was estimated, which was rounded to 120 to ensure that each group had at least 30 samples.

A total number of 260 patients (age range of 8–12 years) were screened. Parental consent was obtained prior to their inclusion in the study. Cooperative children with fully erupted permanent central incisors and permanent first molars having incipient caries with International Caries Detection and Assessment System II (ICDAS II) scores 1 and 2 were included. Children having any intraoral hard or soft tissue infection or pulpally involved caries were excluded. Medically compromised children, or children on fluoride or antimicrobial therapy, and wearing orthodontic appliances were also excluded from the study. A total of 120 children were enrolled for the study on the grounds of pre-established eligibility criteria.

Examination Incipient Lesion

Visual examination was carried out to detect incipient lesions. The ICDAS II was used to standardize the diagnosis (Fig. 2).[6] Two investigators conducted the examination of the incipient lesion, and if there was any disagreement, the third investigator assessed the discrepancy and made the final decision.

To avoid selection bias, allocation concealment using the sequentially numbered, opaque, sealed envelopes approach was implemented. The random concealment was conducted by an investigator who was not engaged in the application of varnish or the measurement of the outcome to prevent intervention bias. An envelope with a dark color and a corresponding serial number on top was sealed with a sheet of paper bearing a randomized group number. After the intervention was allocated, the envelope was opened. The varnish was applied according to the group designated in the document.

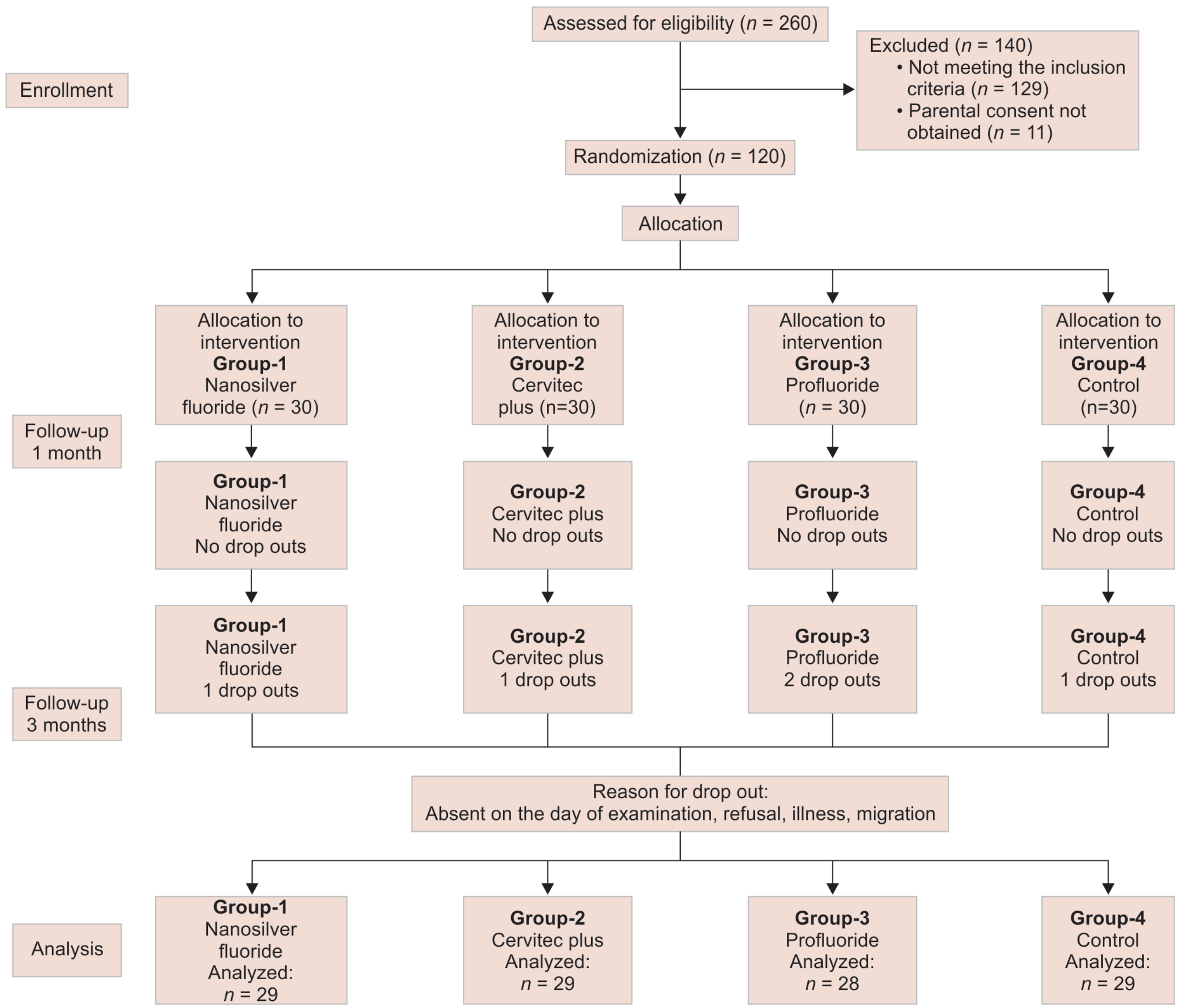

Fig. 1: Consolidated Standards of Reporting Trials flow diagram

The chosen research study participants were allocated randomly to one of four groups (30 children per group) (Table 1).

Preparation of Nanosilver Fluoride

The formulation provided by Targino et al. was followed in the preparation of NSF.[7] Silver nitrate was chemically reduced with sodium borohydride ($NaBH_4$) and chitosan biopolymer as a stabilizing agent to produce silver nanoparticles in an aqueous solution. We dissolved 2.5 mg/mL of chitosan in a 1% acetic acid solution. Magnetic stirring was used to combine the mixture until it was homogeneous. The mixture was then submerged in an ice bath, and it was vigorously stirred while more $NaBH_4$ (0.3 mL, 0.8 M) was added drop by drop. After removal from the cold bath, 10,147 parts per million of NaF were added to the flask. Stirring continued overnight. The resulting solution contained silver nanoparticles (399.33 µg/mL), NaF (10,147 µg/mL), and chitosan (2334 µg/mL). Transmission electron microscopy (TEM) was utilized to assess the shape and size of silver nanoparticles. A TEM image was captured on an FEI-Tecnai G2 F20 with an accelerating voltage of 200 kV. It was determined that 99% of the silver nanoparticles were spherical, with a size of 8 ± 2.0 nm (Fig. 3).

The child's personal information, dental history, and medical history, including any recent exposure to antibiotics, were documented prior to the study's start. During the trial period, food counseling and instructions on oral hygiene were provided.

Evaluation was done for the following:

- Clinical parameter—oral hygiene index-simplified (OHI-S) index: The buccal surface of the index teeth—16, 11, 26, 36, 41, and 46—as well as the incisal two-thirds and cervical region were all traversed by an explorer. Based on the OHI-S, each of the six teeth received a score ranging from 0 to 3.[8]
- Method of dental plaque sample collection: Using a sterile wooden toothpick, the lingual and buccal surfaces of the index teeth—16, 11, 26, 31, and 46—from the occlusal to the gingival third were scraped to obtain plaque samples from each patient between 9 and 10 AM. After being collected, the samples were placed in a microcentrifuge tube (5 mL) with 3 mL of saline solution and sent directly to the lab.
- Method of saliva sample collection: Around 2–3 mm of unstimulated whole saliva was extracted from the child by instructing them to drool into a sterile container. The containers

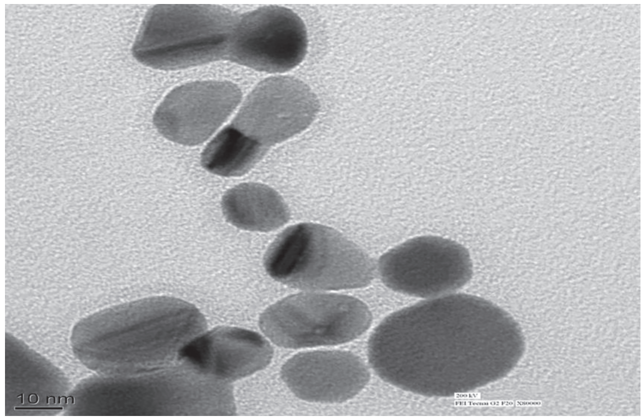

Fig. 3: Transmission electron microscopy image of nanosilver particles used in the study

CODE	DESCRIPTION
0	Sound tooth surface: No evidence of caries after 5 sec air-drying
1	First visual change in enamel: Opacity or discoloration (white or brown) is visible at the entrance to the pit or fissure seen after prolonged air drying
2	Distinct visual change in enamel visible when wet, lesion must be visible when dry
3	Localized enamel breakdown (without clinical visual signs of dentinal involvement) seen when wet and after prolonged drying
4	Underlying dark shadow from dentine
5	Distinct cavity with visible dentine
6	Extensive (more than half the surface) distinct cavity with visible dentine

Fig. 2: International Caries Detection and Assessment System II score and criteria

Table 1: Table showing group allocation and composition of materials used

Groups	*Number of participants*	*Materials*	*Composition*
Group I	30	NSF varnish	NSF group. A special formula as prepared by Targino et al.[7] containing nanosilver particles, NaF and chitosan as a stabilizer
Group II	30	CHX varnish	The CHX varnish (Cervitec Plus by Ivoclar Vivadent) group includes 1% CHX diacetate and 1% thymol as active antimicrobial ingredients
Group III	30	NaF varnish	The NaF (Profluoride Varnish, VOCO GmbH. Cuxhaven, Germany) varnish group contains 5% NaF (22,600 ppm F) with xylitol
Group IV	30	Control	Control group. Saline was used as a placebo control

were labeled and immediately submitted for analysis of *S. mutans*, then stored in a cold bath below 4°C.

Method of Varnish Application

Oral prophylaxis was performed to standardize the oral cavity with the least amount of biofilm before varnish was applied. The teeth were isolated using cotton rollers and a saliva ejector, and for 30 seconds, a three-way air syringe was used to gently inject air into the teeth. Using an applicator tip, approximately 0.1 mL of the chosen varnish was applied quadrant-wise sequentially to every tooth, beginning with the upper arch.

Participants were instructed not to rinse, eat, or drink anything for 3 hours and not to brush until the next day after application. Additionally, toothpaste devoid of fluoride was provided for use during the study.

Laboratory Phase

Two methods were used to evaluate *S. mutans* in plaque and saliva samples:

- Culture test: Mitis salivarius bacitracin agar was prepared to facilitate the multiplication and selection of *S. mutans* on the agar plates. Before distributing the saliva and plaque samples onto the agar plates for colony counting, they were diluted 1:1 and 1:2, respectively. The Petri plate was divided into eight sections, and the number of colonies found in each area was tallied. This number was then multiplied by eight to determine the total number of colonies on the plate. To acquire the total number of colonies in 1 mm of saliva or plaque, multiply the number of colonies obtained by the dilution factor.
- Optical density (OD): At 600 nm, OD was measured using a spectrophotometer (Spectronic 20). The OD method, based on the scattering of light, is used to track the kinetics of growth.

After applying varnish, the clinical and laboratory parameters were evaluated at baseline (T = 0), 1 month (T = 1), and 3 months (T = 3). A total of 5 of the 115 children in the final study sample had dropped out after 3 months (Fig. 1).

Results

A *post hoc* Bonferroni test and a one-way analysis of variance (ANOVA) were used to compare the *S. mutans* count at different intervals according to the application of different varnishes. During the follow-up phase, five participants withdrew from the original sample of 120 subjects, leaving 115 children, ages 8–12, remaining in the study. Of these, 53 boys (46.08%) and 62 girls (53.91%) made up the final study sample after 3 months.

Oral hygiene index-simplified: Each group's mean baseline OHI-S fell into one of four categories—0.4 ± 0.1, 0.5 ± 0.1, 0.5 ± 0.1, and 0.5 ± 0.2. All groups exhibited an increase in their OHI-S score, but group I saw the largest increase after 3 months, measuring 0.30 ± 0.15, which was determined to be statistically significant (Table 2).

Plaque: The four groups had baseline plaque colony-forming units (CFUs) of $4.48 \pm 1.34 \times 10^5$, $4.69 \pm 1.65 \times 10^5$, $4.41 \pm 1.50 \times 10^5$, and $4.57 \pm 1.34 \times 10^5$ CFU/mL, respectively. Group II showed the greatest decrease in plaque CFU score one month following the application of varnish, followed by groups III, I, and IV. Group II saw the greatest reduction after 3 months. Upon analysis, the decrease was found to be statistically significant in all groups with the exception of the control group.

The baseline plaque OD for all the groups was 1.38 ± 0.26, 1.39 ± 0.21, 1.44 ± 0.20, and 1.36 ± 0.17 OD/mL. Group I had the greatest decrease in plaque OD score one month following varnish application, followed by groups II, III, and IV. Group I showed the greatest decline after 3 months. With the exception of the control group, the decrease was statistically significant in every group (Table 2).

After 3 months, the intergroup comparison revealed that there was no statistically significant difference (p-value < 0.01) in the plaque CFU scores between groups I, II, and III. On the other hand, a statistically significant difference (p-value = 0.00) in OD was observed between group I and the remaining groups.

Saliva: The baseline salivary CFUs for all the groups were $4.43 \pm 1.35 \times 10^5$, $4.55 \pm 1.65 \times 10^5$, $4.31 \pm 1.57 \times 10^5$, and $4.05 \pm 1.61 \times 10^5$ CFU/mL. After 3 months, there was a statistically

Table 2: Table showing mean OHI-S, plaque CFU, and OD values recorded for groups I, II, III and IV at baseline (T0), 1 month (T1) and 3 months (T3)

		T0		*T1*		*T3*			
	Parameters	*Mean*	*Standard deviation (SD)*	*Mean*	*SD*	*Mean*	*SD*	*Mean change from T0 to T3*	*p-value*
Group I	OHI-S†	0.4	0.1	0.28	0.13	0.30	0.15	0.12	0.003*
	CFUP‡ ($\times 10^5$ CFU/mL)	4.48	1.34	0.00556	0.00632	0.03115	0.01797	4.45	0.017*
	ODP§ OD/mL	1.38	0.26	0.463	0.181	0.400	0.125	0.98	0.000*
Group II	OHI-S†	0.5	0.1	0.38	0.12	0.43	0.13	0.07	0.113
	CFUP‡ ($\times 10^5$ CFU/mL)	4.69	1.65	0.00315	0.00213	0.02634	0.01151	4.66	0.017*
	ODP§ OD/mL	1.39	0.21	0.888	0.153	0.785	0.169	0.61	0.001*
Group III	OHI-S†	0.5	0.2	0.41	0.14	0.39	0.14	0.08	0.128
	CFUP‡ ($\times 10^5$ CFU/mL)	4.41	1.50	0.00439	0.00504	0.03405	0.01962	4.37	0.001*
	ODP§ OD/mL	1.44	0.20	0.932	0.177	0.913	0.223	0.52	0.000*
Group IV	OHI-S†	0.5	0.2	0.51	0.15	0.49	0.14	0.02800	0.541
	CFUP‡ ($\times 10^5$ CFU/mL)	4.57	1.34	4.26033	1.20203	4.33133	1.23614	0.23533333	0.090
	ODP§ OD/mL	1.36	0.17	1.096	0.105	1.102	0.087	0.259333	0.092

One-way ANOVA applied; *, p-value significant at $p < 0.05$; OHI-S†, oral hygiene index-simplified; CFUP‡, colony forming unit in plaque; ODP§, plaque optical density

significant difference in the *S. mutans* levels for each of the three experimental groups, as determined by the OD and the culture technique. After 1 month, both groups I and II showed the greatest reduction. Group II had the greatest reduction after 3 months (Table 3). After 3 months, the intergroup comparison revealed no discernible differences between groups I, II, and III (Table 4).

An analysis using OD revealed a highly significant difference (*p*-value 0.00) between groups I and II, II and III, and III and IV.

Discussion

The results of the current study demonstrate that after 3 months, a single application of NaF, CHX, and NSF varnish remarkably reduced the amount of *S. mutans* in saliva and plaque in children with dental caries. The etiological factor, which includes host factors, diet, and dental plaque (*S. mutans*), is the most significant risk factor for any disease. In 1980, Hamada and Slade implicated *S. mutans*) as a primary causative organism of dental caries.[9] Hence, to control the cariogenic activity, it is important to suppress the growth of *S. mutans* counts in the oral cavity. The initial stage of tooth decay or demineralization is represented by the incipient carious lesions, which have the potential to progress to cavitation, be arrested, or reversed.

This study adopted a nonintensive varnish application regime, applying the coating once at baseline, which is in line with research conducted by Ben Khadra et al. and Al-Jaradi et al.[4,10] Despite using a more rigorous application regimen in their trial, Twetman et al.

Table 3: Table showing mean saliva CFU and OD values recorded for groups I, II, III and IV at baseline (T0), 1 month (T1) and 3 months (T3)

	Parameters	T0 Mean	T0 SD	T1 Mean	T1 SD	T3 Mean	T3 SD	Mean change from T0 to T3	p-value
Group I	CFUS† (×10^5 CFU/mL)	4.43	1.35	0.00463	0.00368	0.0500	0.0559	4.38	0.044*
	ODS‡ OD/mL	1.40	0.24	0.476	0.164	0.415	0.127	0.98	0.001*
Group II	CFUS† (×10^5 CFU/mL)	4.55	1.65	0.00323	0.00199	0.0264	0.0127	4.53	0.014*
	ODS‡ OD/mL	1.39	0.20	0.887	0.168	0.781	0.172	0.61	0.001*
Group III	CFUS† (×10^5 CFU/mL)	4.31	1.57	0.00938	0.01950	0.0804	0.1133	4.23	0.007*
	ODS‡ OD/mL	1.44	0.19	0.941	0.187	0.916	0.217	0.52	0.000*
Group IV	CFUS† (×10^5 CFU/mL)	4.05	1.61	4.18333	1.59155	4.1460	1.5723	−0.0970	0.070
	ODS‡ OD/mL	1.36	0.20	1.154	0.094	1.141	0.091	0.223333	0.068

One-way ANOVA applied; *, *p*-value significant at $p < 0.05$; CFUS†, colony forming unit in saliva; ODS‡, saliva optical density

Table 4: Intergroup comparison of CFU and OD among the four groups at 3 months

	Group (I)	Group (J)	Mean difference (I–J)	p-value
CFUP† (×10^5 CFU/mL)	I	II	0.00481067	1.00
		III	−0.00290333	1.00
		IV	−4.30018333*	0.000*
	II	III	0.00771400	1.00
		IV	−4.29728000*	0.000*
	III	IV	−4.30499400*	0.000*
ODP‡ OD/mL	I	II	−0.384400*	0.000*
		III	−0.512200*	0.000*
		IV	−0.701333*	0.000*
	II	III	−0.127800*	0.014*
		IV	−0.316933*	0.000*
	III	IV	−0.189133*	0.000*
CFUS§ (×10^5 CFU/mL)	I	II	0.0236033	1.00
		III	−0.0304533	1.00
		IV	−4.0960400*	0.000*
	II	III	0.0540567	1.00
		IV	−4.0655867*	0.000*
	III	IV	−4.1196433*	0.000*
ODS¶ OD/mL	I	II	−0.366000*	0.000*
		III	−0.500833*	0.000*
		IV	−0.725667*	0.000*
	II	III	−0.134833*	0.008*
		IV	−0.359667*	0.000*
	III	IV	−0.224833*	0.000*

Post hoc Bonferroni applied; *, *p*-value significant at $p < 0.05$; CFUP†, colony forming unit in plaque; ODP‡, plaque optical density; CFUS§, colony forming unit in saliva; ODS¶, saliva optical density

found that this did not increase the varnish's efficacy. Even after 1 month, the single treatment regimen used in this investigation significantly reduced the amount of *S. mutans*.[11]

Various literature on evaluating the presence of *S. mutans* have recommended saliva as a suitable method for predicting caries activity and identifying patients with high-risk of dental caries.[12] Gibbons and Houte, in 1975, stated that plaque is more appropriate and superior than saliva for estimating MS in individuals because tooth surfaces are the natural habitat of MS and Plaque.[13] Therefore, in the current study, we analyzed *S. mutans* levels in both saliva and plaque samples.

A novel varnish called NSF combines nanosilver particles with fluoride and chitosan to act as a stabilizing agent. Free radicals produced by the silver nanoparticles harm the bacterial cell membrane, cause it to become porous, and ultimately cause cell death. Moreover, during protein synthesis, silver ions can bind with sulfuryl groups and obstruct DNA replication.[14,15]

Nanosilver fluoride is endowed with remineralizing characteristics by the fluoride it contains, which lowers adhesion and biofilm formation.[16,17] As a result, NSF functions as a remineralizing agent in addition to having an antibacterial impact.

Besinis et al. in 2014 compared the antibacterial effect of silver nanoparticles with CHX and found that the antibacterial activity measured in terms of CFUs of silver nanoparticles was 25-fold higher than CHX.[18]

In 2017, Soekanto et al. assessed the effectiveness of NSF in preventing the production of *S. mutans* biofilms *in vitro*. They discovered that NSF was a more effective inhibitor of *S. mutans* biofilm formation than the industry standard silver diamine fluoride (SDF) (38%).[19]

El-Desouky et al. 2020 evaluated the anticarcinogenic effects of NSF and NaF in an *in vitro* study where the difference between *S. mutans* values in both the groups within a period of 7 days was found to be nonsignificant. Their result is in contrast to the present study since NSF has shown a significantly greater reduction in *S. mutans* count than NaF at the end of 1 and 3 months.[20]

A study by Waikhom et al. in 2022 found that when children without dental cavities applied NSF varnish, the number of *S. mutans* in both plaque and saliva decreased statistically significantly.[21]

In the present study, the CFU count of *S. mutans* in saliva and plaque did not show any statistically significant difference between NSF, CHX and NaF varnish. However, the reduction was significantly greater in NSF when the evaluation was done using the OD method. Since OD measurement is related to changes in morphology, clumping, or formation of long chains of bacteria during growth, it can be assumed that NSF causes some alteration in bacterial growth. The same can be appreciated intraorally by the significant reduction in values of the OHI-S index of the subjects where NSF varnish was used.

According to us, the potential limitation could be that this study was based on NSF varnish concentration, which was prepared by Targino et al. and is not a standardized concentration. However, more studies to standardize the concentration of NSF need to be carried out in future.

Conclusion

The present trial findings depicted that NSF containing remineralizing efficiency of fluoride and antimicrobial activity of nanosilver particles is effective in the reduction of *S. mutans* count in children with incipient caries.

Highlights of Our Study

- This paper acknowledges the use of NSF varnish in reducing *S. mutans* counts in children with caries.
- Nanosilver fluoride is a noninvasive agent that is highly safe for use in younger children.
- Nanosilver fluoride can be considered an alternative treatment modality owing to its promising caries reduction potential, as fluoride in NSF also provides remineralizing potential.

Ethics

Approval for this study was obtained from the local Institutional Review Board (Institute of Dental Studies and Technology, Ghaziabad, Uttar Pradesh, India) Ref. number: IDST/IEC/2020-23/19.

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ORIGINAL RESEARCH

Observation and Assessment of the Parameters of Facial Esthetics in 6-year-old Children with Healthy Dentition

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Abstract

Aim: This study was conducted to observe and assess the dental and facial parameters of esthetics in children with healthy dentition and evaluate whether they are comparable to those of adults.

Materials and methods: An observational study included 70 children with ages ranging from 5 to 6 years who had come to the Department of Pediatric & Preventive Dentistry, Institute of Dental Studies & Technologies, Ghaziabad, Uttar Pradesh, India, with intact primary dentition. Standardized photographs of the children were taken and evaluated. Their facial and dental parameters were recorded and compared to that of those of adults.

Result: The relation of tooth and facial components was established, and it was found that they were not in the same proportion as those of adults.

Conclusion: The proportions of facial and dental parameters of esthetics of children at 6 years of age are different from those of adults.

Clinical significance: Since esthetic rehabilitation of primary teeth is becoming an important requisite of successful dental treatment, it is important to establish a standard guideline of dental and facial parameters for children for prosthetic rehabilitation.

Keywords: Dentofacial esthetics, Esthetics, Primary dentition, Smile.

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Introduction

One of the most important factors that determine the physical appearance of an individual is the face.[1] Numerous studies have been conducted on the significance of physical and facial attractiveness, which may be greatly influenced by a person's smile.[2]

Not only adult patients but even child patients are slowly yet increasingly becoming mindful of the importance of a magnificent smile in terms of facial beauty.[3]

To improve their smile for the greater good and be driven by attractive looks and lovely smiles, patients have sought numerous treatment approaches to enhance dentofacial function and esthetics.[4,5] To be able to obtain the best esthetic results possible, various reference parameters have been introduced and followed previously in a number of studies for adults, but the same has not been done for children.[6–8]

Pediatric dentists should be mindful and aware of children's esthetic perception because, by the age of 6 years, children are capable of comprehending the significance of an esthetic smile, given that they are aware of their appearance.[9] This is so because, at this time, they are exposed to the outside world, and social acceptance among peers becomes an important aspect, and an esthetically pleasing smile plays an important role.

A smile not only helps in expressing a range of emotions but also helps to determine how well a person/child functions in society. A smile that is esthetically pleasing tends to have a significant impact on the patient's quality of existence and sense of self.[10] It also aids in boosting a person's confidence and helps avail a sense of contentment. Thus, in order to harmonize an esthetic smile, a perfect integration of the facial and dental components is required in children as well.

Thus, this study was conducted to determine the dental and facial parameters of esthetics in children and observe whether they are comparable to those of adults.

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Materials and Methods

The study was conducted in the Department of Pediatric & Preventive Dentistry, Institute of Dental Studies & Technologies, Ghaziabad, Uttar Pradesh, India, on children between 5 and 6 years of age. The participants were selected on the basis of the following criteria:

Inclusion Criteria

- Children with caries-free intact primary dentition and proportionally acceptable facial components with all of the teeth intact in both arches.
- The absence of skeletal asymmetries, diseases, and craniofacial deformities.

Exclusion Criteria

Children having restorations, caries, any trauma, caries-related apparent loss of the anterior tooth structure, or fracture.

Any maxillofacial surgery that could affect and disfigure the dentition and face was excluded.

Children with any dental and skeletal malocclusion.

Standardized extraoral and intraoral photographs were taken. Subjects were seated on a chair with the head upright, and two photographs of each subject were taken.

- Smiling (anterior teeth visible).
- Nonsmiling.

The heads were fixed so that the mid-sagittal plane and the horizontal plane of the Frankfort were in line with the center of the camera's lens.

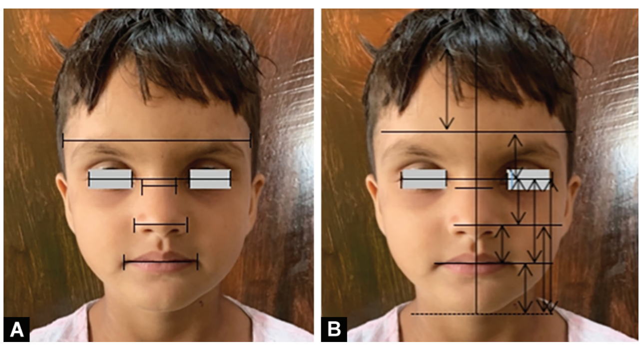
A single-lens reflex digital camera was used with standardized distance, height, and orientation values. The photographs were taken by a single person in one room and were examined and assessed by an independent examiner. Photographs were realigned to determine the facial midline. The division between the philtrum and pupillary line were two anatomical landmarks that were considered and recorded. The dental midline, which is a line that passes through the place where the central incisors of the maxilla make contact with one another and is parallel to the pupillary line, was compared to this face midline.

The pictures were resized and cropped to a typical image size of "5" by "4."

According to Rickett's approach of evaluating the divine proportions in vertical and horizontal facial planes, all images were examined. The reference points used for the face were:

- The extreme lateral commissures of the eyelids are where the lateral canthi of the eyes are placed.
- The supraorbital foramen, which is situated above the eyebrows.
- The dacryons that indicate the intersection of the maxillary, lacrimal, and frontal bones and are situated at the medial commissures of the eyes.
- The lateralmost spots on the face where the soft tissue border of the temporal is located.
- On the edges of the nose's wings are the lateral alae, which are the furthest to the side.
- The chilions, which are situated at the angle of mouth at the most lateral extremes.
- At the inferior most point of the face is the soft tissue menton [soft menton (SM)].

On the basis of the reference points, there were six horizontal measurements taken (Fig. 1A):



Figs 1A and B: (A) Horizontal parameters; (B) Vertical parameters

- Intercanthal (IC): The distance in horizontal terms between the right and left lateral canthus of the respective eyes. The intereye (IE) point was taken as the midpoint of this measurement.
- Interdacryon (ID): The distance horizontally between the left and right dacryons of the eye.
- Interalae (IA): The distances in meters along the horizontal axis between the left and right lateral rims of the nasal ala. The line's center was at the ala point (AP).
- Interchilion (IC): The distance horizontally between the mouth's left and right chilions. The line's midway was the stomion (S).
- Intertemporal (IT): A line drawn across the projected position of the head's supraorbital foramen was used to measure the distance horizontally between the soft tissue lateral borders of the left and right temples.
- Nose width (NW) and eye width (EW).

The origin of the hairline and Ricketts' index point for the vertical measures was taken into account.

Along the facial bisecting vertical line, seven vertical measurements were taken (Fig. 1B).[11]

- Forehead height: Trichion to the intertemporal plane's dividing line.
- Intereye (IE) point to SM.
- Intereye (IE) point to S.
- Intereye (IE) point to AP.
- Ala point (AP) to S.
- Ala point (AP) to SM.
- Stomion (S) to SM.

Using the aforementioned reference points, different parameters were calculated in the horizontal and vertical planes. Comparison was done with standard values of adults. The measurements obtained were subjected to statistical analysis. On the data of the selected children's and adults' smiling and nonsmiling faces, the mean, *N*-value, and standard deviation were determined. Mann–Whitney *U* test was applied for *p*-value.

Result

Tables 1 and 2 depict the mean values of the various parameters in children with smile and without smile, respectively.

When the parameters of the adult and children groups were compared, the findings revealed with a smile, the horizontal measurements had highly significant differences among the mean difference, with their *p*-value ranging from 0.001 to 0.01 (significant *p*-value < 0.05) (Table 3).

In the case of the vertical measurements, there was again a highly significant difference noted among the mean difference with *p*-value = 0.001 (significant *p*-value < 0.05) (Table 3).

On comparison of the dental parameters of children and adults, a highly significant difference was noted, with *p*-value being 0.004 in the case of the length of central incisor and the remaining parameters having *p*-value of 0.001 (significant *p*-value < 0.05) (Table 3).

In the nonsmiling category, the horizontal measurements had highly significant differences among the mean difference with their *p*-value as 0.001 (significant *p*-value < 0.05) (Table 4).

In vertical measurements, not all the parameters could be measured for comparison; those which could be compared were IE–SM, IE–AP, and AP–SM. Highly significant difference noted was 0.001 with *p*-value < 0.05 (Table 4).

The dental parameters could not be measured in this category.

Table 1: Mean values of various parameters of face in children with smile

	Child	
Parameter	*Mean*	*Standard deviation (SD)*
IC	3.31	0.21
ID	1.12	0.09
IA	1.36	0.19
IC	1.76	0.10
IT	4.60	0.43
N/W	0.96	1.30
E/W	0.93	0.06
IE–SM	3.34	0.26
IE–S	2.12	0.21
IE–AP	1.39	0.22
AP–S	0.60	0.04
AP–SM	1.83	0.16
S–SM	1.15	0.11
IL	0.22	0.03
WOCI	0.44	0.49
WOLI	0.18	0.03
Canine	0.16	0.04
IP–CI	0.19	0.12
CI–LI	0.13	0.03
LI–C	0.14	0.12

WOCI, width of central incisor; WOLI, width of lateral incisor; LI, lateral incisor; IL, interlip; IP, incisive papilla; CI, central incisor; C, Canine

Table 2: Mean values of various parameters of face in children without smile

	Child	
Parameter	*Mean*	*SD*
IC	3.13	0.38
ID	1.13	0.11
IA	1.43	0.19
IC	2.63	3.34
IT	4.49	0.44
N/W	0.90	0.96
E/W	0.89	0.07
IE–SM	3.30	0.24
IE–AP	1.43	0.18
AP–SM	1.98	0.19

WOCI, width of central incisor; WOLI, width of lateral incisor; LI, lateral incisor; IL, interlip; IP, incisive papilla; CI, central incisor; C, Canine

Table 3: Mean difference among the two groups with smile

Parameter	*Mean difference*	*p-value*
IC	3.60	0.01
ID	0.73	0.01
IA	0.85	0.01
IC	1.98	0.01
IT	4.76	0.01
N/W	0.87	0.001
E/W	1.07	0.001
IE–SM	4.89	0.001
IE–S	4.25	0.001
IE–AP	1.50	0.001
AP–S	1.85	0.001
AP–SM	3.54	0.001
S–SM	2.20	0.001
IL	0.35	0.001
WOCI	0.51	0.004
WOLI	0.29	0.001
Canine	0.22	0.001
IP–CI	0.20	0.001
CI–LI	0.25	0.001
LI–C	0.15	0.001

WOCI, width of central incisor; WOLI, width of lateral incisor; LI, lateral incisor; IL, interlip; IP, incisive papilla; CI, central incisor; C, Canine

Table 4: Mean difference among two groups in nonsmiling category

Parameter	*Mean difference*	*p-value*
IC	3.51	0.001
ID	0.74	0.001
IA	0.93	0.001
IC	1.28	0.002
IT	4.47	0.001
N/W	0.87	0.001
E/W	1.39	0.001
IE–SM	5.25	0.001
IE–AP	1.54	0.001
AP–SM	3.68	0.001

WOCI, width of central incisor; WOLI, width of lateral incisor; LI, lateral incisor; IL, interlip; IP, incisive papilla; CI, central incisor; C, Canine

Discussion

In this era of social media, where every moment of a child is captured on screen by doting parents, esthetics has gained immense significance in pediatric dentistry. Previously, while anterior tooth loss in a toddler or preschooler was acceptable, in today's society, even discolored primary anterior tooth or unesthetic composite restoration is discarded as bad practice. Esthetic concerns are now prioritized heavily by society, and this applies to both adults and children. It is also becoming more and more important when considering dental treatment.[12] In earlier times, pedodontists concentrated on repairing the primary and permanent dentition's structural integrity and functionality.

As a relatively new field, smile designing is constantly developing its approaches and philosophies.[13] Clinicians must be able to assess what forms the essential elements of the ideal smile. This concept extends beyond only the teeth to one of total dentofacial harmony. Understanding the delicate blending of the key elements of a smile—facial esthetics, gingival esthetics, and macro- and microesthetics of the teeth—is necessary for this.[14]

Many people believe that the golden ratio, commonly referred to as the divine proportion, is the key to comprehending esthetics, attractiveness, and human beauty. It is a number on the order of 1.618033988 and is represented by the symbol phi. To determine and assess the ratios between the many components of the attractive face, Ricketts created a "golden proportion calliper."

He asserted in 1982 that he had discovered numerous excellent lateral and frontal cephalograms after carefully examining them. After looking at pictures of models, he also discovered several divine ratios within the face. Therefore, Ricketts recommended using these divine proportion ratios as a reference while organizing orthognathic surgery. The golden ratio was first suggested for use in dentistry by Lombardi, who added, "It has proved too strong for dental use."

The dentist must carefully examine the situation and design the appropriate course of action to get a satisfying functional and esthetically pleasing result.[15] A successful esthetic outcome can be obtained if clinicians comprehend their patients and provide them with a smile that suits both their aspirations and personalities.

The proportions that were described are simply suggestions because optimal proportions, particularly for growing children, alter over time and depend on the patient's expectations. In orthognathic procedures, the horizontal facial proportions can be used to change the form of the jaws to improve dental occlusion stability, improve temporomandibular joint function (corrective jaw surgery), and correct bilateral asymmetries to improve the patient's face proportions.[11] The optimal facial appearance is the result of a detailed process that takes into account how each feature interacts with the other features of the face.

Therefore, one must take into account the (*n*) number of different measurements that can be taken in children in an area as anatomically complex as the human skull, and more research regarding this mathematical relationship is required before determining its clinical implications as a crucial parameter for achieving esthetic harmony. Other age ranges and racial characteristics can be the subject of future investigation.

Conclusion

Consequently, one conclusion that can be drawn from the current study is that certain adult facial parameters that have been used previously in studies for the purpose of smile designing cannot be used in those of children.

To solve the purpose of smile designing in children, there is a need for further studies to be effortlessly done so that we can achieve a certain set of standardized parameters that can be utilized for designing smiles.

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ORIGINAL RESEARCH

Evaluation of the Effect of Parental Smoking on Gingival Melanin Pigmentation in Children

Ashish Anand[1], Tinesh Raja[2], Vabool Thakur[3], Nidhi Agarwal[4]

Abstract

Background: The presence of melanin pigmentation of the gingiva has unfavorable effects on esthetics in children. Although there are several local and systemic factors that cause melanin pigmentation, they may also be induced by the stimulation of melanocytes by stimuli present in tobacco smoke.

Aim: The aim of the study was to correlate the effect of parental smoking on the pigmentation of gingiva in children of Modinagar, Uttar Pradesh, India.

Materials and methods: The study was a cross-sectional observational study. The study sample was formed by all children between 8 and 14 years of age. Only medically compromised children were excluded from the study. The children were examined for the presence of gingival melanin pigmentation. The status was recorded as present or absent. Determination of the smoking status of family members was done by a self-formulated questionnaire.

Results: The presence of pigmentation was seen in 114 (82%) children, whereas pigmentation was absent in 26 (18%) children. Out of the total sample of 140 children, 95 had one or more family members who were smoking. The Chi-squared test performed to form an association between pigmentation and the type of tobacco used revealed high significance ($p = 0.00$) for the father who smokes bidi.

Conclusion: There is a correlation between parental smoking and melanin pigmentation in the gingiva of children, and the correlation is very high when the father is a smoker, especially when he smokes bidi.

Keywords: Gingival pigmentation, Melanin pigmentation, Parental smoking.

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Introduction

Smoker's melanosis is a recognized phenomenon in smokers in which there is an increase in gingival melanin pigmentation.[1] Nicotine, cotinine, and other volatile chemicals, including acetaldehyde and acrolein, build as a result of long-term smoking exposure.[2] The inhalation of tobacco smoke in the air, known as passive smoking, secondhand smoke, or environmental tobacco smoke (ETS), consists of 15–20% mainstream smoke (smoke exhaled by the smoker) and 80–85% sidestream smoke (smoke from the burning tip of a cigarette).[3]

Research shows that the maximum frequency of oral pigmentation is seen in Indians (89%). The incidence of smoking in the Indian population has been found to be 47% in men and 14% in women.[4] Due to the lack of stringent "smoke-free" rules in India, children who have a smoker in the household are more likely to develop gingival pigmentation.[5]

The presence of melanin pigmentation in gingiva has unfavorable effects on esthetics. Individuals complain about an unhealthy, dirty, and dark appearance of the gingiva, the mismatch of gingival color with that of skin or teeth, and lowered self-esteem.

The literature contains very few studies assessing smoking's impact on gingival pigmentation. Therefore, the purpose of this study is to determine how parental smoking affects the gingival pigmentation of children in Modinagar, Uttar Pradesh, India (Table 1).

Materials and Methods

The study was a cross-sectional observational study. The ethical clearance was obtained from the ethical committee of the Institute of Dental Studies & Technologies, Ghaziabad, Uttar Pradesh, India. Informed consent was obtained from the parents before the commencement of the study. At 80% ($1 - \beta$) power of the investigation, 140 was the minimum suggested sample size to detect the statistical significance of 5% ($\alpha = 0.05$) and effect size (f) 0.39 using G*Power 3.1.

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Table 1: Association between pigmentation and individual smoking (father, mother, or associated family member)

		Father	*Mother*	*Associated family member*
PP	Smoking	58	19	39
	Nonsmoking	56	95	75
PA	Smoking	18	0	24
	Nonsmoking	8	25	19

PP, pigmentation present; PA, pigmentation absent

The study sample was formed by all children between 8 and 14 years of age reporting to the outpatient department of the dental college and associated hospital. The study excluded children who were medically compromised. The children underwent examinations to check for gingival melanin pigmentation. The status was noted either as present or absent.

Evaluation of Gingival Pigmentation

If single pigmentation units or the creation of a continuous ribbon extending from two adjacent units were seen, the pigmentation was considered to be present. The pigmentation was marked absent in cases where there was no pigmentation.

Evaluation of Smoking Status

Family members' smoking status was ascertained using a self-created questionnaire. The questionnaire's reliability, as determined by Cronbach's α, was 0.82, and its face validity was 0.73. When at least one family member smoked once a day at home in the child's presence during the previous 6 months, the child was considered to be a part of the smoker family. Face-to-face interviews of the father, mother, and grandparents, if living together, were carried out by a single examiner.

Results

Out of the 140 children, 56 (40.3%) were girls, and 84 (59.7%) were boys, with a mean age of 11.13 years.

The presence of pigmentation was seen in 114 (82%) children, whereas pigmentation was absent in 26 (18%) children.

Out of the total sample of 140 children, 95 had one or more family members who were smoking.

Among the pigmentation present (PP) group, 58 fathers, 19 mothers, and 39 associated family members were found to be smokers.

Among the pigmentation absent (PA) group, 18 fathers and 24 associated family members were found to be smokers. None of the mothers were found to be smokers in the group.

An association between pigmentation and combined smoking was made, and the result showed high significance ($p = 0.05$) when at least one member of the family had a smoking habit. The odds ratio was found to be 3.167 (Fig. 1).

The Chi-squared test performed to form an association between pigmentation and the type of tobacco used revealed high significance ($p = 0.00$) for the father who smokes bidi (Fig. 2).

Discussion

Pigmentation of the gingiva may be due to a physiological or pathological cause. The level of melanin pigmentation can change depending on a person's age, gender, skin tone, race, lifestyle, and a few other environmental variables.[6]

Children whose parents smoked had higher levels of pigmentation than children whose parents did not smoke.

There are primarily two ways that stimulatory compounds from passive smoking get to the melanocytes[7]:

- By inhaling the smoke, nicotine and its byproducts cause an increase in the activity of melanocytes.
- Dissolving in the saliva affects the oral epithelium.

In the present study, 40.3% of girls and 59.7% of boys had pigmentation, which shows a slight predilection of gingival melanin pigmentation in boys.

Hanioka et al. conducted a case–control study in the Japanese population and found that children with gingival pigmentation had

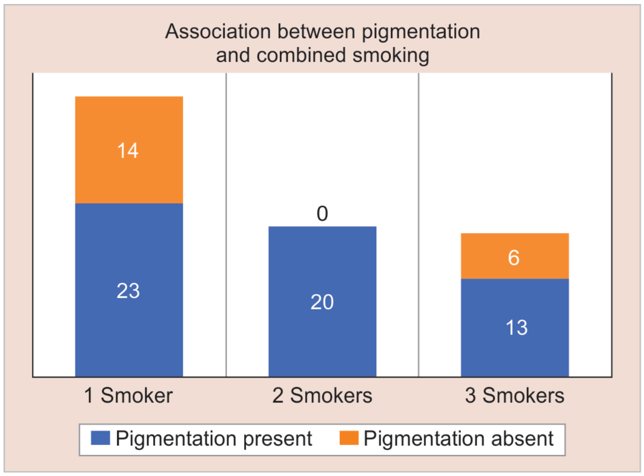

Fig. 1: Association between pigmentation and combined smoking

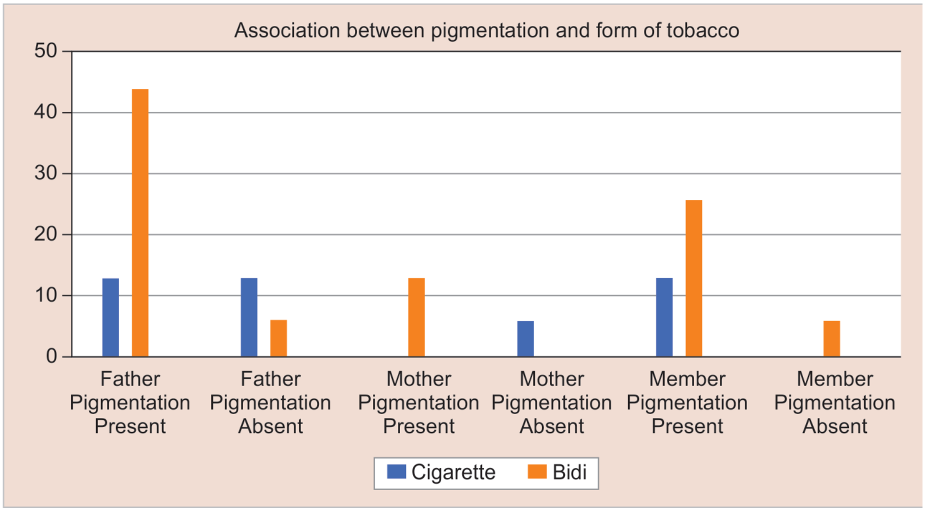

Fig. 2: Association between pigmentation and form of tobacco use

a higher percentage of parental smoking (70–71%) than children without pigmentation (35%).[8]

In Turkey, Boyaci et al. assessed the levels of nicotine metabolite in children's blood and urine and discovered a strong link between gingival pigmentation and passive smoking.[9]

The precise amount of time that smoking parents and their children spent together was not accessible for this study's data. Nonetheless, the majority of parents smoked 6 to 10 cigarettes a day, making them moderate to heavy smokers; as a result, it's possible that their children were exposed to passive smoke.

In the present study, along with the impact of the smoking habit of the father, the habits of the mother and other family members (i.e., grandparents and other relatives in the case of a joint family) were also included, although a significant association was not found.

Additionally, the present study also assessed whether the type of tobacco consumption, such as cigarettes, bidis, and other products, also had any association with pigmentation. It was observed that parental bidi smoking had a greater association with gingival pigmentation than other forms of tobacco products. Bidi contains more particulate matter as they do not have filters, along with a higher amount of nicotine, compared to cigarettes.

Parents' smoking had a discernible effect on their children's gingival pigmentation, although it was unclear how much more melanin was formed as a result. A stronger correlation between melanin pigmentation in human gingiva and passive smoking could be established by conducting additional investigations utilizing quantitative analysis regarding the effects of ETS and gingival pigmentation. Even while it is suggestive of parental smoking, the higher pigmentation in participants exposed to ETS from smoker parents is not conclusive.

Conclusion

Our cross-sectional study's findings lead us to the conclusion that there is a link between parental smoking and melanin pigmentation in children's gingiva, and that association is strongest when the father smokes, particularly when he smokes bidi.

Clinical Significance

The study emphasizes the harm passive smoking causes to youngsters, and further research may be done to understand the various harmful impacts of smoking. This study will be useful in creating awareness and counseling to adults regarding the ill effects of smoking with regard to the impact on children.

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ORIGINAL RESEARCH

A Comparative Evaluation of Nanosilver Fluoride, Chlorhexidine, and Sodium Fluoride When Used as a Varnish on *Streptococcus mutans* Levels in Children with Caries

Tinesh Raja[1], Nidhi Agarwal[2], Zohra Jabin[3], Ashish Anand[4], Nandita Waikhom[5], Vabool Thakur[6]

Abstract

Aim: The purpose of the present study is to evaluate the effect of nanosilver fluoride (NSF), chlorhexidine (CHX), and sodium fluoride (NaF) when used as a varnish on *Streptococcus mutans* levels in children with dental caries.

Study design: A total of 120 children (age range 8–12 years) with incipient caries were randomly assigned to four groups ($n = 30$): group I—NSF varnish, group II—CHX varnish, group III—NaF varnish, and group IV—control. Varnish application at baseline was performed once. To assess the levels of *S. mutans* using the culture method [colony-forming units (CFUs)] and optical density (OD), plaque and samples were taken at baseline (T0), 1 month (T1), and 3 months (T3). Additionally, the oral hygiene index-simplified (OHI-S) was noted for clinical assessment.

Results: By the end of 3 months, a statistically significant reduction in plaque CFU and salivary CFU was found in group II. At the conclusion of the 3 months, group I had the greatest decrease in OHI-S. After 3 months, the plaque CFU score did not differ significantly across groups I, II, and III. However, a statistically significant difference in OD values (p-value of 0.00) was discovered between group I and all other groups.

Conclusion: Children with early caries can effectively lower their *S. mutans* count by using NSF varnish.

Keywords: Chlorhexidine, Incipient caries, Nanosilver fluoride, Sodium fluoride, *Streptococcus mutans*, Varnish.

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Introduction

Dental caries remains the most common dental illness globally and is regarded a serious global health concern. According to the World Health Organization's 2003 oral health report, periodontal diseases and dental caries are pandemic ailments that affect the entire community, irrespective of age, gender, or socioeconomic status.[1] As preventive measures and community oral health care services are more challenging to access in developing nations like India, the issue is more concerning there. According to the 2002–2003 National Oral Health Survey, the decayed, missing, filled teeth (DMFT) index score for Indian children was approximately 2, and the prevalence of caries increased with age, rising from 51.9 to 63.1% in the 5–15-year-old age-group, respectively.[2]

Minimally invasive techniques to halt the progression of dental caries are replacing more traditional methods of treating the condition, which involves surgically removing the damaged dental tissue and then placing an appropriate restorative material. Remineralization aims to prevent dental cavities by comprehensively protecting the patient in the long run by intervening as soon as possible.

Sodium fluoride (NaF) varnish is one of the oldest and most widely used varnishes. It is professionally applied to the tooth surface, with four applications annually at weekly intervals to provide antimicrobial and anticary activity.[3] A cationic bisbiguanide with a broad antimicrobial range is chlorhexidine (CHX). In dentistry, it is widely used in a variety of forms, including dentifrices (0.4%), gels (1%), solutions (0.12 and 0.2%), and varnishes (1, 10, 20, and 35%). Compared to other applied agent forms, it has been proposed that the varnish form of CHX administration leads to a sustained reduction of *S. mutans*.[4]

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However, with advancements in technology, an innovative approach has been made to combat the high incidence of dental caries—the use of nanotechnology in dentistry. Silver nanoparticles, one of many types of nanomaterials, have demonstrated significant promise for use in biological applications. Many of the antibacterial effects of nanomaterials stem from the release of silver ions, which can pass through the cell wall of bacteria and cause both direct and indirect lipid peroxidation, damaging the cell membrane, halting deoxyribonucleic acid (DNA) replication, and affecting both respiratory protein restoration and inhibition.[5]

Thus, the objective of the current study was to discover how to varnish applications of NaF, CHX, and nanosilver fluoride (NSF) altered the levels of *S. mutans* in children with dental caries.

Materials and Methods

The study followed the Consolidated Standards of Reporting Trials (CONSORT) 2010 standards and was a randomized, triple-blinded clinical controlled trial (Fig. 1).

For every group (NSF, CHX, NaF, and control), a minimum sample size of 27 was advised, taking into account a power of 80% (1-β), with a 95% confidence interval and an effect size (*f*) of 0.39 using G*Power 3.1. An overall suggested sample size of 109 was estimated, which was rounded to 120 to ensure that each group had at least 30 samples.

A total number of 260 patients (age range of 8–12 years) were screened. Parental consent was obtained prior to their inclusion in the study. Cooperative children with fully erupted permanent central incisors and permanent first molars having incipient caries with International Caries Detection and Assessment System II (ICDAS II) scores 1 and 2 were included. Children having any intraoral hard or soft tissue infection or pulpally involved caries were excluded. Medically compromised children, or children on fluoride or antimicrobial therapy, and wearing orthodontic appliances were also excluded from the study. A total of 120 children were enrolled for the study on the grounds of pre-established eligibility criteria.

Examination Incipient Lesion

Visual examination was carried out to detect incipient lesions. The ICDAS II was used to standardize the diagnosis (Fig. 2).[6] Two investigators conducted the examination of the incipient lesion, and if there was any disagreement, the third investigator assessed the discrepancy and made the final decision.

To avoid selection bias, allocation concealment using the sequentially numbered, opaque, sealed envelopes approach was implemented. The random concealment was conducted by an investigator who was not engaged in the application of varnish or the measurement of the outcome to prevent intervention bias. An envelope with a dark color and a corresponding serial number on top was sealed with a sheet of paper bearing a randomized group number. After the intervention was allocated, the envelope was opened. The varnish was applied according to the group designated in the document.

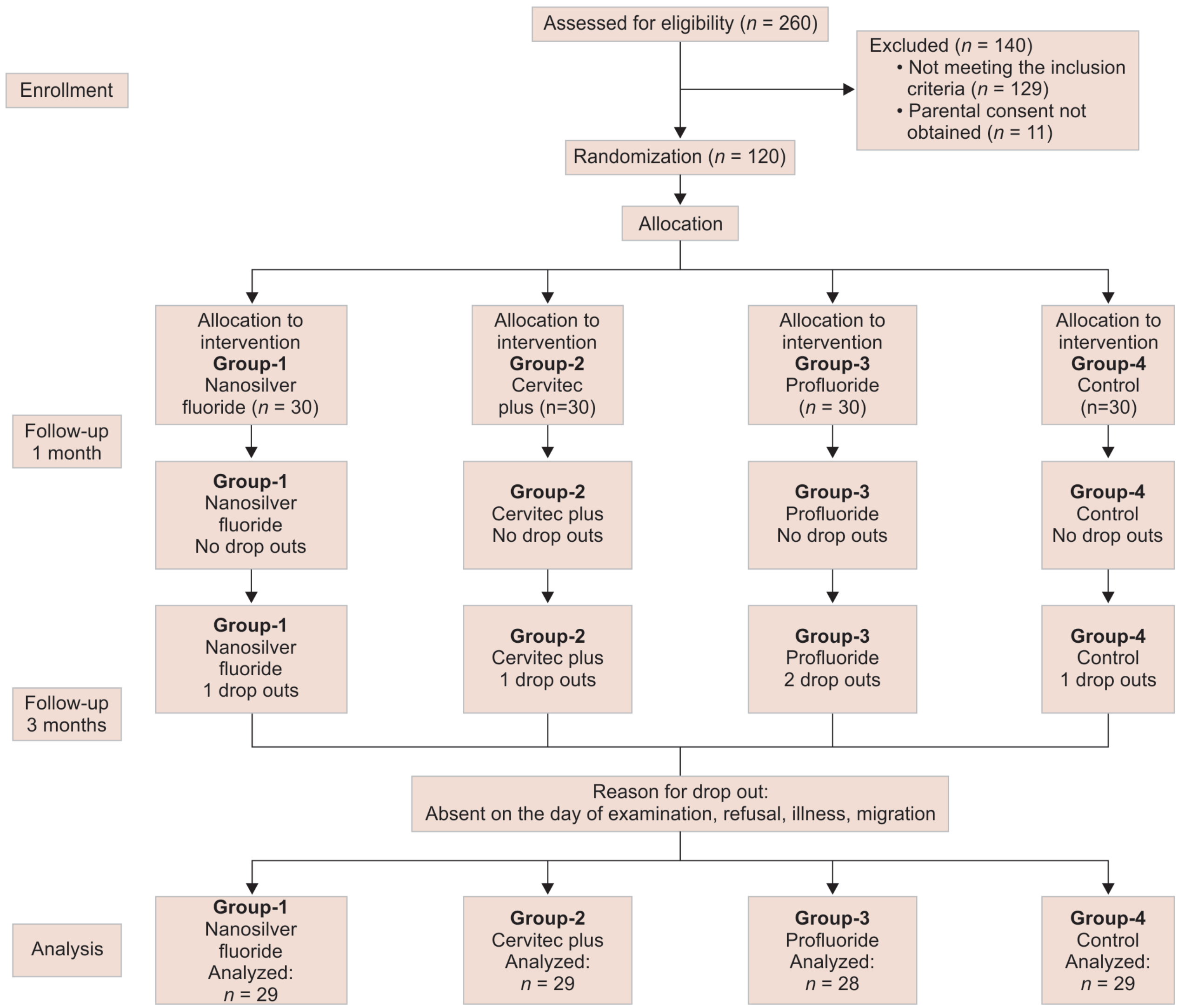

Fig. 1: Consolidated Standards of Reporting Trials flow diagram

The chosen research study participants were allocated randomly to one of four groups (30 children per group) (Table 1).

Preparation of Nanosilver Fluoride

The formulation provided by Targino et al. was followed in the preparation of NSF.[7] Silver nitrate was chemically reduced with sodium borohydride ($NaBH_4$) and chitosan biopolymer as a stabilizing agent to produce silver nanoparticles in an aqueous solution. We dissolved 2.5 mg/mL of chitosan in a 1% acetic acid solution. Magnetic stirring was used to combine the mixture until it was homogeneous. The mixture was then submerged in an ice bath, and it was vigorously stirred while more $NaBH_4$ (0.3 mL, 0.8 M) was added drop by drop. After removal from the cold bath, 10,147 parts per million of NaF were added to the flask. Stirring continued overnight. The resulting solution contained silver nanoparticles (399.33 µg/mL), NaF (10,147 µg/mL), and chitosan (2334 µg/mL). Transmission electron microscopy (TEM) was utilized to assess the shape and size of silver nanoparticles. A TEM image was captured on an FEI-Tecnai G2 F20 with an accelerating voltage of 200 kV. It was determined that 99% of the silver nanoparticles were spherical, with a size of 8 ± 2.0 nm (Fig. 3).

The child's personal information, dental history, and medical history, including any recent exposure to antibiotics, were documented prior to the study's start. During the trial period, food counseling and instructions on oral hygiene were provided. Evaluation was done for the following:

- Clinical parameter—oral hygiene index-simplified (OHI-S) index: The buccal surface of the index teeth—16, 11, 26, 36, 41, and 46—as well as the incisal two-thirds and cervical region were all traversed by an explorer. Based on the OHI-S, each of the six teeth received a score ranging from 0 to 3.[8]
- Method of dental plaque sample collection: Using a sterile wooden toothpick, the lingual and buccal surfaces of the index teeth—16, 11, 26, 31, and 46—from the occlusal to the gingival third were scraped to obtain plaque samples from each patient between 9 and 10 AM. After being collected, the samples were placed in a microcentrifuge tube (5 mL) with 3 mL of saline solution and sent directly to the lab.
- Method of saliva sample collection: Around 2–3 mm of unstimulated whole saliva was extracted from the child by instructing them to drool into a sterile container. The containers

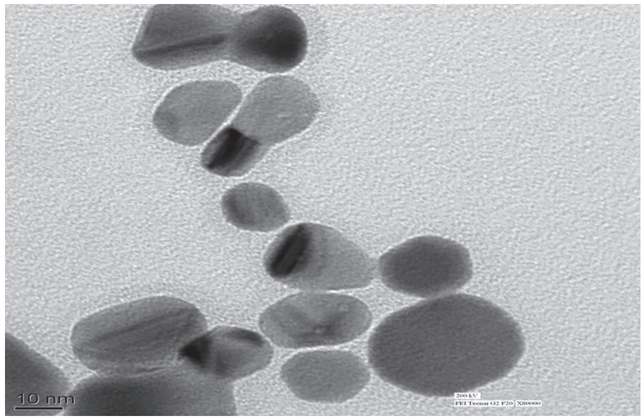

Fig. 3: Transmission electron microscopy image of nanosilver particles used in the study

CODE	DESCRIPTION
0	Sound tooth surface: No evidence of caries after 5 sec air-drying
1	First visual change in enamel: Opacity or discoloration (white or brown) is visible at the entrance to the pit or fissure seen after prolonged air drying
2	Distinct visual change in enamel visible when wet, lesion must be visible when dry
3	Localized enamel breakdown (without clinical visual signs of dentinal involvement) seen when wet and after prolonged drying
4	Underlying dark shadow from dentine
5	Distinct cavity with visible dentine
6	Extensive (more than half the surface) distinct cavity with visible dentine

Fig. 2: International Caries Detection and Assessment System II score and criteria

Table 1: Table showing group allocation and composition of materials used

Groups	*Number of participants*	*Materials*	*Composition*
Group I	30	NSF varnish	NSF group. A special formula as prepared by Targino et al.[7] containing nanosilver particles, NaF and chitosan as a stabilizer
Group II	30	CHX varnish	The CHX varnish (Cervitec Plus by Ivoclar Vivadent) group includes 1% CHX diacetate and 1% thymol as active antimicrobial ingredients
Group III	30	NaF varnish	The NaF (Profluoride Varnish, VOCO GmbH. Cuxhaven, Germany) varnish group contains 5% NaF (22,600 ppm F) with xylitol
Group IV	30	Control	Control group. Saline was used as a placebo control

were labeled and immediately submitted for analysis of *S. mutans*, then stored in a cold bath below 4°C.

Method of Varnish Application

Oral prophylaxis was performed to standardize the oral cavity with the least amount of biofilm before varnish was applied. The teeth were isolated using cotton rollers and a saliva ejector, and for 30 seconds, a three-way air syringe was used to gently inject air into the teeth. Using an applicator tip, approximately 0.1 mL of the chosen varnish was applied quadrant-wise sequentially to every tooth, beginning with the upper arch.

Participants were instructed not to rinse, eat, or drink anything for 3 hours and not to brush until the next day after application. Additionally, toothpaste devoid of fluoride was provided for use during the study.

Laboratory Phase

Two methods were used to evaluate *S. mutans* in plaque and saliva samples:

- Culture test: Mitis salivarius bacitracin agar was prepared to facilitate the multiplication and selection of *S. mutans* on the agar plates. Before distributing the saliva and plaque samples onto the agar plates for colony counting, they were diluted 1:1 and 1:2, respectively. The Petri plate was divided into eight sections, and the number of colonies found in each area was tallied. This number was then multiplied by eight to determine the total number of colonies on the plate. To acquire the total number of colonies in 1 mm of saliva or plaque, multiply the number of colonies obtained by the dilution factor.
- Optical density (OD): At 600 nm, OD was measured using a spectrophotometer (Spectronic 20). The OD method, based on the scattering of light, is used to track the kinetics of growth.

After applying varnish, the clinical and laboratory parameters were evaluated at baseline (T = 0), 1 month (T = 1), and 3 months (T = 3). A total of 5 of the 115 children in the final study sample had dropped out after 3 months (Fig. 1).

Results

A *post hoc* Bonferroni test and a one-way analysis of variance (ANOVA) were used to compare the *S. mutans* count at different intervals according to the application of different varnishes. During the follow-up phase, five participants withdrew from the original sample of 120 subjects, leaving 115 children, ages 8–12, remaining in the study. Of these, 53 boys (46.08%) and 62 girls (53.91%) made up the final study sample after 3 months.

Oral hygiene index-simplified: Each group's mean baseline OHI-S fell into one of four categories—0.4 ± 0.1, 0.5 ± 0.1, 0.5 ± 0.1, and 0.5 ± 0.2. All groups exhibited an increase in their OHI-S score, but group I saw the largest increase after 3 months, measuring 0.30 ± 0.15, which was determined to be statistically significant (Table 2).

Plaque: The four groups had baseline plaque colony-forming units (CFUs) of $4.48 \pm 1.34 \times 10^5$, $4.69 \pm 1.65 \times 10^5$, $4.41 \pm 1.50 \times 10^5$, and $4.57 \pm 1.34 \times 10^5$ CFU/mL, respectively. Group II showed the greatest decrease in plaque CFU score one month following the application of varnish, followed by groups III, I, and IV. Group II saw the greatest reduction after 3 months. Upon analysis, the decrease was found to be statistically significant in all groups with the exception of the control group.

The baseline plaque OD for all the groups was 1.38 ± 0.26, 1.39 ± 0.21, 1.44 ± 0.20, and 1.36 ± 0.17 OD/mL. Group I had the greatest decrease in plaque OD score one month following varnish application, followed by groups II, III, and IV. Group I showed the greatest decline after 3 months. With the exception of the control group, the decrease was statistically significant in every group (Table 2).

After 3 months, the intergroup comparison revealed that there was no statistically significant difference (p-value < 0.01) in the plaque CFU scores between groups I, II, and III. On the other hand, a statistically significant difference (p-value = 0.00) in OD was observed between group I and the remaining groups.

Saliva: The baseline salivary CFUs for all the groups were $4.43 \pm 1.35 \times 10^5$, $4.55 \pm 1.65 \times 10^5$, $4.31 \pm 1.57 \times 10^5$, and $4.05 \pm 1.61 \times 10^5$ CFU/mL. After 3 months, there was a statistically

Table 2: Table showing mean OHI-S, plaque CFU, and OD values recorded for groups I, II, III and IV at baseline (T0), 1 month (T1) and 3 months (T3)

		T0		*T1*		*T3*			
	Parameters	*Mean*	*Standard deviation (SD)*	*Mean*	*SD*	*Mean*	*SD*	*Mean change from T0 to T3*	*p-value*
Group I	OHI-S†	0.4	0.1	0.28	0.13	0.30	0.15	0.12	0.003*
	CFUP‡ ($\times 10^5$ CFU/mL)	4.48	1.34	0.00556	0.00632	0.03115	0.01797	4.45	0.017*
	ODP§ OD/mL	1.38	0.26	0.463	0.181	0.400	0.125	0.98	0.000*
Group II	OHI-S†	0.5	0.1	0.38	0.12	0.43	0.13	0.07	0.113
	CFUP‡ ($\times 10^5$ CFU/mL)	4.69	1.65	0.00315	0.00213	0.02634	0.01151	4.66	0.017*
	ODP§ OD/mL	1.39	0.21	0.888	0.153	0.785	0.169	0.61	0.001*
Group III	OHI-S†	0.5	0.2	0.41	0.14	0.39	0.14	0.08	0.128
	CFUP‡ ($\times 10^5$ CFU/mL)	4.41	1.50	0.00439	0.00504	0.03405	0.01962	4.37	0.001*
	ODP§ OD/mL	1.44	0.20	0.932	0.177	0.913	0.223	0.52	0.000*
Group IV	OHI-S†	0.5	0.2	0.51	0.15	0.49	0.14	0.02800	0.541
	CFUP‡ ($\times 10^5$ CFU/mL)	4.57	1.34	4.26033	1.20203	4.33133	1.23614	0.23533333	0.090
	ODP§ OD/mL	1.36	0.17	1.096	0.105	1.102	0.087	0.259333	0.092

One-way ANOVA applied; *, p-value significant at $p < 0.05$; OHI-S†, oral hygiene index-simplified; CFUP‡, colony forming unit in plaque; ODP§, plaque optical density

significant difference in the *S. mutans* levels for each of the three experimental groups, as determined by the OD and the culture technique. After 1 month, both groups I and II showed the greatest reduction. Group II had the greatest reduction after 3 months (Table 3). After 3 months, the intergroup comparison revealed no discernible differences between groups I, II, and III (Table 4).

An analysis using OD revealed a highly significant difference (*p*-value 0.00) between groups I and II, II and III, and III and IV.

Discussion

The results of the current study demonstrate that after 3 months, a single application of NaF, CHX, and NSF varnish remarkably reduced the amount of *S. mutans* in saliva and plaque in children with dental caries. The etiological factor, which includes host factors, diet, and dental plaque (*S. mutans*), is the most significant risk factor for any disease. In 1980, Hamada and Slade implicated *S. mutans*) as a primary causative organism of dental caries.[9] Hence, to control the cariogenic activity, it is important to suppress the growth of *S. mutans* counts in the oral cavity. The initial stage of tooth decay or demineralization is represented by the incipient carious lesions, which have the potential to progress to cavitation, be arrested, or reversed.

This study adopted a nonintensive varnish application regime, applying the coating once at baseline, which is in line with research conducted by Ben Khadra et al. and Al-Jaradi et al.[4,10] Despite using a more rigorous application regimen in their trial, Twetman et al.

Table 3: Table showing mean saliva CFU and OD values recorded for groups I, II, III and IV at baseline (T0), 1 month (T1) and 3 months (T3)

		T0		*T1*		*T3*			
	Parameters	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean change from T0 to T3*	*p-value*
Group I	CFUS† (×10^5 CFU/mL)	4.43	1.35	0.00463	0.00368	0.0500	0.0559	4.38	0.044*
	ODS‡ OD/mL	1.40	0.24	0.476	0.164	0.415	0.127	0.98	0.001*
Group II	CFUS† (×10^5 CFU/mL)	4.55	1.65	0.00323	0.00199	0.0264	0.0127	4.53	0.014*
	ODS‡ OD/mL	1.39	0.20	0.887	0.168	0.781	0.172	0.61	0.001*
Group III	CFUS† (×10^5 CFU/mL)	4.31	1.57	0.00938	0.01950	0.0804	0.1133	4.23	0.007*
	ODS‡ OD/mL	1.44	0.19	0.941	0.187	0.916	0.217	0.52	0.000*
Group IV	CFUS† (×10^5 CFU/mL)	4.05	1.61	4.18333	1.59155	4.1460	1.5723	−0.0970	0.070
	ODS‡ OD/mL	1.36	0.20	1.154	0.094	1.141	0.091	0.223333	0.068

One-way ANOVA applied; *, *p*-value significant at $p < 0.05$; CFUS†, colony forming unit in saliva; ODS‡, saliva optical density

Table 4: Intergroup comparison of CFU and OD among the four groups at 3 months

	Group (I)	*Group (J)*	*Mean difference (I–J)*	*p-value*
CFUP† (×10^5 CFU/mL)	I	II	0.00481067	1.00
		III	−0.00290333	1.00
		IV	−4.30018333*	0.000*
	II	III	0.00771400	1.00
		IV	−4.29728000*	0.000*
	III	IV	−4.30499400*	0.000*
ODP‡ OD/mL	I	II	−0.384400*	0.000*
		III	−0.512200*	0.000*
		IV	−0.701333*	0.000*
	II	III	−0.127800*	0.014*
		IV	−0.316933*	0.000*
	III	IV	−0.189133*	0.000*
CFUS§ (×10^5 CFU/mL)	I	II	0.0236033	1.00
		III	−0.0304533	1.00
		IV	−4.0960400*	0.000*
	II	III	0.0540567	1.00
		IV	−4.0655867*	0.000*
	III	IV	−4.1196433*	0.000*
ODS¶ OD/mL	I	II	−0.366000*	0.000*
		III	−0.500833*	0.000*
		IV	−0.725667*	0.000*
	II	III	−0.134833*	0.008*
		IV	−0.359667*	0.000*
	III	IV	−0.224833*	0.000*

Post hoc Bonferroni applied; *, *p*-value significant at $p < 0.05$; CFUP†, colony forming unit in plaque; ODP‡, plaque optical density; CFUS§, colony forming unit in saliva; ODS¶, saliva optical density

found that this did not increase the varnish's efficacy. Even after 1 month, the single treatment regimen used in this investigation significantly reduced the amount of *S. mutans*.[11]

Various literature on evaluating the presence of *S. mutans* have recommended saliva as a suitable method for predicting caries activity and identifying patients with high-risk of dental caries.[12] Gibbons and Houte, in 1975, stated that plaque is more appropriate and superior than saliva for estimating MS in individuals because tooth surfaces are the natural habitat of MS and Plaque.[13] Therefore, in the current study, we analyzed *S. mutans* levels in both saliva and plaque samples.

A novel varnish called NSF combines nanosilver particles with fluoride and chitosan to act as a stabilizing agent. Free radicals produced by the silver nanoparticles harm the bacterial cell membrane, cause it to become porous, and ultimately cause cell death. Moreover, during protein synthesis, silver ions can bind with sulfuryl groups and obstruct DNA replication.[14,15]

Nanosilver fluoride is endowed with remineralizing characteristics by the fluoride it contains, which lowers adhesion and biofilm formation.[16,17] As a result, NSF functions as a remineralizing agent in addition to having an antibacterial impact.

Besinis et al. in 2014 compared the antibacterial effect of silver nanoparticles with CHX and found that the antibacterial activity measured in terms of CFUs of silver nanoparticles was 25-fold higher than CHX.[18]

In 2017, Soekanto et al. assessed the effectiveness of NSF in preventing the production of *S. mutans* biofilms *in vitro*. They discovered that NSF was a more effective inhibitor of *S. mutans* biofilm formation than the industry standard silver diamine fluoride (SDF) (38%).[19]

El-Desouky et al. 2020 evaluated the anticarcinogenic effects of NSF and NaF in an *in vitro* study where the difference between *S. mutans* values in both the groups within a period of 7 days was found to be nonsignificant. Their result is in contrast to the present study since NSF has shown a significantly greater reduction in *S. mutans* count than NaF at the end of 1 and 3 months.[20]

A study by Waikhom et al. in 2022 found that when children without dental cavities applied NSF varnish, the number of *S. mutans* in both plaque and saliva decreased statistically significantly.[21]

In the present study, the CFU count of *S. mutans* in saliva and plaque did not show any statistically significant difference between NSF, CHX and NaF varnish. However, the reduction was significantly greater in NSF when the evaluation was done using the OD method. Since OD measurement is related to changes in morphology, clumping, or formation of long chains of bacteria during growth, it can be assumed that NSF causes some alteration in bacterial growth. The same can be appreciated intraorally by the significant reduction in values of the OHI-S index of the subjects where NSF varnish was used.

According to us, the potential limitation could be that this study was based on NSF varnish concentration, which was prepared by Targino et al. and is not a standardized concentration. However, more studies to standardize the concentration of NSF need to be carried out in future.

Conclusion

The present trial findings depicted that NSF containing remineralizing efficiency of fluoride and antimicrobial activity of nanosilver particles is effective in the reduction of *S. mutans* count in children with incipient caries.

Highlights of Our Study

- This paper acknowledges the use of NSF varnish in reducing *S. mutans* counts in children with caries.
- Nanosilver fluoride is a noninvasive agent that is highly safe for use in younger children.
- Nanosilver fluoride can be considered an alternative treatment modality owing to its promising caries reduction potential, as fluoride in NSF also provides remineralizing potential.

Ethics

Approval for this study was obtained from the local Institutional Review Board (Institute of Dental Studies and Technology, Ghaziabad, Uttar Pradesh, India) Ref. number: IDST/IEC/2020-23/19.

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ORIGINAL RESEARCH

Observation and Assessment of the Parameters of Facial Esthetics in 6-year-old Children with Healthy Dentition

Deepanjali Potsangbam[1], Nidhi Agarwal[2], Zohra Jabin[3], Ashish Anand[4]

Abstract

Aim: This study was conducted to observe and assess the dental and facial parameters of esthetics in children with healthy dentition and evaluate whether they are comparable to those of adults.

Materials and methods: An observational study included 70 children with ages ranging from 5 to 6 years who had come to the Department of Pediatric & Preventive Dentistry, Institute of Dental Studies & Technologies, Ghaziabad, Uttar Pradesh, India, with intact primary dentition. Standardized photographs of the children were taken and evaluated. Their facial and dental parameters were recorded and compared to that of those of adults.

Result: The relation of tooth and facial components was established, and it was found that they were not in the same proportion as those of adults.

Conclusion: The proportions of facial and dental parameters of esthetics of children at 6 years of age are different from those of adults.

Clinical significance: Since esthetic rehabilitation of primary teeth is becoming an important requisite of successful dental treatment, it is important to establish a standard guideline of dental and facial parameters for children for prosthetic rehabilitation.

Keywords: Dentofacial esthetics, Esthetics, Primary dentition, Smile.

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Introduction

One of the most important factors that determine the physical appearance of an individual is the face.[1] Numerous studies have been conducted on the significance of physical and facial attractiveness, which may be greatly influenced by a person's smile.[2]

Not only adult patients but even child patients are slowly yet increasingly becoming mindful of the importance of a magnificent smile in terms of facial beauty.[3]

To improve their smile for the greater good and be driven by attractive looks and lovely smiles, patients have sought numerous treatment approaches to enhance dentofacial function and esthetics.[4,5] To be able to obtain the best esthetic results possible, various reference parameters have been introduced and followed previously in a number of studies for adults, but the same has not been done for children.[6–8]

Pediatric dentists should be mindful and aware of children's esthetic perception because, by the age of 6 years, children are capable of comprehending the significance of an esthetic smile, given that they are aware of their appearance.[9] This is so because, at this time, they are exposed to the outside world, and social acceptance among peers becomes an important aspect, and an esthetically pleasing smile plays an important role.

A smile not only helps in expressing a range of emotions but also helps to determine how well a person/child functions in society. A smile that is esthetically pleasing tends to have a significant impact on the patient's quality of existence and sense of self.[10] It also aids in boosting a person's confidence and helps avail a sense of contentment. Thus, in order to harmonize an esthetic smile, a perfect integration of the facial and dental components is required in children as well.

Thus, this study was conducted to determine the dental and facial parameters of esthetics in children and observe whether they are comparable to those of adults.

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Conflict of interest: None

Patient consent statement: The author(s) have obtained written informed consent from the patient's parents/legal guardians for publication of the case report details and related images.

Materials and Methods

The study was conducted in the Department of Pediatric & Preventive Dentistry, Institute of Dental Studies & Technologies, Ghaziabad, Uttar Pradesh, India, on children between 5 and 6 years of age. The participants were selected on the basis of the following criteria:

Inclusion Criteria

- Children with caries-free intact primary dentition and proportionally acceptable facial components with all of the teeth intact in both arches.
- The absence of skeletal asymmetries, diseases, and craniofacial deformities.

Exclusion Criteria

Children having restorations, caries, any trauma, caries-related apparent loss of the anterior tooth structure, or fracture.

Any maxillofacial surgery that could affect and disfigure the dentition and face was excluded.

Children with any dental and skeletal malocclusion.

Standardized extraoral and intraoral photographs were taken. Subjects were seated on a chair with the head upright, and two photographs of each subject were taken.

- Smiling (anterior teeth visible).
- Nonsmiling.

The heads were fixed so that the mid-sagittal plane and the horizontal plane of the Frankfort were in line with the center of the camera's lens.

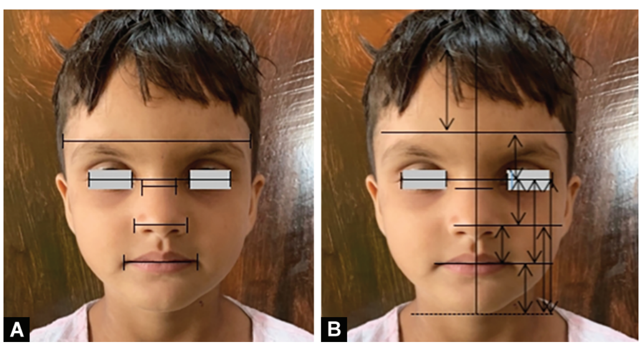
A single-lens reflex digital camera was used with standardized distance, height, and orientation values. The photographs were taken by a single person in one room and were examined and assessed by an independent examiner. Photographs were realigned to determine the facial midline. The division between the philtrum and pupillary line were two anatomical landmarks that were considered and recorded. The dental midline, which is a line that passes through the place where the central incisors of the maxilla make contact with one another and is parallel to the pupillary line, was compared to this face midline.

The pictures were resized and cropped to a typical image size of "5" by "4."

According to Rickett's approach of evaluating the divine proportions in vertical and horizontal facial planes, all images were examined. The reference points used for the face were:

- The extreme lateral commissures of the eyelids are where the lateral canthi of the eyes are placed.
- The supraorbital foramen, which is situated above the eyebrows.
- The dacryons that indicate the intersection of the maxillary, lacrimal, and frontal bones and are situated at the medial commissures of the eyes.
- The lateralmost spots on the face where the soft tissue border of the temporal is located.
- On the edges of the nose's wings are the lateral alae, which are the furthest to the side.
- The chilions, which are situated at the angle of mouth at the most lateral extremes.
- At the inferior most point of the face is the soft tissue menton [soft menton (SM)].

On the basis of the reference points, there were six horizontal measurements taken (Fig. 1A):



Figs 1A and B: (A) Horizontal parameters; (B) Vertical parameters

- Intercanthal (IC): The distance in horizontal terms between the right and left lateral canthus of the respective eyes. The intereye (IE) point was taken as the midpoint of this measurement.
- Interdacryon (ID): The distance horizontally between the left and right dacryons of the eye.
- Interalae (IA): The distances in meters along the horizontal axis between the left and right lateral rims of the nasal ala. The line's center was at the ala point (AP).
- Interchilion (IC): The distance horizontally between the mouth's left and right chilions. The line's midway was the stomion (S).
- Intertemporal (IT): A line drawn across the projected position of the head's supraorbital foramen was used to measure the distance horizontally between the soft tissue lateral borders of the left and right temples.
- Nose width (NW) and eye width (EW).

The origin of the hairline and Ricketts' index point for the vertical measures was taken into account.

Along the facial bisecting vertical line, seven vertical measurements were taken (Fig. 1B).[11]

- Forehead height: Trichion to the intertemporal plane's dividing line.
- Intereye (IE) point to SM.
- Intereye (IE) point to S.
- Intereye (IE) point to AP.
- Ala point (AP) to S.
- Ala point (AP) to SM.
- Stomion (S) to SM.

Using the aforementioned reference points, different parameters were calculated in the horizontal and vertical planes. Comparison was done with standard values of adults. The measurements obtained were subjected to statistical analysis. On the data of the selected children's and adults' smiling and nonsmiling faces, the mean, *N*-value, and standard deviation were determined. Mann–Whitney *U* test was applied for *p*-value.

Result

Tables 1 and 2 depict the mean values of the various parameters in children with smile and without smile, respectively.

When the parameters of the adult and children groups were compared, the findings revealed with a smile, the horizontal measurements had highly significant differences among the mean difference, with their *p*-value ranging from 0.001 to 0.01 (significant p-value < 0.05) (Table 3).

In the case of the vertical measurements, there was again a highly significant difference noted among the mean difference with p-value $= 0.001$ (significant p-value < 0.05) (Table 3).

On comparison of the dental parameters of children and adults, a highly significant difference was noted, with *p*-value being 0.004 in the case of the length of central incisor and the remaining parameters having *p*-value of 0.001 (significant p-value < 0.05) (Table 3).

In the nonsmiling category, the horizontal measurements had highly significant differences among the mean difference with their *p*-value as 0.001 (significant p-value < 0.05) (Table 4).

In vertical measurements, not all the parameters could be measured for comparison; those which could be compared were IE–SM, IE–AP, and AP–SM. Highly significant difference noted was 0.001 with p-value < 0.05 (Table 4).

The dental parameters could not be measured in this category.

Table 1: Mean values of various parameters of face in children with smile

	Child	
Parameter	*Mean*	*Standard deviation (SD)*
IC	3.31	0.21
ID	1.12	0.09
IA	1.36	0.19
IC	1.76	0.10
IT	4.60	0.43
N/W	0.96	1.30
E/W	0.93	0.06
IE–SM	3.34	0.26
IE–S	2.12	0.21
IE–AP	1.39	0.22
AP–S	0.60	0.04
AP–SM	1.83	0.16
S–SM	1.15	0.11
IL	0.22	0.03
WOCI	0.44	0.49
WOLI	0.18	0.03
Canine	0.16	0.04
IP–CI	0.19	0.12
CI–LI	0.13	0.03
LI–C	0.14	0.12

WOCI, width of central incisor; WOLI, width of lateral incisor; LI, lateral incisor; IL, interlip; IP, incisive papilla; CI, central incisor; C, Canine

Table 2: Mean values of various parameters of face in children without smile

	Child	
Parameter	*Mean*	*SD*
IC	3.13	0.38
ID	1.13	0.11
IA	1.43	0.19
IC	2.63	3.34
IT	4.49	0.44
N/W	0.90	0.96
E/W	0.89	0.07
IE–SM	3.30	0.24
IE–AP	1.43	0.18
AP–SM	1.98	0.19

WOCI, width of central incisor; WOLI, width of lateral incisor; LI, lateral incisor; IL, interlip; IP, incisive papilla; CI, central incisor; C, Canine

Table 3: Mean difference among the two groups with smile

Parameter	*Mean difference*	*p-value*
IC	3.60	0.01
ID	0.73	0.01
IA	0.85	0.01
IC	1.98	0.01
IT	4.76	0.01
N/W	0.87	0.001
E/W	1.07	0.001
IE–SM	4.89	0.001
IE–S	4.25	0.001
IE–AP	1.50	0.001
AP–S	1.85	0.001
AP–SM	3.54	0.001
S–SM	2.20	0.001
IL	0.35	0.001
WOCI	0.51	0.004
WOLI	0.29	0.001
Canine	0.22	0.001
IP–CI	0.20	0.001
CI–LI	0.25	0.001
LI–C	0.15	0.001

WOCI, width of central incisor; WOLI, width of lateral incisor; LI, lateral incisor; IL, interlip; IP, incisive papilla; CI, central incisor; C, Canine

Table 4: Mean difference among two groups in nonsmiling category

Parameter	*Mean difference*	*p-value*
IC	3.51	0.001
ID	0.74	0.001
IA	0.93	0.001
IC	1.28	0.002
IT	4.47	0.001
N/W	0.87	0.001
E/W	1.39	0.001
IE–SM	5.25	0.001
IE–AP	1.54	0.001
AP–SM	3.68	0.001

WOCI, width of central incisor; WOLI, width of lateral incisor; LI, lateral incisor; IL, interlip; IP, incisive papilla; CI, central incisor; C, Canine

Discussion

In this era of social media, where every moment of a child is captured on screen by doting parents, esthetics has gained immense significance in pediatric dentistry. Previously, while anterior tooth loss in a toddler or preschooler was acceptable, in today's society, even discolored primary anterior tooth or unesthetic composite restoration is discarded as bad practice. Esthetic concerns are now prioritized heavily by society, and this applies to both adults and children. It is also becoming more and more important when considering dental treatment.[12] In earlier times, pedodontists concentrated on repairing the primary and permanent dentition's structural integrity and functionality.

As a relatively new field, smile designing is constantly developing its approaches and philosophies.[13] Clinicians must be able to assess what forms the essential elements of the ideal smile. This concept extends beyond only the teeth to one of total dentofacial harmony. Understanding the delicate blending of the key elements of a smile—facial esthetics, gingival esthetics, and macro- and microesthetics of the teeth—is necessary for this.[14]

Many people believe that the golden ratio, commonly referred to as the divine proportion, is the key to comprehending esthetics, attractiveness, and human beauty. It is a number on the order of 1.618033988 and is represented by the symbol phi. To determine and assess the ratios between the many components of the attractive face, Ricketts created a "golden proportion calliper."

He asserted in 1982 that he had discovered numerous excellent lateral and frontal cephalograms after carefully examining them. After looking at pictures of models, he also discovered several divine ratios within the face. Therefore, Ricketts recommended using these divine proportion ratios as a reference while organizing orthognathic surgery. The golden ratio was first suggested for use in dentistry by Lombardi, who added, "It has proved too strong for dental use."

The dentist must carefully examine the situation and design the appropriate course of action to get a satisfying functional and esthetically pleasing result.[15] A successful esthetic outcome can be obtained if clinicians comprehend their patients and provide them with a smile that suits both their aspirations and personalities.

The proportions that were described are simply suggestions because optimal proportions, particularly for growing children, alter over time and depend on the patient's expectations. In orthognathic procedures, the horizontal facial proportions can be used to change the form of the jaws to improve dental occlusion stability, improve temporomandibular joint function (corrective jaw surgery), and correct bilateral asymmetries to improve the patient's face proportions.[11] The optimal facial appearance is the result of a detailed process that takes into account how each feature interacts with the other features of the face.

Therefore, one must take into account the (*n*) number of different measurements that can be taken in children in an area as anatomically complex as the human skull, and more research regarding this mathematical relationship is required before determining its clinical implications as a crucial parameter for achieving esthetic harmony. Other age ranges and racial characteristics can be the subject of future investigation.

Conclusion

Consequently, one conclusion that can be drawn from the current study is that certain adult facial parameters that have been used previously in studies for the purpose of smile designing cannot be used in those of children.

To solve the purpose of smile designing in children, there is a need for further studies to be effortlessly done so that we can achieve a certain set of standardized parameters that can be utilized for designing smiles.

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ORIGINAL RESEARCH

A Comparative Evaluation of Nanosilver Fluoride, Chlorhexidine, and Sodium Fluoride When Used as a Varnish on *Streptococcus mutans* Levels in Children with Caries

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Abstract

Aim: The purpose of the present study is to evaluate the effect of nanosilver fluoride (NSF), chlorhexidine (CHX), and sodium fluoride (NaF) when used as a varnish on *Streptococcus mutans* levels in children with dental caries.

Study design: A total of 120 children (age range 8–12 years) with incipient caries were randomly assigned to four groups ($n = 30$): group I—NSF varnish, group II—CHX varnish, group III—NaF varnish, and group IV—control. Varnish application at baseline was performed once. To assess the levels of *S. mutans* using the culture method [colony-forming units (CFUs)] and optical density (OD), plaque and samples were taken at baseline (T0), 1 month (T1), and 3 months (T3). Additionally, the oral hygiene index-simplified (OHI-S) was noted for clinical assessment.

Results: By the end of 3 months, a statistically significant reduction in plaque CFU and salivary CFU was found in group II. At the conclusion of the 3 months, group I had the greatest decrease in OHI-S. After 3 months, the plaque CFU score did not differ significantly across groups I, II, and III. However, a statistically significant difference in OD values (p-value of 0.00) was discovered between group I and all other groups.

Conclusion: Children with early caries can effectively lower their *S. mutans* count by using NSF varnish.

Keywords: Chlorhexidine, Incipient caries, Nanosilver fluoride, Sodium fluoride, *Streptococcus mutans*, Varnish.

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Introduction

Dental caries remains the most common dental illness globally and is regarded a serious global health concern. According to the World Health Organization's 2003 oral health report, periodontal diseases and dental caries are pandemic ailments that affect the entire community, irrespective of age, gender, or socioeconomic status.[1] As preventive measures and community oral health care services are more challenging to access in developing nations like India, the issue is more concerning there. According to the 2002–2003 National Oral Health Survey, the decayed, missing, filled teeth (DMFT) index score for Indian children was approximately 2, and the prevalence of caries increased with age, rising from 51.9 to 63.1% in the 5–15-year-old age-group, respectively.[2]

Minimally invasive techniques to halt the progression of dental caries are replacing more traditional methods of treating the condition, which involves surgically removing the damaged dental tissue and then placing an appropriate restorative material. Remineralization aims to prevent dental cavities by comprehensively protecting the patient in the long run by intervening as soon as possible.

Sodium fluoride (NaF) varnish is one of the oldest and most widely used varnishes. It is professionally applied to the tooth surface, with four applications annually at weekly intervals to provide antimicrobial and anticary activity.[3] A cationic bisbiguanide with a broad antimicrobial range is chlorhexidine (CHX). In dentistry, it is widely used in a variety of forms, including dentifrices (0.4%), gels (1%), solutions (0.12 and 0.2%), and varnishes (1, 10, 20, and 35%). Compared to other applied agent forms, it has been proposed that the varnish form of CHX administration leads to a sustained reduction of *S. mutans*.[4]

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However, with advancements in technology, an innovative approach has been made to combat the high incidence of dental caries—the use of nanotechnology in dentistry. Silver nanoparticles, one of many types of nanomaterials, have demonstrated significant promise for use in biological applications. Many of the antibacterial effects of nanomaterials stem from the release of silver ions, which can pass through the cell wall of bacteria and cause both direct and indirect lipid peroxidation, damaging the cell membrane, halting deoxyribonucleic acid (DNA) replication, and affecting both respiratory protein restoration and inhibition.[5]

Thus, the objective of the current study was to discover how to varnish applications of NaF, CHX, and nanosilver fluoride (NSF) altered the levels of *S. mutans* in children with dental caries.

Materials and Methods

The study followed the Consolidated Standards of Reporting Trials (CONSORT) 2010 standards and was a randomized, triple-blinded clinical controlled trial (Fig. 1).

For every group (NSF, CHX, NaF, and control), a minimum sample size of 27 was advised, taking into account a power of 80% (1-β), with a 95% confidence interval and an effect size (*f*) of 0.39 using G*Power 3.1. An overall suggested sample size of 109 was estimated, which was rounded to 120 to ensure that each group had at least 30 samples.

A total number of 260 patients (age range of 8–12 years) were screened. Parental consent was obtained prior to their inclusion in the study. Cooperative children with fully erupted permanent central incisors and permanent first molars having incipient caries with International Caries Detection and Assessment System II (ICDAS II) scores 1 and 2 were included. Children having any intraoral hard or soft tissue infection or pulpally involved caries were excluded. Medically compromised children, or children on fluoride or antimicrobial therapy, and wearing orthodontic appliances were also excluded from the study. A total of 120 children were enrolled for the study on the grounds of pre-established eligibility criteria.

Examination Incipient Lesion

Visual examination was carried out to detect incipient lesions. The ICDAS II was used to standardize the diagnosis (Fig. 2).[6] Two investigators conducted the examination of the incipient lesion, and if there was any disagreement, the third investigator assessed the discrepancy and made the final decision.

To avoid selection bias, allocation concealment using the sequentially numbered, opaque, sealed envelopes approach was implemented. The random concealment was conducted by an investigator who was not engaged in the application of varnish or the measurement of the outcome to prevent intervention bias. An envelope with a dark color and a corresponding serial number on top was sealed with a sheet of paper bearing a randomized group number. After the intervention was allocated, the envelope was opened. The varnish was applied according to the group designated in the document.

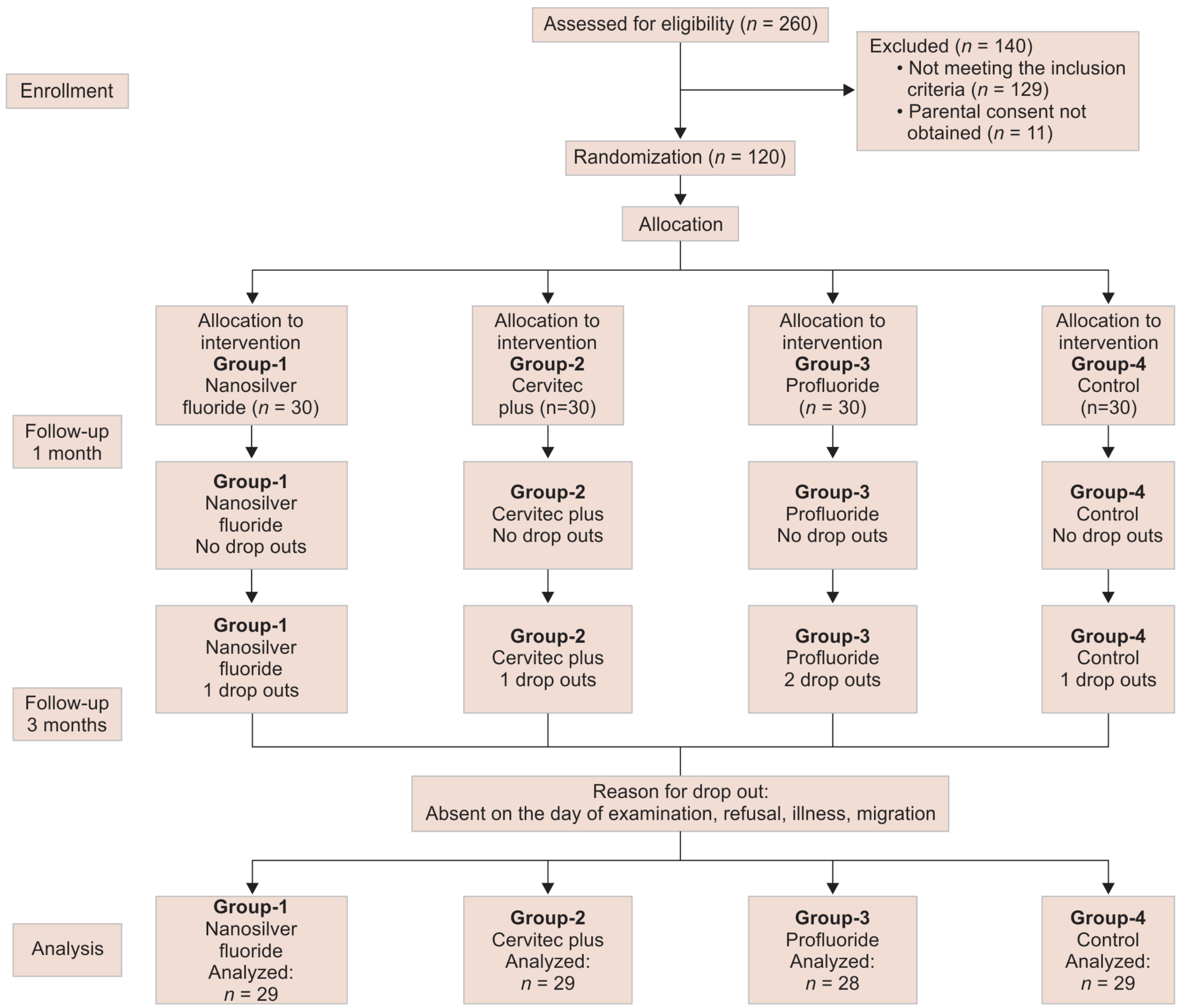

Fig. 1: Consolidated Standards of Reporting Trials flow diagram

The chosen research study participants were allocated randomly to one of four groups (30 children per group) (Table 1).

Preparation of Nanosilver Fluoride

The formulation provided by Targino et al. was followed in the preparation of NSF.[7] Silver nitrate was chemically reduced with sodium borohydride ($NaBH_4$) and chitosan biopolymer as a stabilizing agent to produce silver nanoparticles in an aqueous solution. We dissolved 2.5 mg/mL of chitosan in a 1% acetic acid solution. Magnetic stirring was used to combine the mixture until it was homogeneous. The mixture was then submerged in an ice bath, and it was vigorously stirred while more $NaBH_4$ (0.3 mL, 0.8 M) was added drop by drop. After removal from the cold bath, 10,147 parts per million of NaF were added to the flask. Stirring continued overnight. The resulting solution contained silver nanoparticles (399.33 µg/mL), NaF (10,147 µg/mL), and chitosan (2334 µg/mL). Transmission electron microscopy (TEM) was utilized to assess the shape and size of silver nanoparticles. A TEM image was captured on an FEI-Tecnai G2 F20 with an accelerating voltage of 200 kV. It was determined that 99% of the silver nanoparticles were spherical, with a size of 8 ± 2.0 nm (Fig. 3).

The child's personal information, dental history, and medical history, including any recent exposure to antibiotics, were documented prior to the study's start. During the trial period, food counseling and instructions on oral hygiene were provided.

Evaluation was done for the following:

- Clinical parameter—oral hygiene index-simplified (OHI-S) index: The buccal surface of the index teeth—16, 11, 26, 36, 41, and 46—as well as the incisal two-thirds and cervical region were all traversed by an explorer. Based on the OHI-S, each of the six teeth received a score ranging from 0 to 3.[8]
- Method of dental plaque sample collection: Using a sterile wooden toothpick, the lingual and buccal surfaces of the index teeth—16, 11, 26, 31, and 46—from the occlusal to the gingival third were scraped to obtain plaque samples from each patient between 9 and 10 AM. After being collected, the samples were placed in a microcentrifuge tube (5 mL) with 3 mL of saline solution and sent directly to the lab.
- Method of saliva sample collection: Around 2–3 mm of unstimulated whole saliva was extracted from the child by instructing them to drool into a sterile container. The containers

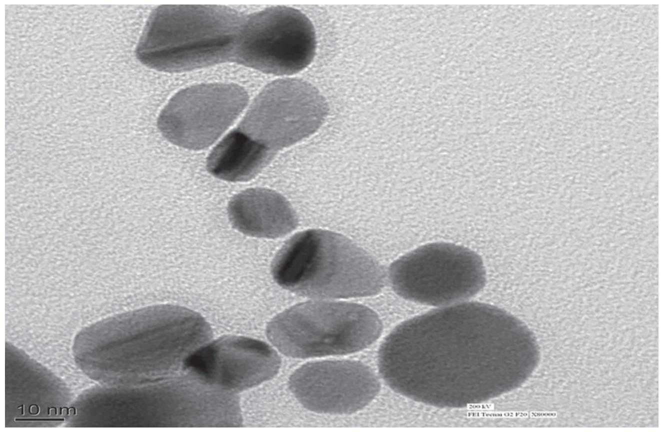

Fig. 3: Transmission electron microscopy image of nanosilver particles used in the study

CODE	DESCRIPTION
0	Sound tooth surface: No evidence of caries after 5 sec air-drying
1	First visual change in enamel: Opacity or discoloration (white or brown) is visible at the entrance to the pit or fissure seen after prolonged air drying
2	Distinct visual change in enamel visible when wet, lesion must be visible when dry
3	Localized enamel breakdown (without clinical visual signs of dentinal involvement) seen when wet and after prolonged drying
4	Underlying dark shadow from dentine
5	Distinct cavity with visible dentine
6	Extensive (more than half the surface) distinct cavity with visible dentine

Fig. 2: International Caries Detection and Assessment System II score and criteria

Table 1: Table showing group allocation and composition of materials used

Groups	*Number of participants*	*Materials*	*Composition*
Group I	30	NSF varnish	NSF group. A special formula as prepared by Targino et al.[7] containing nanosilver particles, NaF and chitosan as a stabilizer
Group II	30	CHX varnish	The CHX varnish (Cervitec Plus by Ivoclar Vivadent) group includes 1% CHX diacetate and 1% thymol as active antimicrobial ingredients
Group III	30	NaF varnish	The NaF (Profluoride Varnish, VOCO GmbH. Cuxhaven, Germany) varnish group contains 5% NaF (22,600 ppm F) with xylitol
Group IV	30	Control	Control group. Saline was used as a placebo control

were labeled and immediately submitted for analysis of *S. mutans*, then stored in a cold bath below 4°C.

Method of Varnish Application

Oral prophylaxis was performed to standardize the oral cavity with the least amount of biofilm before varnish was applied. The teeth were isolated using cotton rollers and a saliva ejector, and for 30 seconds, a three-way air syringe was used to gently inject air into the teeth. Using an applicator tip, approximately 0.1 mL of the chosen varnish was applied quadrant-wise sequentially to every tooth, beginning with the upper arch.

Participants were instructed not to rinse, eat, or drink anything for 3 hours and not to brush until the next day after application. Additionally, toothpaste devoid of fluoride was provided for use during the study.

Laboratory Phase

Two methods were used to evaluate *S. mutans* in plaque and saliva samples:

- Culture test: Mitis salivarius bacitracin agar was prepared to facilitate the multiplication and selection of *S. mutans* on the agar plates. Before distributing the saliva and plaque samples onto the agar plates for colony counting, they were diluted 1:1 and 1:2, respectively. The Petri plate was divided into eight sections, and the number of colonies found in each area was tallied. This number was then multiplied by eight to determine the total number of colonies on the plate. To acquire the total number of colonies in 1 mm of saliva or plaque, multiply the number of colonies obtained by the dilution factor.
- Optical density (OD): At 600 nm, OD was measured using a spectrophotometer (Spectronic 20). The OD method, based on the scattering of light, is used to track the kinetics of growth.

After applying varnish, the clinical and laboratory parameters were evaluated at baseline (T = 0), 1 month (T = 1), and 3 months (T = 3). A total of 5 of the 115 children in the final study sample had dropped out after 3 months (Fig. 1).

Results

A *post hoc* Bonferroni test and a one-way analysis of variance (ANOVA) were used to compare the *S. mutans* count at different intervals according to the application of different varnishes. During the follow-up phase, five participants withdrew from the original sample of 120 subjects, leaving 115 children, ages 8–12, remaining in the study. Of these, 53 boys (46.08%) and 62 girls (53.91%) made up the final study sample after 3 months.

Oral hygiene index-simplified: Each group's mean baseline OHI-S fell into one of four categories—0.4 ± 0.1, 0.5 ± 0.1, 0.5 ± 0.1, and 0.5 ± 0.2. All groups exhibited an increase in their OHI-S score, but group I saw the largest increase after 3 months, measuring 0.30 ± 0.15, which was determined to be statistically significant (Table 2).

Plaque: The four groups had baseline plaque colony-forming units (CFUs) of $4.48 \pm 1.34 \times 10^5$, $4.69 \pm 1.65 \times 10^5$, $4.41 \pm 1.50 \times 10^5$, and $4.57 \pm 1.34 \times 10^5$ CFU/mL, respectively. Group II showed the greatest decrease in plaque CFU score one month following the application of varnish, followed by groups III, I, and IV. Group II saw the greatest reduction after 3 months. Upon analysis, the decrease was found to be statistically significant in all groups with the exception of the control group.

The baseline plaque OD for all the groups was 1.38 ± 0.26, 1.39 ± 0.21, 1.44 ± 0.20, and 1.36 ± 0.17 OD/mL. Group I had the greatest decrease in plaque OD score one month following varnish application, followed by groups II, III, and IV. Group I showed the greatest decline after 3 months. With the exception of the control group, the decrease was statistically significant in every group (Table 2).

After 3 months, the intergroup comparison revealed that there was no statistically significant difference (p-value < 0.01) in the plaque CFU scores between groups I, II, and III. On the other hand, a statistically significant difference (p-value = 0.00) in OD was observed between group I and the remaining groups.

Saliva: The baseline salivary CFUs for all the groups were $4.43 \pm 1.35 \times 10^5$, $4.55 \pm 1.65 \times 10^5$, $4.31 \pm 1.57 \times 10^5$, and $4.05 \pm 1.61 \times 10^5$ CFU/mL. After 3 months, there was a statistically

Table 2: Table showing mean OHI-S, plaque CFU, and OD values recorded for groups I, II, III and IV at baseline (T0), 1 month (T1) and 3 months (T3)

		T0		T1		T3			
	Parameters	*Mean*	*Standard deviation (SD)*	*Mean*	*SD*	*Mean*	*SD*	*Mean change from T0 to T3*	*p-value*
Group I	OHI-S†	0.4	0.1	0.28	0.13	0.30	0.15	0.12	0.003*
	CFUP‡ ($\times 10^5$ CFU/mL)	4.48	1.34	0.00556	0.00632	0.03115	0.01797	4.45	0.017*
	ODP§ OD/mL	1.38	0.26	0.463	0.181	0.400	0.125	0.98	0.000*
Group II	OHI-S†	0.5	0.1	0.38	0.12	0.43	0.13	0.07	0.113
	CFUP‡ ($\times 10^5$ CFU/mL)	4.69	1.65	0.00315	0.00213	0.02634	0.01151	4.66	0.017*
	ODP§ OD/mL	1.39	0.21	0.888	0.153	0.785	0.169	0.61	0.001*
Group III	OHI-S†	0.5	0.2	0.41	0.14	0.39	0.14	0.08	0.128
	CFUP‡ ($\times 10^5$ CFU/mL)	4.41	1.50	0.00439	0.00504	0.03405	0.01962	4.37	0.001*
	ODP§ OD/mL	1.44	0.20	0.932	0.177	0.913	0.223	0.52	0.000*
Group IV	OHI-S†	0.5	0.2	0.51	0.15	0.49	0.14	0.02800	0.541
	CFUP‡ ($\times 10^5$ CFU/mL)	4.57	1.34	4.26033	1.20203	4.33133	1.23614	0.23533333	0.090
	ODP§ OD/mL	1.36	0.17	1.096	0.105	1.102	0.087	0.259333	0.092

One-way ANOVA applied; *, p-value significant at $p < 0.05$; OHI-S†, oral hygiene index-simplified; CFUP‡, colony forming unit in plaque; ODP§, plaque optical density

significant difference in the *S. mutans* levels for each of the three experimental groups, as determined by the OD and the culture technique. After 1 month, both groups I and II showed the greatest reduction. Group II had the greatest reduction after 3 months (Table 3). After 3 months, the intergroup comparison revealed no discernible differences between groups I, II, and III (Table 4).

An analysis using OD revealed a highly significant difference (p-value 0.00) between groups I and II, II and III, and III and IV.

Discussion

The results of the current study demonstrate that after 3 months, a single application of NaF, CHX, and NSF varnish remarkably reduced the amount of *S. mutans* in saliva and plaque in children with dental caries. The etiological factor, which includes host factors, diet, and dental plaque (*S. mutans*), is the most significant risk factor for any disease. In 1980, Hamada and Slade implicated *S. mutans*) as a primary causative organism of dental caries.[9] Hence, to control the cariogenic activity, it is important to suppress the growth of *S. mutans* counts in the oral cavity. The initial stage of tooth decay or demineralization is represented by the incipient carious lesions, which have the potential to progress to cavitation, be arrested, or reversed.

This study adopted a nonintensive varnish application regime, applying the coating once at baseline, which is in line with research conducted by Ben Khadra et al. and Al-Jaradi et al.[4,10] Despite using a more rigorous application regimen in their trial, Twetman et al.

Table 3: Table showing mean saliva CFU and OD values recorded for groups I, II, III and IV at baseline (T0), 1 month (T1) and 3 months (T3)

		T0		*T1*		*T3*			
	Parameters	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean change from T0 to T3*	*p-value*
Group I	CFUS† (×10^5 CFU/mL)	4.43	1.35	0.00463	0.00368	0.0500	0.0559	4.38	0.044*
	ODS‡ OD/mL	1.40	0.24	0.476	0.164	0.415	0.127	0.98	0.001*
Group II	CFUS† (×10^5 CFU/mL)	4.55	1.65	0.00323	0.00199	0.0264	0.0127	4.53	0.014*
	ODS‡ OD/mL	1.39	0.20	0.887	0.168	0.781	0.172	0.61	0.001*
Group III	CFUS† (×10^5 CFU/mL)	4.31	1.57	0.00938	0.01950	0.0804	0.1133	4.23	0.007*
	ODS‡ OD/mL	1.44	0.19	0.941	0.187	0.916	0.217	0.52	0.000*
Group IV	CFUS† (×10^5 CFU/mL)	4.05	1.61	4.18333	1.59155	4.1460	1.5723	−0.0970	0.070
	ODS‡ OD/mL	1.36	0.20	1.154	0.094	1.141	0.091	0.223333	0.068

One-way ANOVA applied; *, p-value significant at $p < 0.05$; CFUS†, colony forming unit in saliva; ODS‡, saliva optical density

Table 4: Intergroup comparison of CFU and OD among the four groups at 3 months

	Group (I)	*Group (J)*	*Mean difference (I–J)*	*p-value*
CFUP† (×10^5 CFU/mL)	I	II	0.00481067	1.00
		III	−0.00290333	1.00
		IV	−4.30018333*	0.000*
	II	III	0.00771400	1.00
		IV	−4.29728000*	0.000*
	III	IV	−4.30499400*	0.000*
ODP‡ OD/mL	I	II	−0.384400*	0.000*
		III	−0.512200*	0.000*
		IV	−0.701333*	0.000*
	II	III	−0.127800*	0.014*
		IV	−0.316933*	0.000*
	III	IV	−0.189133*	0.000*
CFUS§ (×10^5 CFU/mL)	I	II	0.0236033	1.00
		III	−0.0304533	1.00
		IV	−4.0960400*	0.000*
	II	III	0.0540567	1.00
		IV	−4.0655867*	0.000*
	III	IV	−4.1196433*	0.000*
ODS¶ OD/mL	I	II	−0.366000*	0.000*
		III	−0.500833*	0.000*
		IV	−0.725667*	0.000*
	II	III	−0.134833*	0.008*
		IV	−0.359667*	0.000*
	III	IV	−0.224833*	0.000*

Post hoc Bonferroni applied; *, p-value significant at $p < 0.05$; CFUP†, colony forming unit in plaque; ODP‡, plaque optical density; CFUS§, colony forming unit in saliva; ODS¶, saliva optical density

found that this did not increase the varnish's efficacy. Even after 1 month, the single treatment regimen used in this investigation significantly reduced the amount of *S. mutans*.[11]

Various literature on evaluating the presence of *S. mutans* have recommended saliva as a suitable method for predicting caries activity and identifying patients with high-risk of dental caries.[12] Gibbons and Houte, in 1975, stated that plaque is more appropriate and superior than saliva for estimating MS in individuals because tooth surfaces are the natural habitat of MS and Plaque.[13] Therefore, in the current study, we analyzed *S. mutans* levels in both saliva and plaque samples.

A novel varnish called NSF combines nanosilver particles with fluoride and chitosan to act as a stabilizing agent. Free radicals produced by the silver nanoparticles harm the bacterial cell membrane, cause it to become porous, and ultimately cause cell death. Moreover, during protein synthesis, silver ions can bind with sulfuryl groups and obstruct DNA replication.[14,15]

Nanosilver fluoride is endowed with remineralizing characteristics by the fluoride it contains, which lowers adhesion and biofilm formation.[16,17] As a result, NSF functions as a remineralizing agent in addition to having an antibacterial impact.

Besinis et al. in 2014 compared the antibacterial effect of silver nanoparticles with CHX and found that the antibacterial activity measured in terms of CFUs of silver nanoparticles was 25-fold higher than CHX.[18]

In 2017, Soekanto et al. assessed the effectiveness of NSF in preventing the production of *S. mutans* biofilms *in vitro*. They discovered that NSF was a more effective inhibitor of *S. mutans* biofilm formation than the industry standard silver diamine fluoride (SDF) (38%).[19]

El-Desouky et al. 2020 evaluated the anticarcinogenic effects of NSF and NaF in an *in vitro* study where the difference between *S. mutans* values in both the groups within a period of 7 days was found to be nonsignificant. Their result is in contrast to the present study since NSF has shown a significantly greater reduction in *S. mutans* count than NaF at the end of 1 and 3 months.[20]

A study by Waikhom et al. in 2022 found that when children without dental cavities applied NSF varnish, the number of *S. mutans* in both plaque and saliva decreased statistically significantly.[21]

In the present study, the CFU count of *S. mutans* in saliva and plaque did not show any statistically significant difference between NSF, CHX and NaF varnish. However, the reduction was significantly greater in NSF when the evaluation was done using the OD method. Since OD measurement is related to changes in morphology, clumping, or formation of long chains of bacteria during growth, it can be assumed that NSF causes some alteration in bacterial growth. The same can be appreciated intraorally by the significant reduction in values of the OHI-S index of the subjects where NSF varnish was used.

According to us, the potential limitation could be that this study was based on NSF varnish concentration, which was prepared by Targino et al. and is not a standardized concentration. However, more studies to standardize the concentration of NSF need to be carried out in future.

Conclusion

The present trial findings depicted that NSF containing remineralizing efficiency of fluoride and antimicrobial activity of nanosilver particles is effective in the reduction of *S. mutans* count in children with incipient caries.

Highlights of Our Study

- This paper acknowledges the use of NSF varnish in reducing *S. mutans* counts in children with caries.
- Nanosilver fluoride is a noninvasive agent that is highly safe for use in younger children.
- Nanosilver fluoride can be considered an alternative treatment modality owing to its promising caries reduction potential, as fluoride in NSF also provides remineralizing potential.

Ethics

Approval for this study was obtained from the local Institutional Review Board (Institute of Dental Studies and Technology, Ghaziabad, Uttar Pradesh, India) Ref. number: IDST/IEC/2020-23/19.

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A Five Year Retrospective Study of Oral Potentially Malignant Disorders (Opmds) and Oral Squamous Cell Carcinoma (OSCC) and their Associated Risk Factors

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Original Article

A Five Year Retrospective Study of Oral Potentially Malignant Disorders (Opmds) and Oral Squamous Cell Carcinoma (OSCC) and their Associated Risk Factors

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Abstract

Background: Oral squamous cell carcinoma (OSCC) is generally converted from precancerous conditions. The conversion rates are mainly linked to various addiction habits and sometimes to sociodemographic profile of patients. The clinical spectrum of oral potentially malignant disorders (OPMDs) varies between geographical districts or from place to place within the same country. The prevalence of this particular malignancy may be reduced by prompt diagnostic and therapeutic action. **Aims and Objectives:** We focused on the data associated with histo-pathological types of lesion in relation to certain sociodemographic profile and addiction habits in the targeted population. **Materials and Methods:** We performed 5 years retrospective cross-sectional study from January 2013 to December 2017 in the oral pathology department in systematic manner. Data were collected and compiled in Microsoft Excel and were analyzed through SPSS software. Chi-square, Student's *t*-test, and Pearson's correlation tests were used to determine the significance of study parameters between groups. **Results:** Our study suggests a more common relationship of lichen planus with gutkha, pan, and mixed habit; leukoplakia with bidi smoking and mixed habit; verrucous leukoplakia with bidi and cigarette smoking and gutkha chewing; oral submucous fibrosis with pan and gutkha; mild and moderate dysplasia with bidi and alcohol consumption; well-differentiated OSCC and moderately differentiated OSCC with tobacco intake and/or alcohol and poorly differentiated OSCC with alcohol, pan, and bidi. **Conclusion:** OPMDs and OSCC are more associated with various addiction habits. Cessation of these habits along with early intervention may reduce the burden of disease.

Keywords: Addiction, oral potentially malignant disorders, oral squamous cell carcinoma, retrospective study, risk factors

Introduction

Oral cancer is among one of the most deadly diseases globally and its prevalence renders a major threat and challenge worldwide. In India, the most frequently and regularly occurring cancer is oral carcinoma contributing to about 40% of all the primary cancers. Of all the oral carcinoma cases, oral squamous cell carcinoma (OSCC) accounts for the majority of instances with incidence rates of 12.8 and 7.5/100,000 in men and women, respectively.[1] The large range of incidence of oral cancers cannot be attributed to just a single cause but it is usually an outcome of numerous etiologic agents that operate over time and are related to individual's response to these various factors.[2] Tobacco and alcohol consumption in any form constitutes about 75% of all the oral cancers.[3] Oral potentially malignant disorders (OPMDs) are characterized by enhanced chances of malignant transformation and their progression to malignancy is only a potential risk since each such type of disorder cannot always transform into malignant conditions.[4] The large numbers of these disorders are generally asymptomatic just at the beginning of their initiation and may be detected by clinicians on routine oral examination.[5] The prevalence of OPMDs and their malignant transformation varies globally and the etiology ranges from

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exogenous factors such as tobacco and inflammation to being idiopathic or inherited chromosomal abnormalities.[6] The sequelae of OPMDs worsen the quality of life.[7] Identification of etiological factors, stoppage or reduction of habit, and organization of awareness programs so as to educate and warn the patients, can be important determining factors in the prevention of progression of OPMDs and increasing the survival rates.[8] Therefore, it is essential that various health-care professionals have an appropriate knowledge regarding the clinical and diagnostic aspects of OPMD for further investigation and referrals to a specialist for treatment. For confirmation, biopsy is mandatory followed by timely referral.[9]

In the current study, we collected and analyzed the data on the cases of OPMDs and OSCC in and around the belt of Modinagar, UP, which have been reported to the institute between the years 2013 and 2018.

Aim

1. To investigate the prevalence of OPMDs and OSCC among the patients coming to Department of Oral and Maxillofacial Pathology, IDST, Modinagar, UP, over a period of 5 years (i.e., from January 2013 to December 2018)
2. To determine the potential risk factors and indicators associated with the development and high prevalence of these lesions in relation to their sociodemographic and medical factors in this region.

Materials and Methods

Study participants

This work was conducted following the ethical guidelines of the Declaration of Helsinki. A retrospective cross-sectional Study of the patients with OPMDs and oral cancer who attended the outpatient department of IDST for dental complaints from January 2013 to December 2017, was carried out. Permission to use retrospective data present in the department was taken from the head of the department. Ethical clearance was obtained from the Institutional Ethical Committee (Reference number: IDST/IERBC/2018-21/29, Dated: November 19, 2018). We followed STROBE reporting Guideline while writing this paper.

Data collection

Case details were retrieved from the records of the patients who had presented with various oral cavity lesions and were subsequently advised for biopsy. A structured entry form was prepared to collect and compile the information which was filled manually for the each patient at the time of their visit to the department. Demographic data such as name, age, gender, religion, literacy, place of residence (rural/urban), and socioeconomic status were recorded. Habits of addiction to tobacco chewing, tobacco smoking, betel nut chewing, pan masala or gutkha chewing, and alcohol consumption and their respective duration and frequency were also recorded. Clinico-histopathological details of respective patients, like provisional diagnosis, final histopathological diagnosis with site involved was also taken into consideration for various OPMDs like leukoplakia, erythroplakia, palatal lesion of reverse cigar smoking, oral lichen planus, oral submucous fibrosis (OSMF), discoid lupus erythematosus, syphilis and well-differentiated OSCC (WDOSCC), moderately differentiated OSCC (MDOSCC) and poorly differentiated OSCC (PDOSCC). Data were entered and stored into predesigned Microsoft Excel software format and further rechecked and confirmed by the guide in systematic manner. Patients with visible clinical lesions were subjected to biopsy for histopathological evaluation and confirmation to check for any dysplastic changes. Incomplete records and scattered data were excluded from the study [Figure 1].

Statistical analysis

A comprehensive analysis was done on the data collected and results were formulated and statistically analyzed. The statistical software namely SPSS 25.0 (IBM Corp, Armonk, NY) trial version was used to analyze the data and Microsoft Excel to generate tables. Inferential statistical analysis was carried out in the present study. Results on continuous measurements are presented on mean ± standard deviation and results on categorical measurements are presented in numbers and percentage (%). Significance was assessed at 5% level of significance. Chi-square, Student's *t*-test, and Pearson's correlation tests were used to find the significance of study parameters on the categorical scale and ordinal scale between two or more than two groups.

Results

Out of 2620 individual data, a total of 216 cases were taken, out of which OPMDs were 41.20% (89, male = 71, female = 18) and OSCC were 58.80% (127, male = 104, female = 23). The demographic profile was tabulated in very systematic manner [Table 1]. The highest frequency of cases was observed among primary and high school pass outs (n = 43) and least numbers were noted among professionals (n = 10). The

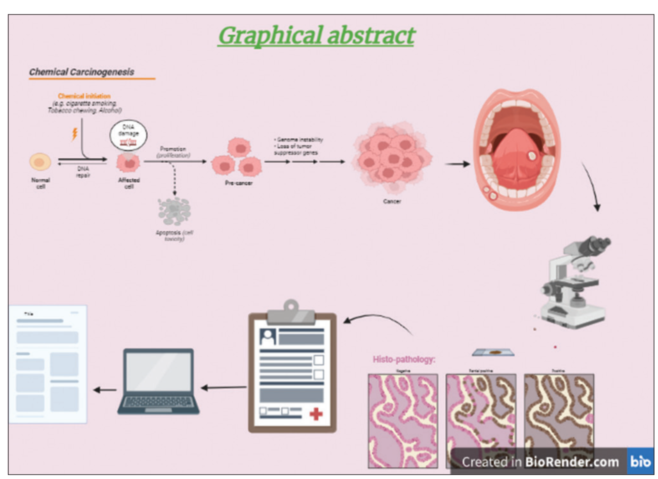

Figure 1: Graphical abstract

study sample was divided according to their occupation into groups of agriculture, business, housewife, labor, service, and unemployed with maximum number of cases in unemployed group (*n* = 48) and minimum number of cases in labor group (*n* = 23). The study sample was divided according to their location into rural and urban areas. The greatest number of subjects were noted in rural group (*n* = 130) and the least number of cases were noted in an urban group (*n* = 86). The study sample was grouped according to its socioeconomic status into lower, middle, and upper class with the highest number of cases in lower economy group (*n* = 96) and lowest number of cases in upper economy group (*n* = 25). In our study, the highest number of individuals were addicted to gutkha (*n* = 159) followed by alcohol (*n* = 107), cigarette (*n* = 100), bidi (*n* = 98) and then pan (*n* = 96). In our study, out of the total study sample (*n* = 216), mixed habit of tobacco and alcohol consumption both was observed in less number of subjects (*n* = 103). The study sample size (*n* = 216) was grouped on the basis of final diagnosis into Atrophic lichen planus (4 cases), erosive lichen planus (2 cases), leukoplakia (5 cases), Lichen planus (13 cases), MDOSCC (41 cases), mild dysplasia (30 cases), moderate dysplasia (14 cases), OSMF (11 cases), PDOSCC (16 cases), severe dysplasia (5 cases), speckled leukoplakia (1 case), verrucous leukoplakia (5 cases), and WDOSCC (69 cases).

Table 1: Sociodemographic characteristics (*n*=216)

	***n* (%)**
Mean age	47.66±14.106
Female	49.07±14.43
Male	47.33±14.05
Gender	
Female	41 (18.98)
Male	175 (81.02)
Literacy	
Graduate	40 (18.52)
High school	43 (19.91)
Illiterate	31 (14.35)
Intermediate	32 (14.81)
Postgraduate	17 (7.87)
Primary	43 (19.91)
Occupation	
Professional	10 (4.63)
Agriculture	34 (15.74)
Business	41 (18.98)
Homemaker	30 (13.89)
Labor	23 (10.65)
Service	40 (18.52)
Unemployed	48 (22.22)
Place of residence	
Rural	130 (60.19)
Urban	86 (39.81)
Socioeconomic status	
Lower	96 (44.44)
Middle	95 (43.98)
Upper	25 (11.57)

In this study, the highest number of males were finally diagnosed with WDOSCC (*n* = 59) followed by MDOSCC, mild dysplasia, and speckled leukoplakia (*n* = 1) whereas in the female group maximum subjects were diagnosed with WDOSCC (*n* = 10) followed by MDOSCC, mild dysplasia and verrucous leukoplakia (*n* = 1). OSMF was more prevalent in males (*n* = 11).

In our study, drinking of alcohol had a strong relationship with a high prevalence for OSCC followed by dysplasia and OSMF. Bidi smoking was linked more to OSCC followed by OSMF and lichen planus. Cigarette smoking was associated with OSCC, OSMF, and leukoplakia. Gutkha chewing was more significant in cases of OSCC and OSMF [Table 2].

In the study, highest numbers of males were addicted to gutkha chewing and females to pan and gutkha chewing. Smoking tobacco habit (bidi and cigarette) was more common in males as compared to females. Males were more alcoholic than females. Overall gutkha chewing was the most prominent addiction in the study sample [Table 3 and Figure 2].

Discussion

In our study population, OPMDs and OSCC patients were approximately in the ratio of 2:3. Average 524 biopsies/year were examined and around 43 (8.24%) cases/year had been diagnosed as OPMDs and OSCC. Gender-wise ratio distribution of males and females in both OPMDs and OSCC was 4:1. Similar findings were noted in the study conducted by Gupta *et al*.[10] and Gowhar *et al*.[11] The prevalence was significantly higher in males as compared to females. Similar findings were also noted by Kumar *et al*.[12] In the present study, the mean age was 47.6 ± 14.1 years, 47.3 ± 14.1 years for males and 49.1 ± 14.4 years for females. The median age in the previous studies by Kumar *et al*.[12] was 43 years and by Cancela Mde *et al*.[13] was 56 years respectively. Takezaki *et al*.[2] observed the highest incidence (30.1% in men, 27.3% in women) with the age group of 60–69 years whereas, Shyam *et al*.[14] found majority of the cases in the age group of 21–30 years. In our study, the illiteracy rate was found to be 14.35% quite resembling the findings of Gupta *et al*.[10] and Behura *et al*.[15] We found a higher prevalence of cases in rural population than urban (3:2)

Key-points:

- Atrophic and Erosive Lichen Planus are positively related to pan chewing. Dysplasia is positively related to tobacco smoking. Unemployed are prone to OSCC & OPMD.
- Verrucous Leukoplakia and OSMF are three times prone to Gutka chewing.
- Oral Squamous cell Carcinoma is related to tobacco and alcohol intake, but two times higher in pan, alcohol and mixed habits

Figure 2: Key points

Table 2: Final diagnosis and habit-wise distribution in the study sample

Habit	Atrophic lichen planus	Erosive lichen planus	Leukoplakia	Lichen planus	MDOSCC	Mild dysplasia	Moderate dysplasia	OSMF	PDOSCC	Severe dysplasia	Speckled leukoplakia	Verrucous leukoplakia	WDOSCC	Total
Alcohol														
No	3	2	3	11	16	17	9	9	3	3	0	4	29	109
Yes	1	0	2	2	25	13	5	2	13	2	1	1	40	107
Bidi														
No	3	2	3	11	20	19	7	6	5	5	1	3	33	118
Yes	1	0	2	2	21	11	7	5	11	0	0	2	36	98
Cigarette														
No	3	2	3	9	18	21	10	6	9	2	0	3	30	116
Yes	1	0	2	4	23	9	4	5	7	3	1	2	39	100
Gutkha														
No	2	0	2	4	8	13	6	1	4	2	0	1	14	57
Yes	2	2	3	9	33	17	8	10	12	3	1	4	55	159
Pan														
No	2	0	4	11	18	23	9	4	4	5	0	4	36	120
Yes	2	2	1	2	23	7	5	7	12	0	1	1	33	96

OSMF: Oral submucous fibrosis, WDOSCC: Well-differentiated squamous cell carcinoma, PDOSCC: Poorly differentiated squamous cell carcinoma, MDOSCC: Moderately differentiated squamous cell carcinoma

having consistent result of study conducted by Gupta *et al*.[10] and Neufeld *et al*.[16] They also concluded that tobacco chewing; tobacco smoking and alcohol use was recorded to be 1.2, 1.5, and 1.3 times more likely in rural population respectively.

The present study also assessed the addiction pattern of bidi, cigarettes, gutkha, pan, and alcohol as 45.37%, 46.3%, 73.61%, 44.44%, and 49.54%, respectively. Maximum numbers of patients were gutkha chewers and almost half of the population was alcoholic. Among 90.28% of tobacco consumers, tobacco smoking was prevalent in 71.76% while tobacco chewing was common in 82.41%. A mixed habit of tobacco and alcohol consumption was found in 47.69% of cases. In our finding pan chewing was a more common habit in females while alcohol usage and mixed addiction were highest among men. Keluskar and Kale *et al*.[17] had a similar findings of the predominant use of smokeless tobacco in women as compared to men.

We found that bidi smoking was much more prevalent in diseases namely PDOSCC followed by WDOSCC, MDOSCC, moderate dysplasia, and OSMF (relative risk [RR] =1.8, 1.2, 1.14, 1.09, 1.00 respectively). Cigarette smoking was more common in individuals suffering from severe dysplasia followed by WDOSCC and MDOSCC (RR = 1.35, 1.34, 1.27 respectively). Pan chewing was more commonly observed in PDOSCC followed by, OSMF, MDOSCC and atrophic and erosive lichen planus and then WDOSCC (RR = 2.32, 1.56, 1.32, 1.11, 1.09 respectively). Gutkha addiction was more closely associated in individuals with the disease OSMF followed by WDOSCC, MDOSC, verrucous leukoplakia and then PDOSCC (RR = 3.005, 1.44, 1.43, 1.32, and 1.06, respectively). Alcohol drinking was highest in PDOSCC followed by MDOSCC and WDOSCC (RR = 2.82, 1.36, 1.29, respectively). Mixed habit (tobacco and alcohol) was seen maximum in PDOSCC followed by MDOSCC and WDOSCC same as alcohol (RR = 2.08, 1.87, 1.64 respectively). Similar findings were observed by Ahmad *et al*.[9] and Takezaki *et al*.[2] who found that mixed habits of smoking and drinking alcohol were more pronounced as compared to smoking alone in case of OPMDs. Gupta *et al*.[10] established that the presence of habit posed higher risk for OSMF followed by leukoplakia, OSCC, and lichen planus (RR = 8.47, 7.87, 5.5, and 3.6, respectively). Drinking alcohol had an increased risk of OSMF, leukoplakia, and lichen planus [Tables 4 and 5].

Linear and multiple regression also shows that dependent variables (addiction habits) are positively related to dysplasia. However, pan chewing habit was seen significantly related to the independent variable (dysplasia) in multiple regression analysis [Table 6].

The present study showed that tobacco was related with a higher prevalence of OPMDs and OSCC. This was coherent with the study conducted by Ramya *et al*.[18] and Srivastava *et al*.[19]

Table 3: Incidence of tobacco, alcohol, and mixed habits according to gender

	Bidi, *n* (%)	Cigarette, *n* (%)	Pan, *n* (%)	Gutkha, *n* (%)	Alcohol, *n* (%)	Mixed, *n* (%)
Male	84 (48.0)	98 (56.0)	74 (42.29)	139 (79.43)	99 (56.57)	96 (54.86)
Female	14 (34.15)	2 (4.88)	22 (53.66)	20 (48.78)	8 (19.51)	7 (17.07)
Total	98 (45.37)	100 (46.30)	96 (44.44)	159 (73.61)	107 (49.54)	103 (47.69)

Table 4: Relative risks of addiction to premalignant lesions and oral squamous cell carcinoma

Disease	Bidi	Cigarette	Pan	Gutkha	Alcohol	Mixed
Lichen planus	0.6299	0.7614	0.6346	0.8485	0.5705	0.5123
Atrophic lichen planus	0.7233	0.7107	1.1132	0.5189	0.6670	0.4906
Erosive lichen planus	0.5421	0.5327	1.1132	Undefined	0.5000	Undefined
Leukoplakia	0.9084	0.8926	0.6832	0.6517	0.8373	0.6161
Verrucous leukoplakia	0.9084	0.8926	0.6832	1.3270	0.6220	0.6161
Speckled leukoplakia	0.5422	Undefined	Undefined	Undefined	Undefined	Undefined
OSMF	1.0016	0.9837	1.5561	3.0049	0.5962	Undefined
Mild dysplasia	0.8404	0.7296	0.6802	0.5459	0.8729	0.3831
Moderate dysplasia	1.0990	0.7347	0.8548	0.5891	0.7701	0.8863
Severe dysplasia	0.5355	1.3507	0.5450	0.6517	0.8373	0.6161
WDOSCC	1.2090	1.3456	1.0952	1.4417	1.2949	1.6429
MDOSCC	1.1480	1.2756	1.3276	1.4350	1.3618	1.8753
PDOSCC	1.8080	0.9511	2.3200	1.0600	2.8267	2.0800

OSMF: Oral submucous fibrosis, WDOSCC: Well-differentiated squamous cell carcinoma, PDOSCC: Poorly differentiated squamous cell carcinoma, MDOSCC: Moderately differentiated squamous cell carcinoma

The results of our study showed that Lichen planus risk was linked more to the addiction of gutkha, pan and mixed habit; leukoplakia was linked more to bidi smoking and mixed habit. On the other hand, verrucous leukoplakia had strong relationship with bidi and cigarette smoking and gutkha chewing and OSMF had a significant relationship with pan (betel nut) and gutkha. Mild and moderate dysplasia was associated more with bidi and alcohol consumption. WDOSCC and MDOSCC were seen in patients with more tobacco intake (both smoking and smokeless) and/or alcohol whereas PDOSCC had a strong relationship with alcohol, pan, and bidi. This was in coherence with the study conducted by Saraswathi *et al*.[20] who reconfirmed that smokers had much higher prevalence of soft tissue lesions and were more likely to develop smoker's melanosis as compared to other lesions whereas alcoholics were having a higher prevalence of leukoplakia and OSMF was more common in tobacco and gutkha chewers.

Tobacco use and oral cancer is a major public health problem globally, especially in developing countries of the world like India where the incidence rates are highest.[11] The disease mostly occurs in elderly males during 5th–8th decade of life and is rarely seen in younger individuals. Usually, oral malignancies like OSCC arises from certain preexisting lesions and conditions in the oral cavity commonly grouped now as OPMDs which have many times more risk of malignant transformation.[14] Control of the occurrence of OSCC and OPMDs can be achieved by adopting effective preventive measures like elimination of tobacco usage through tobacco cessation programs carried out both at workplace and community levels and also by detecting and arresting these lesions in their initial developing stages through proper and careful oral examination and histopathological evaluation of the suspicious lesions thereby decreasing the burden of the disease.[17]

Conclusion

This study revealed that the most common finding was "mild dysplasia" among OPMDs and "WDOSCC" among oral cancer. We found increased risk of OSMF with gutkha chewing while pan chewing was more related to lichen planus and OSMF. Alcohol consumption significantly increased the risk of oral carcinoma especially the combination of bidi and alcohol was the strongest risk factor for PDOSCC. OPMDs and OSCC were associated mainly with lower socioeconomic groups residing particularly in rural areas.

Epidemiological studies create awareness among the masses about the potential hazards of addiction and its cessation to eradicate its use thereby making it easier for oral pathologists and practitioners in making early and better diagnosis and treatment planning. Tobacco, both in smoked and chewed form acted as a major risk factor in the development of single or multiple oral precancerous lesions especially in the older male population because of its increased consumption and also due to lack of awareness regarding its potential hazards. These lesions can mostly be identified by simple oral cavity examination before they undergo malignant transformation. Hence, a periodic screening of such changes in the oral cavity is mandated.

Table 5: Logistic regression showing different types of addictions related with premalignant lesions and oral squamous cell carcinoma

Disease	Habit	OR	95%	CI	Co-efficient	SE	*Z*	*P*
Lichen planus	Alcohol	0.2403	0.0487	1.1854	−1.4258	0.8142	−1.7510	0.0799
	Bidi	0.2788	0.0529	1.4687	−1.2772	0.8477	−1.5065	0.1319
	Cigarette	0.4899	0.1110	2.1615	−0.7135	0.7573	−0.9422	0.3461
	Gutkha	1.8568	0.1944	17.7371	0.6188	1.1515	0.5374	0.5910
	Pan	0.2501	0.0505	1.2384	−1.3859	0.8162	−1.6980	0.0895
	Mixed	1.0130	0.0678	15.1460	0.0129	1.3800	0.0094	0.9925
	Constant	*	*	*	−1.7215	0.6281	−2.7407	0.0061
Atrophic lichen planus	Alcohol	0.4696	0.0414	5.3296	−0.7559	1.2394	−0.6099	0.5419
	Bidi	0.3535	0.0250	4.9929	−1.0400	1.3510	−0.7697	0.4415
	Cigarette	0.3651	0.0227	5.8837	−1.0076	1.4183	−0.7104	0.4774
	Gutkha	0.2871	0.0212	3.8895	−1.2478	1.3297	−0.9384	0.3480
	Pan	1.6505	0.1923	14.1650	0.5011	1.0968	0.4568	0.6478
	Mixed	2.8806	0.0834	99.4747	1.0580	1.8071	0.5854	0.5582
	Constant	*	*	*	−3.3177	1.0860	−3.0549	0.0023
Leukoplakia	Alcohol	0.7916	0.1155	5.4244	−0.2337	0.9820	−0.2380	0.8119
	Bidi	1.3638	0.1429	13.0146	0.3103	1.1509	0.2696	0.7875
	Cigarette	0.8590	0.0966	7.6367	−0.1520	1.1148	−0.1364	0.8915
	Gutkha	0.5423	0.0515	5.7086	−0.6119	1.2010	−0.5095	0.6104
	Pan	0.2983	0.0297	2.9924	−1.2097	1.1764	−1.0283	0.3038
	Mixed	1.1744	0.0403	34.2602	0.1607	1.7211	0.0934	0.9256
	Constant	*	*	*	−3.0465	1.0357	−2.9414	0.0033
Verrucous leukoplakia	Alcohol	0.2443	0.0243	2.4532	−1.4095	1.1770	−1.1975	0.2311
	Bidi	1.3817	0.1733	11.0190	0.3233	1.0593	0.3052	0.7602
	Cigarette	1.2633	0.1609	9.9208	0.2338	1.0515	0.2223	0.8241
	Gutkha	56,872.0696	0.0000	>1.0E12	10.9486	252.6917	0.0433	0.9654
	Pan	0.3132	0.0323	3.0359	−1.1608	1.1589	−1.0017	0.3165
	Mixed	0.0000	0.0000	>1.0E12	−10.9912	252.6945	−0.0435	0.9653
	Constant	*	*	*	−2.9424	1.0314	−2.8529	0.0043
OSMF	Alcohol	0.1487	0.0284	0.7795	−1.9056	0.8452	−2.2546	0.0242
	Bidi	0.8145	0.2181	3.0413	−0.2052	0.6722	−0.3052	0.7602
	Cigarette	1.2457	0.3296	4.7079	0.2197	0.6783	0.3239	0.7460
	Gutkha	1.8479	0.2190	15.5953	0.6140	1.0883	0.5642	0.5726
	Pan	2.6034	0.6649	10.1934	0.9568	0.6964	1.3739	0.1695
	Mixed	137,239.1434	0.0000	>1.0E12	11.8295	313.7327	0.0377	0.9699
	Constant	*	*	*	−15.0001	313.7309	−0.0478	0.9619
Mild dysplasia	Alcohol	1.1171	0.4712	2.6487	0.1108	0.4405	0.2515	0.8014
	Bidi	1.0363	0.3807	2.8209	0.0357	0.5109	0.0698	0.9443
	Cigarette	0.4908	0.1812	1.3296	−0.7117	0.5084	−1.3997	0.1616
	Gutkha	0.5417	0.1773	1.6552	−0.6130	0.5699	−1.0757	0.2821
	Pan	0.3467	0.1351	0.8898	−1.0592	0.4808	−2.2029	0.0276
	Mixed	0.8438	0.1849	3.8509	−0.1699	0.7746	−0.2193	0.8264
	Constant	*	*	*	−0.6906	0.4394	−1.5715	0.1161
Moderate dysplasia	Alcohol	0.5862	0.1758	1.9547	−0.5342	0.6145	−0.8693	0.3847
	Bidi	1.4372	0.3715	5.5604	0.3627	0.6903	0.5255	0.5993
	Cigarette	0.4228	0.1059	1.6879	−0.8608	0.7063	−1.2188	0.2229
	Gutkha	0.2966	0.0800	1.0992	−1.2153	0.6683	−1.8185	0.0690
	Pan	0.5810	0.1727	1.9553	−0.5429	0.6191	−0.8769	0.3805
	Mixed	3.5208	0.4225	29.3414	1.2587	1.0818	1.1635	0.2446
	Constant	*	*	*	−2.3537	0.7458	−3.1558	0.0016
WDOSCC	Alcohol	1.3053	0.6956	2.4493	0.2664	0.3211	0.8297	0.4067
	Bidi	1.4007	0.7113	2.7585	0.3370	0.3458	0.9746	0.3298
	Cigarette	1.7847	0.9309	3.4218	0.5793	0.3321	1.7443	0.0811
	Gutkha	1.4262	0.5884	3.4570	0.3550	0.4517	0.7859	0.4319

Contd...

Table 5: Contd...

Disease	Habit	OR	95%	CI	Co-efficient	SE	*Z*	*P*
	Pan	1.0551	0.5656	1.9683	0.0537	0.3181	0.1687	0.8661
	Mixed	0.6957	0.1851	2.6150	−0.3629	0.6756	−0.5371	0.5912
	Constant	*	*	*	−1.3058	0.4713	−2.7709	0.0056
MDOSCC	Alcohol	1.4753	0.6909	3.1501	0.3888	0.3871	1.0046	0.3151
	Bidi	0.9725	0.4417	2.1412	−0.0278	0.4027	−0.0691	0.9449
	Cigarette	1.4146	0.6603	3.0306	0.3468	0.3887	0.8922	0.3723
	Gutkha	1.2996	0.4546	3.7152	0.2620	0.5359	0.4890	0.6249
	Pan	1.6827	0.8045	3.5196	0.5204	0.3765	1.3822	0.1669
	Mixed	0.9976	0.1906	5.2219	−0.0024	0.8445	−0.0028	0.9977
	Constant	*	*	*	−2.2735	0.6267	−3.6279	0.0003
PDOSCC	Alcohol	5.0074	1.2060	20.7906	1.6109	0.7263	2.2179	0.0266
	Bidi	1.4948	0.4196	5.3252	0.4020	0.6482	0.6202	0.5351
	Cigarette	0.5884	0.1863	1.8581	−0.5304	0.5867	−0.9039	0.3660
	Gutkha	0.7236	0.1742	3.0057	−0.3235	0.7265	−0.4452	0.6562
	Pan	3.4822	0.9961	12.1736	1.2477	0.6386	1.9538	0.0507
	Mixed	0.9248	0.0670	12.7574	−0.0781	1.3389	−0.0584	0.9535
	Constant	*	*	*	−4.0016	1.0842	−3.6909	0.0002

OSMF: Oral submucous fibrosis, WDOSCC: Well-differentiated squamous cell carcinoma, PDOSCC: Poorly-differentiated squamous cell carcinoma, MDOSCC: Moderately-differentiated squamous cell carcinoma, CI: Confidence interval, SE: Standard error, OR: Odds ratio

Table 6: Linear and multiple regression analysis of dependent variables

	Simple regression analyses					95% CL		Multiple regression analysis						95% CL	
	R^2	*F*	β	*t*	*P*	Lower	Upper	R^2	AR	*F*	β	*t*	*P*	Lower	Upper
Bidi	0.027	4.731	0.505	2.175	0.031*	0.047	0.963	0.156	0.132	6.239	0.061	0.241	0.809	−0.437	0.558
Cigarette	0.034	6.029	0.568	2.455	0.015*	0.111	1.025				0.396	1.698	0.091	−0.064	0.856
Pan	0.091	17.231	0.935	4.151	<0.001*	0.491	1.379				0.812	3.450	0.001*	0.347	1.277
Gutka	0.041	7.458	0.708	2.731	0.006*	0.196	1.221				0.375	1.397	0.164	−0.154	0.904
Alcohol	0.048	8.662	0.680	2.943	0.003*	0.224	1.136				0.407	1.731	0.085	−0.057	0.871

**P* value <0.05 significant CL: Confidence limit, AR: Adjusted R

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Conflicts of interest

There are no conflicts of interest.

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Human Urinary Metabolomics as Biomarkers in Tobacco Users: A Systematic Review

Abstract

Aim: Urine as a biofluid has been rarely used as a diagnostic fluid in oral diseases. The article aims to systematically review the utility of human urinary carcinogen metabolites as an approach for obtaining important information about tobacco and cancer. **Materials and Methods:** The following article reviews the use of urine and its metabolites as biomarkers in various lesions of the oral cavity including oral squamous cell carcinoma and as a screening method in evaluating tobacco and its components. A bibliographic comprehensive search was carried out in the main databases: PUBMED, SciELO, Google Scholar, VHL, and LILACS for articles that were published from 1985 to 2020. The inclusion criteria were "urinary metabolites," "oral cancer/HNSCC," "body fluids," "tobacco," and "metabolomics." A total of 55 articles were collected which included laboratory studies, systematic reviews, and literature of urinary metabolites in tobacco users. **Results:** Most of the studies carried out show accurate results with high sensitivity of urinary metabolite biomarkers in individuals with tobacco-based habits and lesions caused by them. **Conclusion:** The review indicates that urinary metabolite analysis demonstrates its applicability for the diagnosis and prognosis of disease. Urine is a remarkable and useful biofluid for routine testing and provides an excellent resource for the discovery of novel biomarkers, with an advantage over tissue biopsy samples due to the ease and less invasive nature of collection.

Keywords: *Biomarkers, body fluids, carcinogenesis, metabolites, urine*

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Introduction

The use of body fluids can be an interpretative tool in the diagnosis of various diseases.[1] Body fluids such as blood and urine have been used in pathology for quite some time.[2] Laboratory tests carried out in these body fluids can help know the presence or absence of disease to its severity and prognosis in a patient.[1] Recent advances in the field of biologic science have sparked new interest in the area of identifying biomarkers in body fluids. It has been shown that mutations present in the primary tumors or disease can also be identified in the body fluids of the affected patients.[2,3] Cancer-related analysis in blood, urine, and cerebrospinal fluid has been used successfully as cancer biomarkers.[4]

The oldest known test on body fluids was done on urine in ancient times (before 400 BC).[5] Urine is a very useful biofluid for routine testing and a wonderful means for discovering novel biomarkers. It has an advantage over tissue biopsies due to the ease and noninvasive nature of collection.[6] The current article is an attempt to review such urinary biomarkers that can be studied in tobacco users and oral squamous cell carcinoma (OSCC) patients.

Tobacco kills half of its users. More than 8 million tobacco users are killed annually. Eighty percent of the world's tobacco users are from developing nations. Smoked and smokeless tobacco forms are the two main ways to consume tobacco. Both are equally damaging to health and addictive.[7] These forms of tobacco contain toxic chemicals and constituents that are carcinogenic having cancer-promoting substances. Vast epidemiological studies conclude the risk of oral cancers and premalignant conditions attributed to tobacco use and dependence.[8] Other possible causative risk factors such as age, gender, alcohol, diet, and human papillomavirus may be associated, but tobacco is the most common.[9,10]

The incidence of head-and-neck (H and N) cancer exceeds half a million cases annually worldwide.[11] Oral cancer is the sixth most

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common human cancer, with a high morbidity rate and an overall 5-year survival rate of <50%.[12] About 75% of H and N cancers are oral cancers, and 90% of oral cancers are diagnosed as OSCCs.[13] It has been proven that the development of OSCC is associated with tobacco use. Various studies show how tobacco can cause epigenetic alteration of oral epithelial cells through its toxic metabolites and induce OSCC.[8] H and N cancers tend to be malignant in nature with chances of recurrence. Their prognosis has not improved despite technological and therapeutic advances.[14,15] There is an urgent need to discover more biomarkers for diagnosis, prognosis, therapeutic response prediction, and population screening of human cancers, which can hopefully improve treatment and reduce cancer mortality. Pathophysiological stimuli by such risk factors such as tobacco can alter the metabolic profile of biofluids such as urine, serum, saliva, and blood which can be used as an advanced and precise screening modality in disease state.[16] Urinary metabonomic analysis demonstrates its applicability for the diagnosis and prognosis of disease[17-19] and can be used as a complementary approach for early detection of oral cancer (OSCC)[20,21] [Figure 1].

Materials and Methods

The present systematic review was conducted according to the guidelines provided by the PRISMA statement. Published literature was searched to discuss the use of urinary metabolites as a biomarker for oral lesions as a screening tool in tobacco users. A comprehensive bibliographic search in the main electronic databases: PubMed (www.pubmed.gov), SciELO (www.scielo.org), Google Scholar (www.scholar.google.com.br), BVS (http//bvsalud.org/), and LILACS (http://lilacs.bvsalud.org) was performed using the inclusion criteria "urinary metabolites," "tobacco," "biomarkers," "body fluids," and "metabolomics." We collected papers with cross-references that were published from 1985 to 2020. The search included original laboratory studies, systematic reviews, and literature that were developed on human species. The search included a total of 55 articles from wherein we reviewed the utility of urinary metabolites as biomarkers in tobacco users.

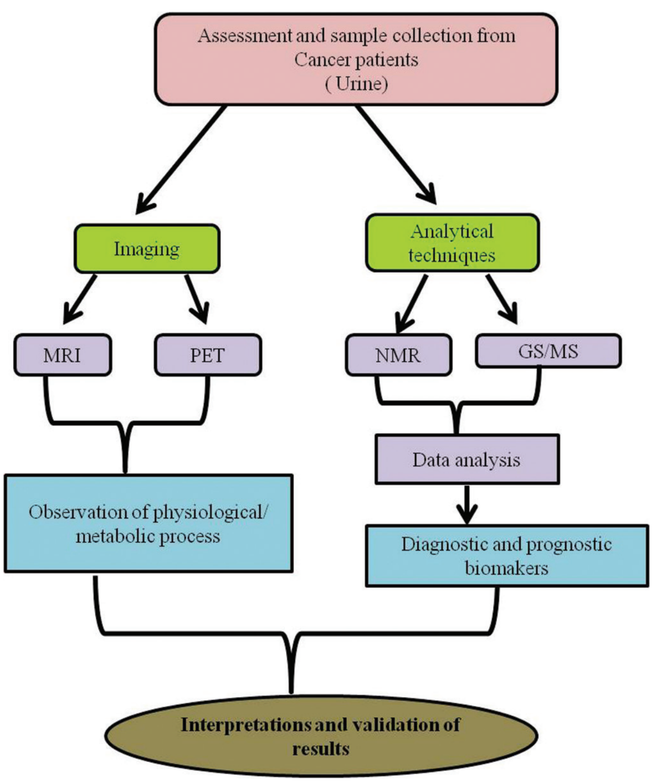


Figure 1: Step-wise method to use urinary metabolites as biomarkers in cancer screening

Urinary carcinogenic metabolites

Measurement of human urinary carcinogen metabolites is a practical approach for obtaining important information about tobacco and cancer.[22] Studies and research material show that OSCC and precancerous lesions are not only because of aberrant expression of genes and proteins but also abnormal concentrations of endogenous metabolites. Urine samples are not commonly used in H and N cancer metabolomic studies as compared to other body fluids, whereas it is widely used by metabolomic researchers for other conditions or diseases as it is easy to obtain and has a wide metabolic cover.[23]

Several types of carcinogenic biomarkers have been used till date. Human urinary carcinogenic metabolites can be an alternative means of detecting toxicity and carcinogenesis in subjects with tobacco habits [Figure 2]. Biomarkers from urine can help us understand tobacco-related cancer mechanisms. This will also help us develop preventive strategies which may decrease the toll of cancers[24] [Figure 3].

Urinary metabolites in tobacco smokers and nonsmokers

Carcinogenesis links nicotine addiction and cancers. Tobacco is consumed in various forms by millions of people in India. Individuals who do not smoke are exposed to passive smoking. These tobacco products contain thousands of chemical constituents including major alkaloids (nicotine) and minor alkaloids (noricotine, anabasine, anatabine, etc.). These alkaloids can react with nitrite to form nitrosamines such as 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone (NNK) and 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanol (NNAL), which are called tobacco-specific nitrosamines. These tobacco constituents are important progenitors in the formation of tobacco-specific nitrosamines.[25] The major constituents of tobacco such as nicotine, cotinine, and nitrites + nitrates are excreted in the urine of tobacco-exposed individuals and used as the markers of tobacco exposure. Methods such as thin-layer chromatography, high-performance liquid chromatography (HPLC), gas chromatography (GC), and mass spectrophotometry (MS) can be used to estimate urine cotinine and nicotine levels in urine. Tobacco exposure to electrophilic moieties increases

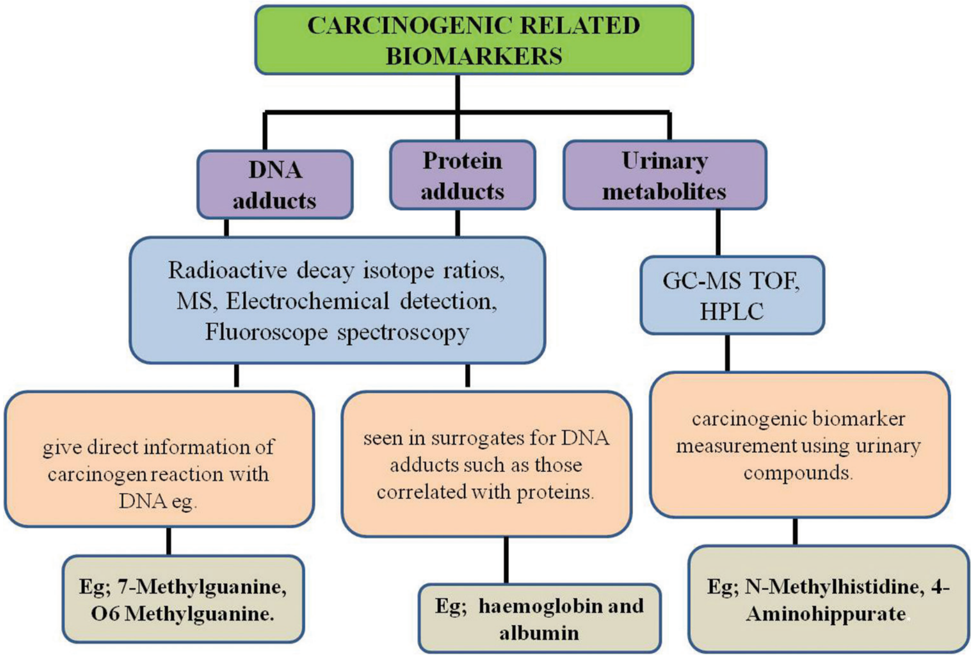


Figure 2: Types of carcinogenic biomarkers

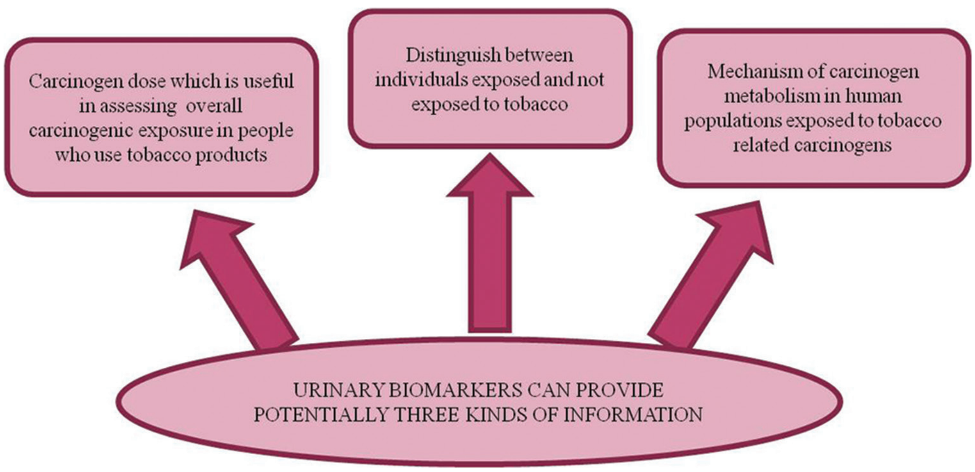


Figure 3: Uses of urinary biomarkers

urinary thioether levels which is another useful biomarker of tobacco exposure.[16,24-26]

Measurements of urinary compounds have many advantages. Important among these is their quantity which is sufficient enough with the use of modern analytical methods giving reliable data. Urine is simple to obtain in large quantity, and compliance is not a problem.[5,22,27]

Results

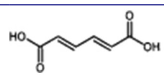
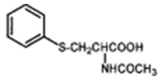
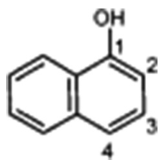
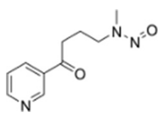
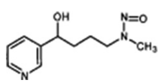
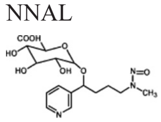
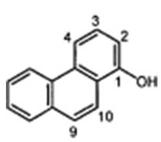
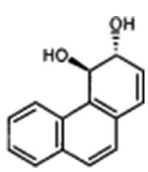
While reviewing the articles and literature, we came across various studies where urinary metabolites were assessed in smokers and nonsmokers. The studies showed results which supported and favored the presence of biomarkers in the urine of individuals with varying tobacco habits. The results of all those studies are summarized in Table 1 and further talked over in the discussion.

Discussion

Nuclear magnetic resonance (NMR) spectroscopy is a commonly used analytical method to analyze the small molecule composition that is the metabolome of body fluids such as urine and blood serum. Metabolite concentration is associated with the biochemical state of the organism. Conditions such as disease state and response to chemical treatment can change these metabolic concentrations. Recent studies demonstrate the applicability of NMR-based metabolomics using serum and urine samples for the diagnosis and prognosis of disease.[21]

Multiple researches on tobacco demonstrate that nicotine-derived nitrosamines such as NNK and NNN as well as nornicotine-, anabasine-, and anatabine-derived nitrosamines significantly contribute to tobacco carcinogenesis.[41] Wei

Table 1: Common Urinary Biomarkers

Chemical compound	Chemical structure of the urinary biomarker studies	Results in various studies and type of tobacco habit: Smokers	Nonsmokers
Benzene metabolite	 tt-MA	Significantly elevated levels in the urine of smokers. 1.4–4.8 times greater than nonsmokers[28] Boogaard *et al*.; no significant difference between tobacco habits[29]	No significant levels detected Mixed results obtained by environmental tobacco smoke-exposed subjects[22]
	 S-PMA	Significantly higher in smokers[30]	No significant levels detected
	 1-and 2-naphthol	Various studies suggest elevated levels in smokers[31,32] Nan *et al*. reported almost twice the levels in smokers and significant results (P<0.01)[33]	No significant levels were detected in studies
N-nitrosamine	 NNK		
	Strongest detected carcinogen that plays an important role in cancer induction (oral cancer, leukoplakia, and lung cancer)[34]		
	Ratio of the following two metabolites of NNK have been intensively studied and detected in the urine of tobacco habit users in assessing exposure and screening oral cancers		
	 NNAL	Identified in urine along with NNAL-O-Gluc as NNAL is not present in cigarette smoke[35]	Not excreted in urine[35] Exceptionally high levels of both NNAL and NNAL-O-Gluc excreted[36]
	 NNALgluc (conjugated glucuronide form of NNAL-O-Gluc)	Present in urine, comprise 50±25% of total NNAL-0-Gluc[37] Both NNAL and NNAL-O-Gluc found[34]	Present in urine, comprise 24±12% of total NNAL-0-Gluc[37] Both metabolites of NNK are readily determined in tobacco chewers and snuff dippers. Same levels as smokers[34]
Polyaromatic hydrocarbon	 1-HOP	Significantly higher levels in smokers in most studies. Many studies show twice and even more levels of 1-HOP in smokers than nonsmokers[22,38]	Nonsignificant levels detected
	 Phenenthrene-1,2-dihydrodiol and phenanthrene-3,4-dihydrodiol	The ratio between these two metabolites decreases further with an increase in smoking	Studies done by Jacob *et al*.[39] and Heudorf and Angerer[40] show similar results of lower ratio of the two metabolites in both habit groups

tt-MA: Trans,trans-muconic acid; S-PMA: S-phenylmercapturic acid; 1-HOP: 1-hydroxypyrene; NNK: 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone; NNAL: 4-(methylnitrosamino)-1-(-3pyridyl)-1-butanol

et al. in their study established that NNK levels in the urine of tobacco-exposed individuals can help investigators ascertain the best means to protect people's health and help prevent cancer.[42] As mentioned in Table 1, Murphy *et al*. in their study using urine samples analyzed NNAL, and its glucuronide NNAL-O-Gluc along with 1-hydroxypyrene and anatabine found a positive correlation between anatabine and urinary NNAL and NNAL-O-Gluc (both metabolites of the tobacco-specific carcinogen NNK) showing their usefulness as a biomarker of tobacco exposure.[36,43] Kresty *et al*. concluded a potentially important finding and relationship between the levels of NNAL, NNAL‑Gluc along with cotinine in urine, and the presence of oral leukoplakia in their study.[34] Experiments have shown the induction of oral tumors in rat mucosa on applying a mixture of NNK metabolites validating the role of these products in inducing precancerous lesions of the oral cavity.[44]

One of the first attempts to study urine metabolites in screening oral lesions was done by Xie *et al*. using GC‑MS in a combination of three differential metabolites. They used 6‑hydroxynicotic acid, cysteine, and tyrosine to segregate between OSCC and OLK. Their study had a sensitivity and specificity of 85% and 89.7%, respectively, with an accuracy of 92.7%. Their study clearly indicated that urinary metabolite profiling can be a promising diagnostic tool for the early stages of OSCC and for differentiating between other oral lesions and conditions.[16]

As discussed in Table 1, benzene metabolites such as trans, trans‑muconic acid (tt‑MA) and S‑phenylmercapturic acid (S‑PMA) have been studied extensively to assess tobacco exposure and significantly high levels of these metabolites have been found in the urine of smokers.[28,29] Both tt‑MA and S‑PMA are the most sensitive biomarkers, the latter being more according to Boogaard.[29] Similarly, Nan *et al*. using benzene metabolites 1‑ and 2‑naphthols came to the conclusion of the presence of high levels of these metabolites in smokers although no significant levels were noted in nonsmokers.[33]

The presence of polycyclic aromatic hydrocarbon metabolites in urine was first demonstrated by Jongeneelen[38] using HPLC, and since then, many variations to this method have been used to study the presence of these metabolites in the urine of tobacco‑exposed individuals.

Besides the metabolites discussed above, studies to assess the role of tobacco habits as a risk factor for the development of oral cancer have been done by evaluating other urinary metabolites such as nicotine, cotinine, thioether, nitrite, and nitrate levels that have been compared in subjects with and without tobacco habit as discussed in the following section. Modified HPLC using a UV detector is used to analyze urinary nicotine and cotinine levels. Levels of nitrites + nitrates in tobacco and urine and urinary thioether levels are estimated by spectrophotometry. It has shown that tobacco chewing and smoking habits are prominent risk factors for the development of oral cancer. Urinary nicotine, cotinine, nitrite + nitrate, and thioether levels can be helpful for screening programs for oral cancer.[24,26]

Patel *et al*. in a study done in Gujarat, India, evaluated urinary nicotine, cotinine, thioether, and NO2 + NO3 levels in healthy individuals without habits of tobacco, healthy individuals with habits of tobacco, patients with oral precancers, and oral cancer patients; their results confirmed that tobacco chewing and smoking habits are prominent risk factors for the development of oral cancer. Urinary nicotine, cotinine, NO2 + NO3, and thioether levels can be helpful for screening programs for oral cancer.[24] In another study, Behera *et al*. using HPLC assay analyzed the urine of smokers and chewers for nicotine and cotinine levels and found these components as useful markers to assess the effects of different tobacco types.[45] Similarly, a study by Oberoi and Oberoi concluded a significant increase in urinary cotinine levels among smokers and smokeless tobacco individuals compared to nonsmokers.[46] Urinary cotinine is a widely used biomarker as it has the advantage of being 4–6 times more than blood or salivary cotinine and is highly sensitive when assessed.[47,48] Both smoked and chewed forms of tobacco are highly linked to the induction of OSCC. Higher risk is associated with greater amounts and longer duration of tobacco use.[24,41]

Urine metabolomics has emerged as an outstanding noninvasive realm in discovering biomarkers that can detect the slightest of metabolic discrepancies in response to a specific disease or therapeutic interpretation.[49] The development and advances in LC‑MS/MS have revolutionized analytical studies of biomolecules including urine metabolome by enabling their accurate identification and in an unprecedented manner.[50] A study done by the Internal Radiation and Clinical Oncology Department, Maria Sklodowska‑Curie Institute‑Oncology Center, Poland, showed that metabolic alterations using NMR can be detected already at the beginning of the treatment, making it possible to monitor the patients with a higher risk.[51] MS‑based metabolomic technology has provided exciting opportunities in the field of health and medical science. It is believed that, with the continuous progress in technologies, there will be more and more effective biomarkers for the diagnosis of clinical diseases and treatment.[52]

Conclusion

Urinary metabolomics is an efficient and accurate means to retrieve data about tobacco exposure and oral cancer. The biomarkers discovered and obtained from urine can enhance our knowledge and understanding of tobacco‑related cancer mechanisms, which can help us evolve new strategies and action plans to help combat the loss of life to cancers. Various studies performed demonstrate that this robust and noninvasive profiling approach can be a promising screening tool for the early diagnosis of oral cancer. Furthermore, studies can highlight the applicability of urinary metabolite markers that can be used as a stratification tool in the diagnosis of different oral conditions, complementary to the existing clinical procedures.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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Unveiling Biological and Therapeutic Properties of Calotropis Procera: A Promising Traditional Medicine

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KEYWORDS
Calotropis procera; Phytochemistry; Traditional medicine; Pharmacognosy; Anti-cancer; Anti-inflammatory; Antioxidant, Oral Health, Dental Disorders, Dentistry

ABSTRACT:
Since the dawn of civilization, people have utilized plants as a secure and efficient form of treatment for a variety of illnesses. A number of traditional medicines are formed from certain plants with medicinal and therapeutic properties. It has long been known that Calotropis procera offers potential as a therapy for many different conditions. This xerophytic, erect shrub is native to the tropics of Asia and Africa, where it reaches a height of roughly 6 meters. Numerous illnesses, such as rheumatism, fever, diarrhea, diabetes, malaria, asthma, and many more, have been treated using its constituents.

The latex has demonstrated strong benefits against inflammation, cancer, wound healing, hepatoprotection, inflammation prevention, nerve regeneration, antiulcer, insecticidal, and antimalarial bacteria. The study also discovered that consuming too much has detrimental impacts on health. The study found a wealth of documentation supporting the biological assessment of C. procera in both in vitro and in vivo animal models. However, human safety and efficacy remain to be fully investigated, and more carefully planned clinical trials are needed to validate preclinical results. Establishing a standard dose and ensuring its safety are crucial.

This review provides the biological information that is currently available about the potential therapeutic and biological uses of C. procera for the management of various illnesses with an insight on its potential applications in oral health and dentistry.

1. INTRODUCTION

Herbal remedies have been employed over thousands of years to cure ailments in individuals as well as animals.[1] Plants have historically been trusted as a reliable source of both preventive medicine and therapy in many cultures. In many parts of the developing

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world, herbal remedies continue to be the main source of healthcare.[2] Traditional medicines are used to address prevalent healthcare concerns by 80% of the global population, primarily in developing countries. In nearly all cultural backgrounds, they are used as nutrition and as a medicine. [3,4] Even more astounding is the fact that plants serve as the foundation for around 25% of modern medications.[4] Their use greatly enhances the provision of basic medical care and they are seen as indispensable sources of medicinal items, including herbal remedies. The healthcare and biopharmaceutical sectors have made bioactive plant products an essential component of their scientific and technological advancement. [5] A species of plant in the Asclepediaceae family called *Calotropis procera (C. procera*), commonly known as "Madar," has been utilized for centuries in ancient therapy. This shrub is continuously subjected to harsh conditions, but it nevertheless yields latex and grows well in natural environments.[5,6] The plant discharges a creamy latex substance, which is particularly prevalent in its aerial segments, when it is wounded. In addition to being rich in beneficial additional chemicals and enzymes, it shields the plant against damage and has been revered in traditional medicine for its diverse therapeutic properties.[5,6] Indigenous communities have utilized various parts of the plant for centuries, recognizing its potential in treating a range of ailments. The latex extracted from *Calotropis procera* has demonstrated notable anti-inflammatory properties, making it valuable in managing conditions like arthritis and skin disorders. Additionally, the plant exhibits antimicrobial effects, contributing to its application in wound healing and skin infections. [7,8]

The roots of *C. procera* have been traditionally employed for their analgesic qualities, offering relief from pain associated with conditions such as rheumatism and muscular injuries. Its efficacy in addressing respiratory issues has also been acknowledged, attributing the plant's use in overall well-being.[8] Furthermore, it has shown potential as an anti-cancer agent, with certain compounds exhibiting cytotoxic effects on cancer cells that has sparked interest in its potential role in modern medicine. [9] This review aimed to conduct a thorough literature assessment on the biological and therapeutic importance of its constituent parts. This article also discusses its potential benefits for dental health and how its ingredients are used in dentistry.

2. METHODS

An electronic search through PubMed, Scopus and Google Scholar for “Calotropis procera”, “antioxidant”, “traditional medicine”, “anti diabetic”, “anti bacterial”, “anti viral”, “anti microbial”, “ethnopharmacology”, “toxicity”, investigating a number of studies. Then, we consecutively screened abstracts and, full-text articles published in English. A total of 138 articles were found in PubMed and 9 duplicate papers were excluded. Additionally, 85 articles were excluded as they were case reports, case series, editorials, letter to editor, commentaries and conference proceedings. Finally, 45 papers published in last 20 years were analyzed in this article. In Figure 1, were analyzed in this review.

3. REVIEW

<u>Anti inflammatory property</u>

In pharmacologic models of formaldehyde-induced arthritis, cotton pellet granuloma, and carrageenin-induced foot oedema in rats, significant dose-related activity was demonstrated for a chloroform-soluble fraction ($p<0.001$). When it came to preventing the development of foot oedema, the extract at a specific and substantial doze was effective.[10] Macroscopic and microscopic analyses has revealed that colonic mucosal damage in colitic rats is much decreased after receiving Methanol extract of dried latex (MeDL) therapy, and oxidative stress level in tissues and proinflammatory mediators were recovered.[11] Also the plant extract exhibits the strongest anti-inflalmmatory effects with IC50 values of 7.6 µM against 5-LOX and 2.7 µM against 15-LOX,. [12] The extract administered at 100 and 200 mg/kg, significantly reduced inflammation. At these dozes, the extract shows 21.6 and 71.6% inhibition, respectively. This extract at doses 50 and 500 mg/kg has also proven to decrease inflammation in rats with arthritis.[13] In vivo testing at dosages of 200 and 400 mg/kg, respectively has also shown considerable anti-inflammatory effectiveness employing hydroalcoholic and chloroform extracts of this plant.[14]

Anti microbial property

Studies have demonstrated both antibacterial and antifungal properties of *C. Procera* in it different forms. These properties have been found in cardenolide (proceragenin) against S. aureus, S. pyogens and S. saprophyticus and in the ethanol extract of the leaves and latex against E. coli and P. aeruginosa of this plant. Water-soluble extract (250 μg/mL) has been found effective against C. perfringens and S. faecalis. The maximum efficiency against the examined bacterial strains has been demonstrated by the crude flavonoid fraction and the leaf and bark extracts prepared with 50% methanol are effective against B. subtilis and K. pneumonia. [16]

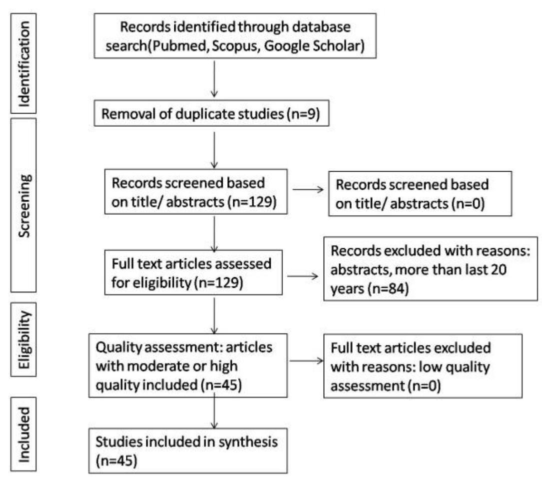
Many antifungal properties have also been found in it's extract, however, ethanol and chloroform extracts showed remarkable performance over water extract and were effective against C. albicans.[16] Crude flavonoids were the most effective portion of flavonoids, which had 30 mm-diameter inhibitory zones against C. albicans. T. rubrum and A. terreus after being treated with Latex silver nanoparticles. The IC50 values of all the peptidases (procerain and procerain B) evaluated in previous studies were approximately 50 μg/mL thereby inhibiting the fungi in vitro.[17]

Antioxidant and anti–cancer property

Studies have demonstrated that the plant extracts accounts for 42–90% free radical scavenging activity with 2,2-Diphenylpicrylhydrazyl (DPPH) radical scavenging assay. Also in the assays using hydrogen peroxide and hydroxyl radicals, the methanol extract exhibited maximum scavenging activity (83.63%) at 500 μg/mL over ferric thiocyanide, while the DPPH assay revealed least activity (50.82%).[18] The use of dry latex of this plant for 31 days, decreases Thiobarbituric acid-reactive substances (TBARS) levels. Root extracts and ethanol floral extract have lowest level of antioxidants (IC50 = 0.27 mg/mL, IC50 = 142 μg/mL), while lyophilized latex extracts and aqueous flower extract have greatest values (IC50 = 0.060 mg/mL, IC50 = 85 μg/mL) as a radical scavenger.[19] For DPHH, the ethyl acetate extract has the most radical scavenging activity (95%), followed by ethanolic floral extract (88.1%) and aqueous extract of methanol (85.5%).[20] Antioxidant property by the phenolics is exhibited by the location of the functional groups surrounding their nucleus and the quantity and configuration of their H-donating hydroxyl groups present within calotropogenin, calotropin, latex and calotoxin parts of the plant.[21]

Wound healing Activity

In a study topical application of sterile latex solution has improved wound healing due to its ability to stimulate collagen, DNA, and protein production resulting in re-epithelization of the wound.[22] Similar studies on rats demonstrated faster wound healing time and wound contraction after application of the extract.[23]



4. DISCUSSION

4.1 Provenance of the plant and phytochemistry

C. procera, erect, velvety woody shape achieves a height of 2.5–6 m. It is found everywhere in the world because it prefers temperatures that are warm, dry, sandy, and alkaline soils. It grows well in a range of various habitats, such as sand dunes, highway channels, swamps, waste dumps, and derelict areas.[24] It harbors a rich tapestry of phytochemical constituents, contributing to its diverse therapeutic properties. The phytochemical profile of this plant encompasses a variety of compounds, each playing a distinct role in its pharmacological activities. [25]

Alkaloids and Terpenoids:

Calotropin and Uscharin are notable alkaloids found in *C. procera*, contributing to its anti-inflammatory

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properties. These compounds have been associated with inhibiting inflammatory mediators. Terpenoids like β-sitosterol contribute to the overall pharmacological profile of *C. procera* and is a phytosterol with potential anti-inflammatory and analgesic effects. Tannins, including gallic acid, contribute to the astringent properties of *C. procera*. These compounds may play a role in wound healing and tissue repair. [26]

Flavonoids and Glycosides:

C. procera contains flavonoids with antioxidant properties such as Quercetin and Kaempferol Derivatives. These compounds play a role in scavenging free radicals and contribute to the plant's overall therapeutic potential. An active glycoside found in the latex of *C. procera*, known for its antimicrobial properties is Calotropin, which contributes to the plant's efficacy in addressing various microbial infections. Certain parts of *C. procera* contain cardiac glycosides, such as calotoxin. However, caution is advised in their use due to potential toxic effects, emphasizing the importance of proper dosage and preparation. [27,28]

4.2 <u>Biological and Therapeutic activities pertaining to oral health</u>

C. procera emerges as a versatile traditional medicine, offering a spectrum of therapeutic benefits. From addressing inflammatory and microbial challenges to providing relief in pain management of various dental disorders, the plant also holds promise across various healthcare domains.

4.2.1 Anti-Inflammatory and Analgesic Activity:

The presence of compounds like calotropin and uscharin present in the latex of this plant atribute to this activity. These compounds inhibit the synthesis of prostaglandins, suppress pro-inflammatory cytokines and inhibit NF- kB activation ultimately leading to overall anti-inflammatory effect. Root extracts of *C. procera* showcase analgesic properties, offering relief from pain associated with rheumatism and muscular injuries thereby attributing in pain management.[29]

4.2.2 Antimicrobial Potency:

The robust antimicrobial activity against bacteria and fungi is due to presence of proceroside, proteolytic enzymes, syriogenine, cardenolides, carbohydrates, cardiac-active glycosides, calactin, calotropain, calotoxin, alkaloids, tannins, flavonoids, and procerain present in the plant. It disrupts the integrity of cell membrane, inhibits the ergosterol synthesis and alters the fungal cell wall components collectively contributing to the antifungal effect.[30,31]

4.2.3 Antioxidant and Anti-Cancer Potential:

Flavanol glycosides, cardinolides and lignans present in this plant exhibit promising cytotoxic effects on cancer cells, suggesting a potential role in cancer treatment. The exploration of its anti-cancer pharmacology opens avenues for further research in oncological applications.[29]

4.2.4 Wound Healing activity

The extract from this plant contains triterpenoids such as amyrin, flavonoids, cardiac glycosides, cardenolide anthocyanins, mudarine, lupeol, sitosterol, flavanols, resin, a nontoxic proteolytic enzyme called calotropin, and a strong bacteriolytic enzyme called calactin. These products stimulate the proliferation of fibroblasts and collagen deposition, facilitating tissue repair and regeneration. Additionally, these extracts exhibit analgesic effects, which alleviate pain associated with wounds. The plant's ability to enhance angiogenesis, the formation of new blood vessels, further supports tissue repair by ensuring an adequate blood supply to the wounded area.[32]

4.3 <u>Biological and Therapeutic activities pertaining to general and overall health</u>

4.3.1 Respiratory Health Benefits:

The plant's products are effective in managing respiratory conditions such as asthma and bronchitis. Active compounds contribute to bronchodilation and anti-inflammatory effects, supporting its traditional use in respiratory ailments.[33]

4.3.2 Antifertility Activity:

This is attributed to its ability to disrupt various stages of reproductive function. It may inhibit spermatogenesis in males and interfere with ovarian function in females, leading to contraceptive effects.[34]

4.3.3 Antiglaucoma Activity:

Studies have shown that extracts of *C. procera* possess is believed to reduce intraocular pressure, which is a key factor in the pathogenesis of glaucoma, thereby helping to manage the condition.[35]

4.3.4 Antimalarial Activity:

Its bioactive compounds have been found to inhibit the growth and replication of the malaria parasite, making it

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a promising candidate for malaria treatment and prevention.[36]

4.3.5 Antidiarrheal Activity:

The products of this plant have the ability to reduce intestinal motility and secretion, alleviating diarrhea by exerting an inhibitory effect on various pathways involved in diarrheal mechanisms.[37]

4.3.6 Anticonvulsant Activity:

Calotropis procera demonstrates anticonvulsant effects, making it potentially useful in the management of epilepsy and other seizure disorders. Its bioactive constituents modulate neurotransmitter activity and neuronal excitability, thereby reducing the frequency and severity of seizures.[38]

4.3.7 Antidiabetic Activity:

Studies have indicated that *Calotropis procera* exhibits antidiabetic properties by lowering blood glucose levels and improving insulin sensitivity. Its mechanisms of action include enhancing pancreatic function, promoting glucose uptake by cells, and inhibiting carbohydrate digestion and absorption.[39]

4.3.8 Hepatoprotective Activity:

Calotropis procera demonstrates hepatoprotective effects, which can help safeguard the liver against various insults and toxins. It aids in the regeneration of liver cells, reduces oxidative stress, and inhibits inflammation, thereby promoting liver health and function.[40]

4.4 Toxicology:

Despite its therapeutic promise, it's essential to approach the use of *C. procera* with caution, as improper dosage or preparation can lead to adverse effects. Integrating traditional knowledge with contemporary research will enhance our understanding of this plant's medicinal potential and pave the way for its responsible incorporation into modern healthcare practices. Caution is warranted in the utilization of *C. procera*, as certain parts of the plant contain toxic compounds, including cardiac glycosides. Improper dosage or preparation may lead to adverse effects. Rigorous studies on toxicology are imperative to establish safe usage guidelines and mitigate potential risks associated with its traditional medicinal applications.[41]

5. CONCLUSION:

Nature contains vast array of compounds that may be used to create remedies for a variety of chronic diseases. Numerous therapeutic plants and their components have been shown to –provide great therapeutic benefits and one such plant is *C. procera*. Calotropis procera's journey from phytochemistry to pharmacology unfolds a narrative of diverse therapeutic potential. As research progresses, understanding its toxicological aspects becomes paramount for safe integration into healthcare practices. This comprehensive review sheds light on the intricate interplay of phytochemical constituents, pharmacological actions, therapeutic applications, and the imperative need for cautious exploration in the realm of *C. procera*.

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Assessment of neurovascular channels in lateral maxillary sinus wall using cone-beam computed tomography: An imperative clinicians guide for implant placements

ABSTRACT

Background: The aim of this study is to evaluate the location and radio morphometric features of the posterior superior alveolar artery (PSAA) in patients undergoing rehabilitation of posterior maxilla and other sinus augmentation surgical procedures by cone-beam computed tomography (CBCT).

Materials and Methods: A total of 816 CBCT scans were included. Various radio morphometric measurements were done to assess the PSAA location, diameter, and distances to the sinus floor and alveolar crest.

Results: The PSAA was mostly intraosseous in the maximum in the age group 31–51 years (56%), in males (53.4%), and in dentate patients (57.4%). The artery tends to be wider in older patients. Distances to the sinus floor or the alveolar crest tend to be shorter in women.

Conclusions: This study suggests that CBCT is a valuable pre-surgical tool and the evaluation of the PSAA on CBCT images could reduce the likelihood of excess bleeding during surgery in the maxillary posterior region.

Keywords: Alveolar antral artery, cone-beam computed tomography, maxillary sinus, posterior superior alveolar artery

INTRODUCTION

The posterior superior alveolar artery (PSAA) can be damaged during a number of surgical procedures and must be carefully analyzed during pre-assessment of the dental implantation site using CBCT.[1] Damage to this artery results in the potential risk of bleeding during the procedure which obscures the vision of the operator and may also lead to perforation of the Schneiderian membrane.[2] During placement of implants in the maxillary posterior region, the amount of residual bone present in this region plays a key role in its success. This may be affected by the maxillary sinus pneumatization, loss of alveolar bone due to tooth extraction, or vertical loss of residual bone. Therefore, careful pre-assessment of the amount of residual bone from the alveolar crest to the maxillary sinus should be considered in planning implantation in this region.[3] Cone-beam computed tomography (CBCT) aids in providing the best treatment plan by determining the location and characteristics of important anatomical landmarks before surgery.[4] Limited data are available to assess PSAA and residual bone together in posterior maxillae in Indian sub-populations. Hence, we aimed to investigate the information about the differences in radio morphometric measurements of PSAA and residual bone in the premolar and molar areas which may be useful for the rehabilitation of the maxillary posterior regions. The null hypothesis is that there is no statistical difference in the

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prevalence and location of PSAA and residual bone among different age groups, genders, and dentate status.

MATERIALS AND METHODS

This retrospective cross-sectional study was performed on 1000 CBCT volumes who had retrospectively undergone CBCT imaging at the Outpatient Department of Oral Medicine and Radiology for treatment purposes. The protocol ethics were approved by the research committee of the Institute, in accordance with the Helsinki Declaration. However, the final sample size was determined as 811 CBCT scans that met the inclusion criteria of the study and on the minimum radiologic prevalence of PSAA in the literature (i.e., 50%) which was necessary for calculating the maximum sample size, and a precision of $d = 0.05$ at a 95% level of confidence.

The study population was divided into three age groups: 10–30 years, 31–51 years, and 52–72 years. Comparisons were made age wise, gender wise, and dentate status, i.e., dentulous or partially edentulous. For Ethical Clearance was obtained from Institute of Dental Studies and Technologies Institutional Ethical Committee with Ref no IDST/IERBC/2017-20/25 dated 23/11/2017. A written consent was obtained from each patient to access their CBCT data for research.

CBCT Measurements

The cases were sampled randomly from the archive of existing CBCT volumes obtained from Kodak CS 9300 (Carestream Dental, Atlanta, USA) dental imaging system. Linear measurements were carried out to localize the mediolateral and vertical position of the posterior superior alveolar artery in postero-lateral wall of the maxillary sinus and its proximity to the floor of the maxillary sinus using CS 3D imaging 3.7.0 software program. The exposure settings during the scan included 60 kVp, 12 mA, voxel size 0.2 mm, and FOV 11 × 5 cm with an exposure time of 15s. Reformatting of the 3D reconstructions was created by using the axial CBCT scans on a local workstation using CS 3D imaging 3.7.0 dental imaging software. The cross-sectional images were obtained with 1 mm of slice thickness.

The exclusion criteria comprised poor quality scans, scans with artifacts and pathological lesions disrupting normal sinus anatomy, and severe periodontal bone loss.

Each CBCT scan was oriented prior to the location of PSAA. The cross sections were obtained of the 1st and 2nd premolar and 1st and 2nd molar region in dentulous or edentulous maxillary scans and evaluated for the optimal visualization of the radiolucent PSAA in postero-lateral wall of the maxillary sinus. The relative position of PSAA to mediolateral wall of the maxillary sinus was determined as: (a) Type I: intrasinusal (b) Type II: intraosseous, and (c) Type III: superficial. [Figure 1] The location of PSAA was assessed in most caudal position of PSAA by using the following measurements: distance from PSAA to mesial wall of sinus (D1) [Figure 2], height from alveolar bone crest to floor of sinus (H2) [Figure 3], height from lower border of PSAA to alveolar bone crest (H1) [Figure 4].

The measurements were used to estimate the interobserver reliability. The resulting intra-class correlation coefficients ranged between 95 and 99%, indicating excellent inter-observer agreements.

Statistical analysis

Descriptive statistics and 95% confidence intervals (CI) were calculated. The data were analyzed using SPSS version 21.0 (IBM Corporation, New York, USA). Distribution of artery localization and radio morphometric measurements according to age and gender were carried out using Chi-square test and one-way ANOVA test, respectively. $P \leq 0.05$ was considered as statistically significant.

RESULTS

Overall, the PSAA canal was detected in 810 patients (99.87%) out of 811 approved subjects irrespective of age, gender, and dentate status. The prevalence of PSAA was seen maximum in 31–51 years (41.9%) and least in 52–72 years (23%). Of the 810 patients, 474 (58.4%) were males and 336 (41.4%) were females. There were 158 (19.5%) partially edentulous regions and 652 (80.4%) dentulous regions in which the canal was observed. Artery localization and tooth-wise distribution according to age, gender, and dentate status are described in Tables 1 and 2.

A detailed description of the distribution of PSAA and its various radiographic morphometric measurements according to age, gender, and dentate status are described in Tables 3-6.

The minimum artery diameter (0–1 mm) was seen maximum in the age group 31 to 51 years, in males and in dentate subjects, whereas the maximum artery diameter (>2.0 mm) was seen maximum in 31 to 51 years, in males and in dentate subjects, and the results were statistically significant ($P = 0.001$) [Table 3].

The mean height from lower border of PSAA to alveolar bone crest (H1) in both 10–30 and 31–51 years was found maximum at 1st premolar and minimum at 2nd molar region, whereas for 52–72 years, it was found maximum at 2nd premolar and minimum at 2nd molar region. In males, it was maximum at

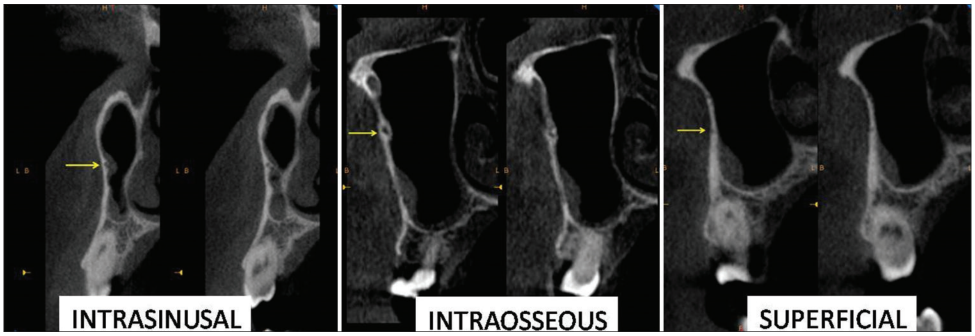

Figure 1: TYPE OF PSAA

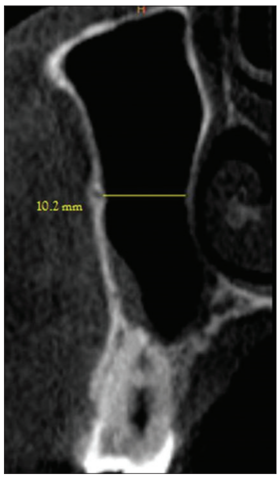

Figure 2: Distance from PSAA to medial wall of sinus (D1)

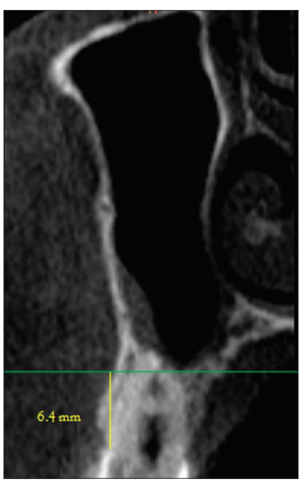

Figure 3: Height from alveolar crest to floor of sinus

1st premolar and minimum at 1st molar region, whereas for females, it was maximum at 1st premolar and minimum at 2nd molar region. According to dentate status in dentates, it was maximum at 1st premolar and minimum at 2nd molar region, whereas for partially dentates, it was maximum at 1st premolar and minimum at 2nd molar region and the results were statistically significant for the age group 10–30 years, gender wise and partially dentates (P = 0.001) [Table 4].

The mean height from alveolar bone crest to floor of sinus (H2) was found maximum at 1st premolar in all three age groups, whereas it was minimum at 2nd molar region for 10–30 years, at 1st molar region for 31–51 years, and at 2nd premolar region for 52–72 years, respectively. Irrespective of gender, it was maximum at 1st premolar and minimum at 1st molar region. According to dentate status in dentates, it was maximum at 1st premolar and minimum at 1st molar region, whereas for partially dentates, it was maximum at 1st premolar and minimum at 2nd molar region and the results were statistically significant (P = 0.001), except for males (P = 0.029). [Table 5]

The mean distance from PSAA to medial wall of sinus (D1) in all age groups was found minimum at 1st premolar region except for 52–72 years where it was at 2nd premolar region, whereas maximum was found at 2nd molar region. Irrespective of gender and dentate status, it was maximum at 2nd molar region and minimum at 1st premolar region and the results were statistically significant (P = 0.001), except for dentates (P = 0.033). [Table 6]

DISCUSSION

The challenges faced by surgeons during the rehabilitation of edentulous posterior maxilla depend on alveolar bone loss, post-extraction, or sinus pneumatization.[5] Common complications encountered during the surgical intervention in this region include perforation of the Schneiderian membrane and hemorrhage as a result of damage to PSAA bvgt65t. This may further lead to reduced visibility, postoperative hematoma, infection, and complete loss of graft.[5,6]

Therefore, a thorough knowledge of the blood supply of this region is of utmost important for the surgeon before planning any intervention. PSAA anastomoses with the infraorbital artery and supply the lateral wall of the maxillary sinus.[4]

The advent of CBCT and the vast array of advantages of using this advanced imaging modality have revolutionized the diagnosis and treatment planning in dentistry. In cases of dental rehabilitation of the posterior maxillary region, CBCT has proven to be a boon to surgeons and implantologists as it aids in radiological pre-assessment of the implant site in terms of one density assessment and other morphometric measurements of the implant site.[5,6]

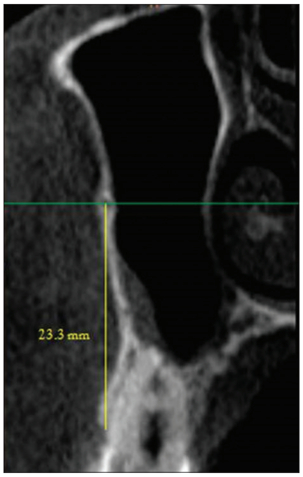

Figure 4: Height from lower of border PSAA to alveolar crest

The current study assessed gender-wise age-wise, tooth-wise differences in dentulous and edentulous patients in terms of localization, diameter of PSAA, height from lower border of PSAA to alveolar bone crest, height from lower border of PSAA to floor of sinus, distance from PSAA to medial wall of sinus, and height from alveolar bone crest to floor of sinus.

Further, the current study included 474 males and 336 females. Similar studies have been conducted in the past by Danesh-Sani *et al*.[5] and Tehranchi *et al*.[7] In the present study, PSAA was observed in dentate ($n = 652$) and partially edentulous

Table 1: Artery localization according to age, gender, and dentate status

		Absent	Type I	Type II	Type III	p value
		N (%)	N (%)	N (%)	N (%)	
Age	**10–30 years**	0	138 (49.6%)	140 (50.4%)	0	
	31–51 years	1 (0.3%)	74 (21.7%)	191 (56%)	75 (22%)	**0.0001***
	52–72 years	0	54 (28.1%)	108 (56.3%)	30 (15.6%)	
Gender	**Males**	0	164 (34.6%)	253 (53.4%)	57 (12%)	0.290
	Females	1 (0.3%)	102 (30.3%)	186 (55.2%)	48 (14.2%)	
Dentate status	**Dentate**	1 (0.2%)	234 (35.9%)	375 (57.4%)	43 (6.6%)	**0.0001***
	Partially Dentate	0	32 (20.3%)	64 (40.5%)	62 (39.2%)	

*P value significant at $P<0.05$, Chi-square test applied

Table 2: Tooth-wise distribution of different types of PSAA according to age, gender, and dental status

Variable		N (%)	PM1	PM2	M1	M2	p value
			N (%)	N (%)	N (%)		
Age	**10–30 years**	**Type I**	1 (0.7%)	74 (54.0%)	19 (13.2%)	44 (32.1%)	**0.001**
		Type II	57 (40.7%)	83 (59.3%)	0	0	
		Type III	0	0	0	0	
	31–51 years	**Type I**	26 (35.1%)	0	6 (8.1%)	42 (56.8%)	**0.001**
		Type II	47 (24.6%)	44 (23%)	74 (38.7%)	26 (13.6%)	
		Type III	0	27 (36%)	48 (64%)	0	
	52–72 years	**Type I**	0	29 (53.7%)	25 (46.3%)	0	**0.001**
		Type II	0	53 (49.1%)	30 (27.8%)	25 (23.1%)	
		Type III	0	0	30 (100%)	0	
Gender	**Males**	**Type I**	26 (15.9%)	103 (62.8%)	0	35 (21.3%)	**0.001**
		Type II	42 (16.6%)	145 (57.3%)	66 (26.1%)	0	
		Type III	0	27 (47.4%)	30 (52.6%)	0	
	Females	**Type I**	1 (1%)	0	50 (49%)	51 (50%)	**0.001**
		Type II	62 (33.3%)	35 (18.8%)	38 (20.4%)	51 (27.4%)	
		Type III	0	0	48 (100%)	0	
Dentate status	**Dentate**	**Type I**	27 (11.2%)	77 (33%)	44 (18.9%)	86 (36.9%)	**0.001**
		Type II	81 (21.6%)	149 (39.7%)	104 (27.7%)	41 (10.9%)	
		Type III	0	27 (62.8%)	16 (37.2%)	0	
	Partially dentate	**Type I**	0	26 (81.3%)	6 (18.8%)	0	**0.001**
		Type II	23 (35.9%)	31 (48.4%)	0	10 (15.6%)	
		Type III	0	0	62 (100%)	0	

*P value significant at $P<0.05$, Chi-square test applied

Table 3: Artery diameter distribution according to age, gender, and dental status

		0–1 mm	1–1.5 mm	1.5–2.0 mm	>2.0 mm	p value
		N (%)	N (%)	N (%)	N (%)	
Age	10–30 years	137 (49.5%)	98 (35.4%)	42 (15.2%)	0	
	31–51 years	222 (65.1%)	118 (34.6%)	0	1 (0.3%)	0.001
	52–72 years	55 (28.6%)	137 (71.4%)	0	0	
Gender	Males	218 (46%)	213 (44.9%)	42 (8.9%)	1 (0.2%)	
	Females	196 (58.3%)	140 (41.7%)	0	0	0.001
Dentate status	Dentate	301 (46.2%)	308 (47.2%)	42 (6.4%)	1 (0.2%)	
	Partially Dentate	113 (71.5%)	45 (28.5%)	0	0	0.001

*P value significant at $P < 0.05$, Chi-square test applied

Table 4: Mean height from the lower border of PSAA to alveolar bone crest (H1) according to different parameters

		PM1	PM2	M1	M2	p value
Age	10–30 years	28.05±2.81	24.72±3.63	20.8±0.0	16.2±5.24	0.001
	31–51 years	27.24±2.06	22.68±3.91	20.33±2.41	16.28±1.54	0.030
	52–72 years	-	21.17±1.99	17.34±2.43	17.5±0.0	0.014
Gender	Males	27.13±2.07	24.06±3.18	18.12±2.05	20.09±1.37	0.001
	Females	28.10±2.73	17.42±0.91	20.08±2.88	15.27±2.63	0.001
Dentate status	Dentate	27.26±2.57	24.21±3.34	19.12±3.19	16.30±3.21	0.030
	Partially dentate	29.20±0.0	19.31±1.99	19.63±0.98	19.0±0	0.001

*P value significant at $P<0.05$, ANOVA applied

Table 5: Mean height from alveolar bone crest to floor of sinus (H2) according to different parameters

		PM1	PM2	M1	M2	p value
Age	10–30 years	23.57±2.19	15.08±3.84	13.3±0.0	11.20±3.32	0.001
	31–51 years	14.64±0.58	10.48±1.42	7.07±3.34	7.87±3.00	0.001
	52–72 years	14.63±3.79	6.31±0.62	9.40±0.0	10.27±4.64	0.001
Gender	Males	19.78±4.48	14.21±3.84	7.56±1.99	13.66±0.80	0.029
	Females	17.32±4.63	11.55±3.59	7.12±3.69	7.69±2.05	0.001
Dentate status	Dentate	19.26±4.94	14.63±3.81	8.44±2.37	9.74±2.67	0.001
	Partially dentate	15.5±0.0	10.72±2.52	4.57±2.97	2.60±0.0	0.001

*P value significant at $P<0.05$, ANOVA applied

Table 6: Mean distance from PSAA to medial wall of sinus (D1) according to different parameters

		PM1	PM2	M1	M2	p value
Age	10–30 years	3.52 ± 1.36	8.71 ± 2.54	10.50 ± 0.0	16.58 ± 2.01	0.001
	31–51 years	6.19 ± 0.08	10.96 ± 1.17	12.98 ± 1.54	17.18 ± 1.06	0.001
	52–72 years	-	10.61 ± 0.94	11.67 ± 1.46	17.0 ± 0.0	0.001
Gender	Males	4.29 ± 1.47	9.87 ± 1.83	12.02 ± 1.89	17.74 ± 0.99	0.001
	Females	5.79 ± 1.38	8.53 ± 3.94	12.49 ± 1.44	16.68 ± 1.39	0.001
Dentate status	Dentate	4.73 ± 1.65	9.49 ± 2.33	12.49 ± 1.51	16.79 ± 1.30	0.033
	Partially dentate	6.30 ± 0.0	10.75 ± 1.11	11.83 ± 1.91	19.0 ± 0.0	0.004

*P value significant at $P < 0.05$, ANOVA applied

patients ($n = 158$). Similar studies were conducted in the past by Danesh-Sani *et al*.[5] and Ibrahim *et al*.[8]

The prevalence of PSAA in our study was 99.87% close to previously conducted cadaveric studies which was 100%.[9] In this study, age wise the most common course of PSAA was identified to be Type II (intraosseous) irrespective of age group but at different locations; at 2nd premolar region in 10–30 years ($n = 83$), at 1st molar region in 31–51 years ($n = 74$), and at 2nd premolar region in 52–72 years ($n = 53$). Gender wise it was again identified to be Type II (intraosseous) but at different locations; at 2nd premolar region in males ($n = 145$) and at 1st premolar region in females ($n = 62$). Dentate wise it was identified to be Type II (intraosseous) at 2nd premolar region in dentates ($n = 149$) and Type III (superficial) at 1st molar region in partially dentates ($n = 62$) and the results were statistically significant, respectively ($P = 0.001$) [Table 2]. Danesh-Sani *et al*.,[5] Tehranchi *et al*.,[7] Ibrahim *et al*.,[8] Chitsazi *et al*.,[9] and Ilguy *et al*.[10] Localization of the course of PSAA age wise, gender wise, and dentate wise in this study provides a better understanding PSAA in addition to other studies.

The diameter of PSAA has a direct impact on the extent and severity of hemorrhage. In this study, age wise the diameter of PSAA was found to be 0–1 mm in maximum 31–51 years (65.1%), 1–1.5 mm in maximum 52–72 years (71.4%), 1.5–2 mm in maximum 10–30 years (15.2%), and >2 mm in maximum 31–51 years (0.3%) and the results were found to be statistically significant ($P = 0.001$). However, Danesh-Sani *et al*.[5] and Rathod *et al*.[6] found no significant correlation between age and the size of the PSAA. Furthermore, different studies in the past have found the mean diameter of PSAA as 1.15 (±0.38) mm (Ibrahim *et al*.[8]); 1.52 (±0.47) mm (Kim *et al*.[11]); 1.3 (±0.5) mm (Güncü *et al*.[12]). These values are more than the results of the current study which could be attributable to ethnic differences and methodological differences. Gender-wise males had a larger diameter of PSAA with 0–1 mm found maximum in 46%, 1–1.5 mm found maximum in 44.9%, 1.5–2.0 mm found maximum in 8.9%, and >2 mm found maximum in 0.2% and the results were statistically significant ($P = 0.001$). The greater value in males could be attributed to larger skeletal features within males. Also, it has been reported by Ibrahim *et al*.[8] that genetic variance and racial differences could have an impact on these measurements. Dentate status wise it was more in dentate than partially dentate and 0–1 mm was maximum in 46.2%, 1–1.5 mm was maximum in 47.2%, 1.5–2.0 mm was maximum in 6.4%, and >2.0 mm was maximum in 0.2% Similar studies have been conducted in past by Kim *et al*.[11] where irrespective of age, gender, and dentate status almost no cases of PSAA diameter >2 mm were noted. Therefore, it can be assumed that the study population might have lowest risk of severe bleeding as a result of damage to the PSAA.

The mean distance between the lower border of PSAA to alveolar bone enables the clinician to assess length of implant planned or the extent of sinus elevation required to avoid risk of iatrogenic injury to PSAA. In the present study, irrespective of age it was shortest for 2nd molar and longest for 1st premolar except for 52–72 years where it was longest for 2nd premolar and the result was statistically significant ($P = 0.001$, $P = 0.030$, $P = 0.014$, respectively). Gender wise for males it was shortest for 1st molar and longest for 1st premolar for females it was shortest for 2nd molar and longest for 1st premolar and the result were statistically significant for both ($P = 0.001$). Dentate wise for dentate it was shortest for 2nd molar and longest for 1st premolar for partially dentate it was shortest for 2nd molar and longest for 1st premolar and the results were statistically significant ($P = 0.030$ and $P = 0.001$, respectively). These results were concurrent with other published studies by Chitsazi *et al*.,[9] Ilguy *et al*.,[10] Güncü *et al*.,[12] Watanabe *et al*.,[13] Kqiku *et al*.[14]

The mean height from the alveolar bone crest to floor of sinus was determined to assess the height of the alveolar ridge in the posterior maxilla which aids in the localization of PSSA. In the present study, for the age group 10–30 years it was shortest for 2nd molar and longest for 1st premolar, for 31–51 years it was shortest for 1st molar and longest for 1st premolar, for 52–72 years it was shortest for 2nd premolar and longest for 1st premolar and the result was statistically significant for all age groups ($P = 0.001$, respectively). Gender wise irrespective of gender it was shortest for 1st molar and longest for 1st premolar and males had a larger value with statistically significant results for both ($P = 0.029$, $P = 0.001$). Dentate wise for dentate it was shortest for 1st molar and longest for 1st premolar and for partially dentate it was shortest for 2nd molar and longest for 1st premolar and the results were statistically significant for both ($P = 0.001$, respectively). These results were similar to previous studies conducted by Kqiku *et al*.[14] and Apostolakis *et al*.,[15] where the values irrespective of age or gender or dentate status are minimum at 1st molar region increase slightly at 2nd molar region and are maximum at 1st premolar region. This may be attributed to the anatomy of the sinus which gets higher anteriorly. Also, PSAA's course in the anterior region moves superiorly to anastomose with the infraorbital artery. However, Shams *et al*.[16] did not have significant changes from the posterior side (8.0 mm) to the anterior side (4.0 mm). Also, Lee *et al*.,[17] found that the mean height of PSAA from floor of sinus was almost similar in the 2nd premolar, 1st molar, and 2nd molar regions.

The mean distance of PSAA to the medial wall of sinus is considered a more stable landmark for evaluation of the mediolateral position of PSAA as vertical dimensions are affected by sinus lift or ridge augmentation procedures. In the present study, irrespective of age it was shortest for 1st premolar, the values gradually increased and were maximum for 2nd molar except for 52–72 years where it was longest for 2nd molar and shortest for 2nd premolar. The results were statistically significant ($P = 0.001$, respectively). Gender wise irrespective of gender was shortest for 1st premolar the values gradually increased and were maximum for 2nd molar. The results were statistically significant for both ($P = 0.001$, respectively). Dentate wise irrespective of dentate status was shortest for 1st premolar the values gradually increased and were maximum for 2nd molar. The result was statistically significant for both ($P = 0.033$ and $P = 0.004$, respectively). In our study, the results showed that dentition status influenced the location of PSAA and partially dentate patients showed higher values. Pandharbale *et al*.[18] found similar results and suggested that it could be due to progressive atrophy of the alveolar bone. However, the results were not in accordance with those of Velasco-Torres *et al*.[19] and Hayek *et al*.[20] which showed that dentate had larger measurements.

CONCLUSIONS

The study supports that a careful evaluation of PSAA is imperative before surgical treatment of the maxillary sinus since it may complicate intraoperative bleeding and affect the integrity of the sinus and its membrane during the procedure. The intraosseous type was the most common variant of PSAA. Age-wise, gender-wise, and dentate wise the morphometric measurements of PSAA differ significantly in the study population. 3D imaging modality such as CBCT is useful to localize the PSAA as it provides finer details and should be recommended in clinical practices.

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Conflicts of interest

There are no conflicts of interest.

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3-Dimensional Evaluation of Two PNAM Techniques (Modified Grayson & AlignerNAM) on Facial Soft Tissue Morphology: A Randomised Clinical Trial

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Abstract

Objective: Evaluate facial changes after Presurgical Naso-Alveolar Molding (PNAM) in unilateral cleft lip and palate (UCLP) patients treated with Modified Grayson Technique and AlignerNAM (with DynaCleft nasal elevator) using a 3D facial scan.

Design: Randomised clinical trial.

Setting: Institutional study. Participants: 20 UCLP patients allocated to two groups (10 patients each).

Interventions: Group A patients underwent PNAM with Modified Grayson Technique and Group B patients underwent AlignerNAM (with DynaCleft nasal elevator). Their 3D facial scans were obtained by using an iOSbased application (Bellus3D FaceApp) mounted on a novel frame. These .stl files were analysed using 3D software (GOM INSPECT) at three-time intervals; before intervention (T0), after intervention (T1) and one month after lip repair surgery (T2).

Main Outcome Measure(s): Changes in facial and nasolabial morphology.

Results: Both techniques brought significant improvement in the columellar length, nasal tip projection, columella angle, nasal tip angle and a significant reduction in cleft width. At T1, a statistically significant difference in angular and linear measurements was present in both groups. At T2, no statistically significant difference in linear parameters was observed between the two groups except for the outer lateral height of the non-cleft side, basal lateral height of the non-cleft side, and philtrum width. Similar pattern was observed in angular measurements with no statistically significant difference between the two groups except in nasolabial angle, anterior nasal base triangle III, and anterior nasal root triangle.

Conclusions: Aligner NAM and Modified Grayson technique are equally effective PNAM methods with similar clinical results in nasolabial morphology after lip repair surgery.

Keywords
nasoalveolar molding, cleft lip and palate, facial esthetics

Introduction

Patients with clefts often have convoluted nasolabial esthetics which impacts not only the shape in all three planes of space but also the patient's mental and psychosocial well-being.[1] In patients with unilateral cleft lip and palate (UCLP) asymmetrical pull affects the growing nasal septal and alar cartilage along with the lip and alveolus, resulting in a short medial crus with an elongated lateral crus drawn into 'S' shape on

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the cleft side with the nasal septal cartilage deviated to the same side.

The Modified Grayson technique is a Presurgical nasoalveolar moulding (PNAM) technique widely used all over the world. In this modification, an acrylic nasal stent is added to the vestibular shield of the oral molding plate to exert pressure and mould the nasal alar cartilage in an upward and outward direction.[2,3] In the short term, the tissues are well aligned before primary lip and nose repair, which enables the surgeon to achieve a better and more predictable outcome with less scar tissue formation.[4] In the long term, the changes in nasal shape are more stable with better lip and nasal form after presurgical nasoalveolar molding. This improvement is reported to reduce the number of surgical revisions carried out to correct excessive scar tissue, oronasal fistulae and nasolabial deformities.[5]

CAD CAM-created 3D printed molding plates are amongst the newer innovations in NAM therapy. The first digital activation of a NAM appliance (D-NAM) was introduced by Abd El-Ghafour M et al.,[6] who used a software to 3D print a number of models in the activation sequence and manufacture the appliances with acrylic. In 2019, OrthoAligner NAM was introduced in infant orthopaedics, wherein a series of aligners along with DynaCleft were used to carry out nasoalveolar moulding. This resulted in a reduction in both the bulkiness of the appliance and number of patient visits.[7] However, these two most commonly used PNAM techniques i.e., the modified Grayson and Aligner NAM (with Dynacleft Nasal elevator), differ in the direction of the force vector applied for nasal elevation.

Furthermore, facial aesthetics and profile assessment have typically been evaluated using 2D photographic views of the patients. Although, this is a simple method and the technology is readily available, new trends have revealed a need for complete 3D image acquisition and analysis, particularly in relation to nasolabial aesthetics. While the anecdotal evidence and limited studies have suggested positive outcomes, a comprehensive evaluation of the facial changes using advanced three-dimensional facial scanning technology would ascertain the effectiveness of these two techniques in providing optimal nasal projection and symmetry.

Thus, the purpose of the present study was to compare the effectiveness of PNAM using the modified Grayson technique and Aligner NAM (with Dynacleft Nasal elevator) on facial changes in patients with unilateral cleft, employing non-invasive 3D facial scanning. The null hypothesis for the study was that there exists no difference between the two techniques.

Materials and Methods

Design and Setting

A total of 25 patients were initially screened for the study, of which 20 patients satisfied the inclusion criteria. 5 patients were excluded from the study as 4 patients declined to participate in the study, and one was detected to be syndromic during the initial investigations. The study obtained institutional clearance (****/IERBC/2***-2*/02) and was registered in the Clinical Trial Registry of India (****/2020/03/02****).

The patients were allocated to two groups with the help of computer-generated random number tables with allocation concealment carried out according to the SNOSE technique. Group A consisted of 10 patients who were treated with modified Grayson technique and Group B had 10 patients who underwent treatment with OrthoAligner NAM with Dynacleft nasal elevator (Figure 1).

The sample size calculation was done keeping the power of the study at 80% and alpha of 0.05 with an effect size of 0.6 calculated from a previous study.[8] Based on the calculation, a minimum sample of 8 was computed, but considering a 20% dropout, the sample size was increased and computed as 10.

The patient recruitment started in December 2020 and concluded in August 2021. All the patients were treated by the same operator, who had prior experience with the modified Grayson Technique and Aligner NAM (with nasal elevator) under the supervision of other more experienced clinicians.

Patient Selection

The patients with unoperated non-syndromic complete UCLP were initially screened for the study. The patients with low birth weight and patients/guardians who did not consent to undergo the procedure were excluded. Moderate to well-nourished babies between the age range of 1 to 4 weeks were included in the study.

Following the inclusion into the study, each patient was followed up based upon the respective treatment protocol of each group.

Treatment Protocol

Modified Grayson protocol. The impressions were made with heavy-body polyvinyl A-silicone (Affins, Coltene) following all the standard precautions for impression-making in infants with cleft lip and palate anomaly.[2] A dental stone cast was made from the impression and a molding appliance was fabricated with self-cure acrylic resin after blocking out the cleft defect and undercuts using modelling wax. The edges of the appliance were rounded and trimmed smoothly. Retention of the appliance was achieved with the help of a retentive button attached to the plate anteriorly at an angle of 40 degrees; secured bilaterally with orthodontic elastic bands (pre-stretched, 3/16″,3.5 oz) and to the cheek using 3 M Micropore surgical tape.

The patients were recalled weekly and appliances were adjusted to bring about movements of the alveolar segments. During these visits, the appliance was selectively trimmed at the location where the ridge segments needed to be positioned, and on the other side, a soft liner was added to give a positive moulding pressure that resulted in the desired arch shape. To maintain the physiological moulding pressure and avoid the build-up of torsional forces in the alveolar bone, segmental movement was limited to less than 1 mm cumulatively. When the alveolar gap was reduced to less than 5 mm, the

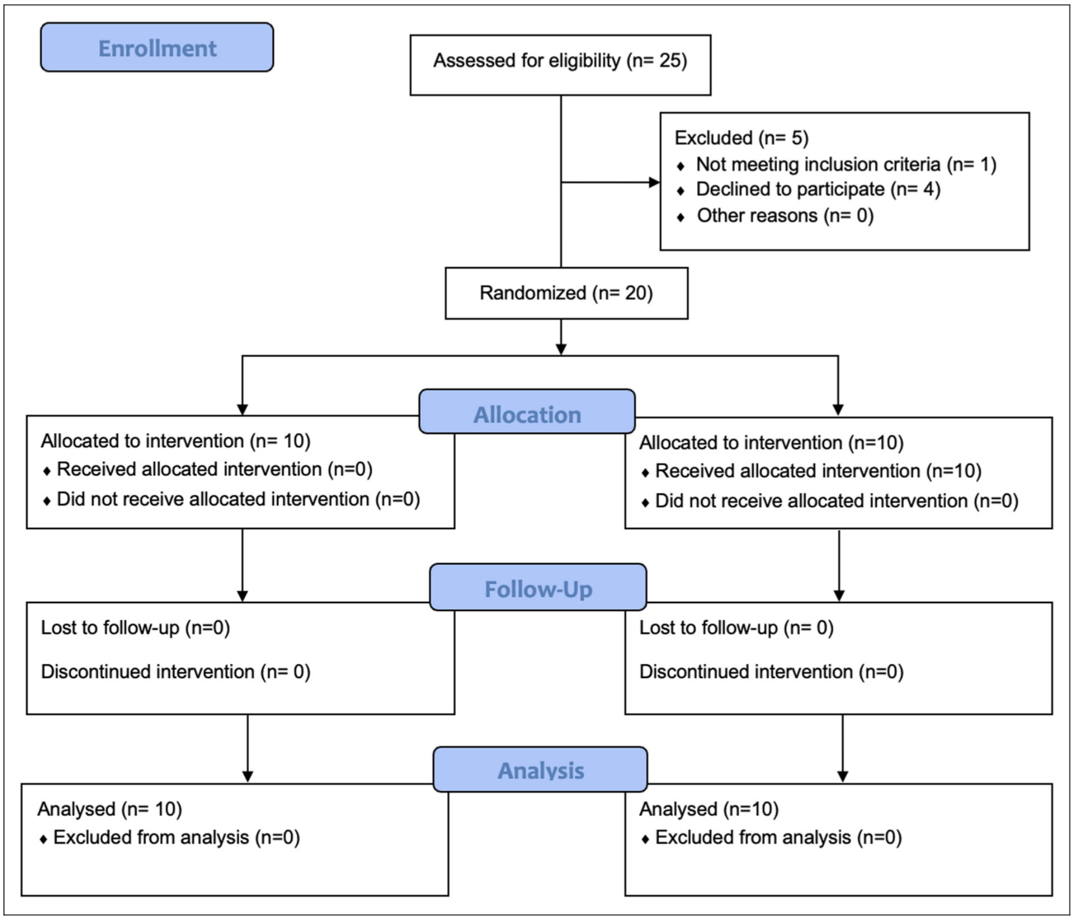

Figure 1. CONSORT flowchart.

moulding appliance was refabricated and the nasal stent was attached to the labial flange with a "swan-neck shaped" 0.036″ stainless steel wire with an acrylic bulb at the end. The bulb was adjusted and positioned with the upper lobe lifting the nasal dome, while the lower lobe lifted the nostril apex and maintained moulding pressure (moderate amount of tissue blanching) in an outward and forward direction on the lower lateral nasal cartilage. This resulted in improving the symmetry of the nasal base and alar rim segment. Precautions were observed to avoid bulky acrylic bulbs that could cause an unwanted increase in the circumference of the lateral alar wall leading to the formation of "mega-nostril".

Aligner NAM (with DynaCleft nasal elevator) protocol. The impression was made with a heavy-bodied polyvinyl silicone similar to modified Grayson Group. The maxillary cast obtained was scanned with the help of a blue light technology (Solutionix C500) scanner to create a 3D- virtual model of the maxilla with a reverse modelling software program. The major and minor segments were delineated in the virtual set-up and the desired movements were incrementally simulated at the rate of 1 mm in each stage. The models for each stage were 3D printed and thermoformed aligners of 0.66 mm thickness were fabricated using OrthoAligner Ultimate (Compass 3D, Belo Horizonte, Brazil).[2] A customised nasal elevator system (DynaCleft) was used for simultaneous nasal elevation and approximation of lip segments. This provided an additional advantage of nasal moulding performed alongside alveolar moulding. However, since the system derives support from the forehead, the force vector for carrying out nasal elevation is in an upward and backward direction. The force vector and moulding pressure were carefully monitored during the recall visits by adjusting the nasal elevator hook and length of the Dynacleft tape.

Outcome Measurement

3D facial scans were recorded in both groups at three time points i.e., prior to the start of treatment (T0), after NAM Therapy (T1), and after surgery (T2). This was performed

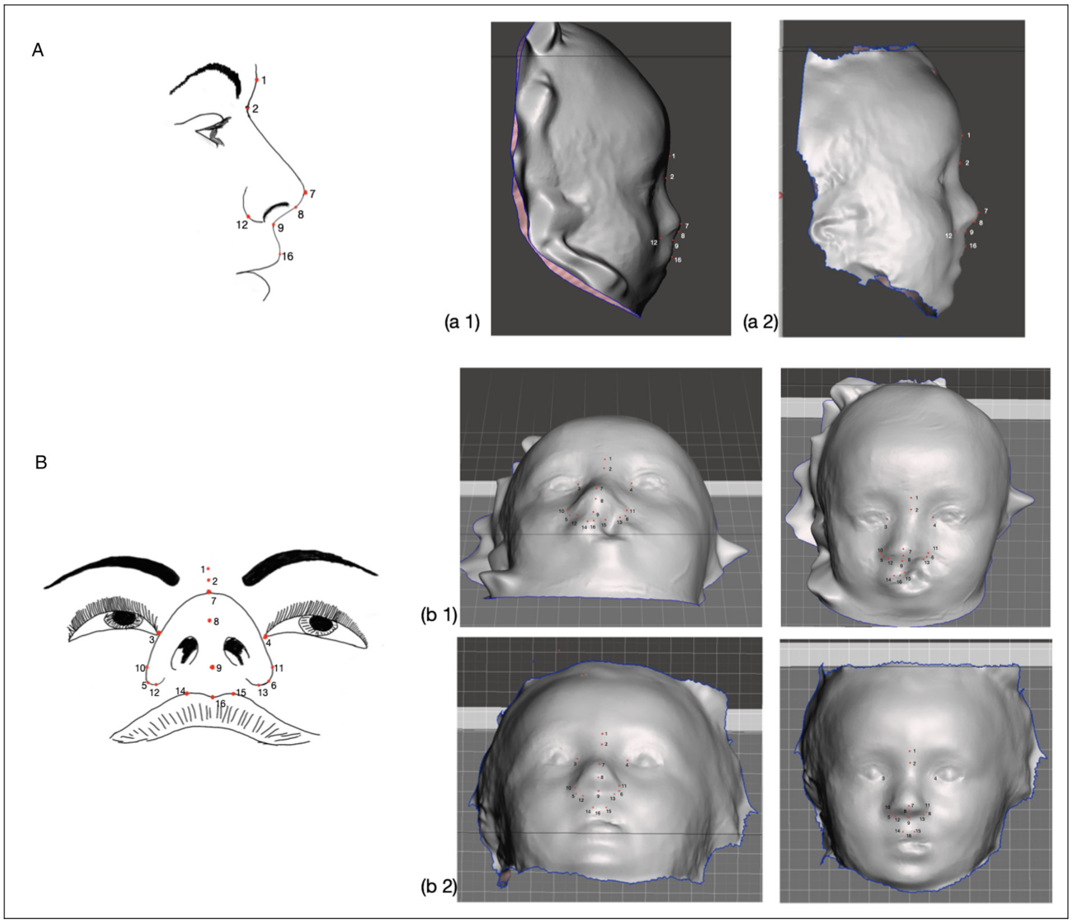

Figure 2. (A) Schematic profile and (B) Worm-eye view of the soft tissue landmarks; profile view of infant with UCLP (a1) and after lip repair (a2), worm-eye and frontal view from the 3D scan of an infant with UCLP (b1) and after lip repair (b2). Sixteen anthropometric landmarks were used in the present study. (1) glabella; (2) nasion (n) (3) endocanthion left; (4) endocanthion right; (5) alar curvature left; (6) alar curvature right (7) pronasale (prn) (8) Highest point of columella (9) subnasale (sn) (10) alare left (11) alare right (12) subalare left (13) subalare right (14) crista philtra left (15) crista philtra right (16) labiale superius.

using an iOS-based app and a TrueDepth camera using projected infrared dots (Bellus 3D FaceApp) and an ingeniously built frame to stabilise the camera. This helped to carry out the scan in the pre-determined motion covering all facial aspects and also created a highly accurate face model by standardising the 3D scans, considering that the patients being treated were newborns.[8] The 3D scans were exported as STL files into the GOM Inspect software (Carl Zeiss GOM Metrology GmbH). Sixteen anthropometric landmarks were identified on the scans based on the anatomical structures, with a point accuracy of 0.05 mm (Figure 2). A total of 19 frontal and profile-based angular and linear parameters were assessed and analysed by two investigators (AK and AJ) in the software to determine the relative changes in the nasolabial position and projection (Table 1). Furthermore, each investigator repeated the assessment after 4months to determine intra and inter-rater reliability.

Statistical Analysis

The data was entered in Microsoft Excel 2021 and was analysed using the Statistical Package for the Social Sciences (SPSS) statistical software 20.0 Version. The descriptive statistics included mean and standard deviation with 95% confidence interval. The intra-group comparison for the time intervals was done using linear modelled ANOVA factoring repeated measures. The independent t-test was done for the inter-group comparisons after NAM therapy.

Results

Participants

Amongst the total of 25 patients who were initially screened for the study, 20 patients satisfied the inclusion criteria. 5 patients were excluded from the study as 4 patients declined

Table 1. Description of the Facial Landmarks Along with Linear and Angular Measurement of Modified Grayson Technique.

Measure	Landmark description	Timeline	Mean	SD	95% confidence interval Lower bound	Upper bound
Linear measurements						
Nasal Height	Nasion- Subnasale	T0	28.564	2.66589	26.697	30.430
		T1	35.883	2.83072	33.714	38.051
		T2	37.796	3.71832	34.928	40.664
Intercanthal distance	Right Endocanthion- Left Endocanthion	T0	22.315	1.23129	21.374	23.257
		T1	24.269	1.53288	23.084	25.454
		T2	26.011	1.41574	24.916	27.106
Outer lateral height (Cleft side)	Alar curvature to endocanthion	T0	18.817	1.90272	17.361	20.273
		T1	21.539	1.81331	20.158	22.920
		T2	23.238	1.92484	21.754	24.722
Outer lateral height (Non-cleft side)		T0	17.821	1.41781	16.763	18.879
		T1	21.850	2.05423	20.262	23.439
		T2	23.475	2.11709	21.907	25.042
Basal lateral height (Cleft side)	Subalare to endocanthion	T0	19.848	.96957	19.104	20.591
		T1	23.416	1.53022	22.397	24.435
		T2	25.259	1.95352	23.750	26.769
Basal lateral height (Non-cleft side)		T0	19.112	1.71270	17.808	20.415
		T1	23.726	2.22241	22.026	25.427
		T2	25.402	1.87276	24.001	26.802
Columellar length	Subnasale to Highest point of the columella	T0	4.422	1.01592	3.662	5.181
		T1	6.735	1.15815	5.871	7.598
		T2	7.269	1.07352	6.440	8.099
Left philtrum length	Left Crista Philtri to Basal line	T0	8.740	1.33219	7.815	9.666
		T1	10.451	1.67381	9.272	11.630
		T2	12.090	1.61796	10.862	13.319
Right philtrum length	Right Crista Philtri to Basal line	T0	8.241	2.41047	6.446	10.036
		T1	10.664	2.64094	8.640	12.688
		T2	12.325	2.10726	10.701	13.948
Philtrum width	Right Crista Philtri to Left Crista Philtri	T0	18.072	2.71621	15.976	20.168
		T1	7.662	1.50672	6.574	8.750
		T2	5.365	1.04495	4.771	5.959
Angular measurements						
Nasal tip projection	Nasion- Pronasale – Highest point of columella	T0	135.979	2.192	132.540	139.419
		T1	150.329	3.956	144.429	156.230
		T2	146.057	3.242	141.311	150.803
Nasal tip angle	Nasion- Pronasale- Subnasale	T0	141.982	2.277	138.453	145.512
		T1	132.745	2.167	129.360	136.131
		T2	129.044	1.840	126.176	131.912
Nasolabial angle	Labial superiousis- Subnasale-Pronasale	T0	138.720	1.287	136.501	140.939
		T1	148.455	1.547	145.984	150.926
		T2	145.586	1.244	143.664	147.508
Subnasal angle	Crista philtra- Subnasale- Highest point of columella	T0	139.733	1.583	136.970	142.495
		T1	152.380	1.889	149.313	155.447
		T2	146.107	.913	143.608	148.606
Anterior nasal base triangle I	Angle between alar base and nasal tip Right subalare -Pronasale- Left subalare	T0	98.179	1.081	96.270	100.087
		T1	106.731	.863	105.033	108.429
		T2	104.260	.692	103.053	105.468
Anterior nasal base triangle II	Angle between Alar base and Subnasal point Right subalare- Subnasale – Left subalare	T0	131.451	1.340	129.383	133.519
		T1	127.431	1.358	125.386	129.476
		T2	129.010	1.355	126.983	131.037
Anterior nasal base triangle III	Angle between Outer alar wall and nasal tip Alar curvature- Pronasale- Alar curvature	T0	105.696	.848	104.310	107.082
		T1	100.218	.913	98.776	101.661

(continued)

Table 1. (continued)

Measure	Landmark description	Timeline	Mean	SD	95% confidence interval Lower bound	Upper bound
		T2	101.627	.821	100.250	103.004
Anterior nasal root triangle	Endocanthion-Nasion-Endocanthion	T0	108.680	1.190	106.849	110.511
		T1	93.926	.932	92.457	95.395
		T2	86.760	.738	85.598	87.923
Columellar angle	Highest point of Columella-Subnasale and line joining right and left outer alar curvature.	T0	30.059	.880	28.519	31.600
		T1	82.978	1.166	81.249	84.708
		T2	89.634	.867	88.271	90.997

to participate in the study, and one was detected to be syndromic during the initial investigations. Amongst the 20 patients, 15 patients had UCLP(Left) and 5 patients had UCLP(Right). The mean transverse cleft gap between the anterior-most points of the alveolar crest in the major and minor segments was 10.48 ± 2.21 mm. No patients were lost to follow-up and all were analysed for the PSIO treatment changes using pre and post-treatment records.

Age and Gender Distribution

The mean age of the included infants in Group A (modified Grayson Technique) was 22.54 days and Group B (Aligner NAM with Dynacleft) was 25.82 days (T0). The treatment time for PNAM therapy was approx. 16-19 weeks in both groups. Consequently, the mean age of the patients in both Group A and B was 19.3 and 20.7 weeks, respectively at the time of completion of PNAM therapy (T1). Primary lip repair was carried out for infants from both groups as they turned over 6 months with the mean age of the patients being 6.7 months (T2). Amongst the 20 patients, 11 were males and 9 were females with no statistically significant difference in the age distribution between both the groups. There were no medical complications reported during the trial. The linear and angular measurements were rounded off to the nearest 3 decimal points and tabulated as given in Tables 1 and 2; thus depicting the overall 3D assessment of the nasolabial parameters. Overall, a high level of inter- and intra-observer reliability was measured with Cronbach's alpha of 0.665 and 0.756 respectively.

Linear Measurements

A statistically significant difference was observed in nasal height between Groups A and B, after PNAM therapy (T1) with a difference of 4.725 (P-value < .000). When nasal height was compared at T2 (ie, after surgery) between the two techniques, the mean difference was 3.233 mm (P-value .004**). For both the time points, the nasal height was more in Group A as compared to Group B.

Similarly, a significant mean difference was observed in the outer lateral height of the cleft side between the two groups, with a difference of 1.969 mm (P-value .013*) after PNAM therapy (T1). At T2, the mean difference was slightly less i.e., 1.103 mm (P-value .042*).

A significant mean difference of 1.330 mm (P-value .028*) was also observed in philtrum width at T1. However, the mean difference was 0.864 mm (P-value .040*) at T2 i.e., after surgery in Group B patients, which was comparatively less than in Group A.

No statistically significant difference was observed in intercanthal distance, columella length, basal lateral height when the techniques were compared post-PNAM (T1) and post-surgery (T2).

Angular Measurements

A statistically significant mean difference of −6.30° (P-value .001**) was observed in the nasolabial angle between the two groups at T1, whereas after the lip repair surgery (T2) the mean difference was −3.56° (P-value .003**).

A statistically significant mean difference of −2.34° (P-value .023**) was also observed in anterior nasal base triangle III at T1, which was almost the same after surgery i.e., −2.33° (P-value .010*).

No statistically significant difference was observed in nasal tip projection, nasal tip angle, subnasale angle, anterior nasal triangle I, II and columella angles between both the groups after PNAM and post-surgery.

Intra-group Comparison

Following the successful treatment, paired t-test was performed to assess the treatment results after PNAM and lip repair surgery.

A statistically significant difference ($P < .05$) was seen in all the linear and angular measurements after PNAM therapy in both the modified Grayson and AlignerNAM with Dynacleft group (Table 3).

Intergroup Comparison

There was no statistically significant difference between the two groups when assessed using independent t-test, except in

Table 2. Descriptive Linear and Angular Measurement of AlignerNAM Technique.

Measure	Timeline	Mean	SD	95% Confidence interval for difference	
				Lower bound	Upper bound
Linear measurements					
Nasal Height	T0	28.949	1.68084	27.662	30.236
	T1	31.158	1.27921	30.373	31.942
	T2	32.095	1.64280	31.141	33.050
Intercanthal distance	T0	24.147	.94056	23.430	24.864
	T1	25.256	1.38970	24.220	26.293
	T2	26.417	1.53221	25.325	27.509
Outer lateral height (Non-cleft side)	T0	19.353	1.38995	18.282	20.424
	T1	21.791	1.66743	20.524	23.057
	T2	23.043	1.05070	22.309	23.778
Outer lateral height (Cleft side)	T0	17.680	1.11820	16.815	18.544
	T1	19.882	.97099	19.131	20.633
	T2	22.419	1.66052	21.305	23.533
Basal lateral height (Cleft side)	T0	20.623	1.39956	19.541	21.704
	T1	23.232	1.55947	22.031	24.434
	T2	24.593	1.10649	23.758	25.428
Basal lateral height (Non-cleft side)	T0	18.324	1.07615	17.675	18.974
	T1	21.110	1.62648	19.979	22.241
	T2	41.374	56.2327	−1.218	83.966
Columellar length	T0	4.541	.64355	4.073	5.009
	T1	6.872	.74208	6.328	7.416
	T2	7.612	.42414	7.312	7.913
Left philtrum length	T0	8.434	.91408	7.740	9.127
	T1	10.861	1.01992	10.073	11.648
	T2	11.816	1.32210	10.794	12.839
Right philtrum length	T0	9.292	.93776	8.696	9.888
	T1	11.653	.56973	11.217	12.089
	T2	12.507	.62790	12.037	12.978
Philtrum width	T0	17.053	1.32120	16.139	17.967
	T1	6.331	.89822	5.645	7.018
	T2	5.243	.44371	4.921	5.565
Angular measurements					
Nasal tip projection	T0	137.023	1.52680	135.870	138.176
	T1	147.943	2.30499	146.575	149.312
	T2	145.375	1.53310	144.719	146.031
Nasal tip angle	T0	139.694	2.47051	137.811	141.577
	T1	132.324	2.44154	130.436	134.213
	T2	130.130	1.97543	128.672	131.588
Nasolabial angle	T0	137.946	1.82369	136.536	139.356
	T1	154.782	1.92103	153.559	156.004
	T2	150.628	1.31522	149.632	151.625
Subnasal angle	T0	135.020	1.92792	133.572	136.469
	T1	152.312	2.31719	150.703	153.922
	T2	142.976	1.74962	141.701	144.250
Anterior nasal base triangle I	T0	99.371	1.78329	98.015	100.728
	T1	107.659	2.72237	105.928	109.391
	T2	107.159	.65086	106.763	107.555
Anterior nasal base triangle II	T0	130.929	1.26624	129.989	131.870
	T1	128.008	1.00689	127.232	128.784
	T2	130.741	.98330	129.992	131.491
Anterior nasal base triangle III	T0	110.944	1.40162	109.961	111.927
	T1	102.525	.98985	101.770	103.280
	T2	101.191	1.21219	100.297	102.084

(continued)

Table 2. (continued)

Measure	Timeline	Mean	SD	95% Confidence interval for difference	
				Lower bound	Upper bound
Anterior nasal root triangle	T0	112.814	1.11880	111.950	113.679
	T1	96.916	1.03756	96.232	97.600
	T2	85.111	.87192	84.444	85.779
Columellar angle	T0	27.482	.88215	26.802	28.162
	T1	84.628	.95113	84.089	85.166
	T2	91.336	1.09639	90.513	92.158

Table 3. Intra Group Comparison of Measurements (Linear and Angular).

Measure	(I) Parameter at respective timeline	(J) Comparative timeline of same parameter	Mean difference (I-J)	Std. error	Sig.	95% Confidence interval for difference	
						Lower bound	Upper bound
Modified Grayson Group							
Linear measurements							
Nasal Height	T0	T1	−7.319	.799	.000	−9.729	−4.909
	T1	T2	−1.913	.489	.013	−3.389	−.437
Intercanthal distance	T0	T1	−1.953	.461	.009	−3.345	−.562
	T1	T2	−1.742	.258	.000	−2.519	−.965
Outer lateral height (Cleft side)	T0	T1	−2.722	.828	.033	−5.218	−.226
	T1	T2	−1.699	.392	.007	−2.881	−.518
Outer lateral height (Non-Cleft side)	T0	T1	−4.029	.903	.006	−6.753	−1.305
	T1	T2	−1.624	.356	.006	−2.699	−.549
Basal lateral height (Cleft side)	T0	T1	−3.568	.469	.000	−4.982	−2.155
	T1	T2	−1.843	.396	.005	−3.039	−.648
Basal lateral height (Non-cleft side)	T0	T1	−4.615	.746	.001	−6.865	−2.364
	T1	T2	−1.675	.732	.154	−3.881	.531
Columellar length	T0	T1	−2.313	.083	.000	−2.562	−2.064
	T1	T2	−.535	.106	.003	−.855	−.214
Left philtrum length	T0	T1	−1.711	.331	.003	−2.708	−.713
	T1	T2	−1.639	.298	.002	−2.538	−.741
Right philtrum length	T0	T1	−2.423	.595	.011	−4.218	−.627
	T1	T2	−1.661	.334	.003	−2.667	−.655
Philtrum width	T0	T1	10.410	1.053	.000	7.235	13.585
	T1	T2	2.297	.398	.001	1.096	3.497
Angular measurements							
Nasal tip projection	T0	T1	−14.122	2.142	.001	−20.582	−7.662
	T1	T2	4.352	1.259	.026	.554	8.149
Nasal tip angle	T0	T1	9.289	1.595	.001	4.478	14.100
	T1	T2	3.795	1.893	.240	−1.914	9.504
Nasolabial angle	T0	T1	−9.622	1.795	.002	−15.036	−4.208
	T1	T2	2.949	.996	.054	−.054	5.952
Subnasal angle	T0	T1	−12.420	1.319	.000	−16.399	−8.441
	T1	T2	6.052	1.537	.013	1.417	10.688
Anterior nasal base triangle I	T0	T1	−8.830	1.309	.000	−12.778	−4.882
	T1	T2	2.654	.639	.010	.727	4.581
Anterior nasal base triangle II	T0	T1	4.013	.622	.001	2.137	5.889
	T1	T2	−1.590	.374	.008	−2.718	−.462
	T0	T1	5.415	.867	.001	2.799	8.031

(continued)

Table 3. (continued)

Measure	(I) Parameter at respective timeline	(J) Comparative timeline of same parameter	Mean difference (I-J)	Std. error	Sig.	95% Confidence interval for difference Lower bound	Upper bound
Anterior nasal base triangle III	T1	T2	−1.418	.197	.000	−2.013	−.823
Anterior nasal root	T0	T1	14.703	1.230	.000	10.994	18.412
Triangle	T1	T2	7.180	.817	.000	4.715	9.645
Columellar angle	T0	T1	−52.863	1.578	.000	−57.622	−48.103
	T1	T2	−6.545	1.171	.002	−10.078	−3.013
Aligner NAM group							
Linear measurements							
Nasal Height	T0	T1	−2.209	.480	.005	−3.655	−.762
	T1	T2	−.938	.375	.110	−2.068	.192
Intercanthal distance	T0	T1	−1.109	.224	.003	−1.786	−.433
	T1	T2	−1.160	.362	.038	−2.253	−.068
Outer lateral Height	T0	T1	−2.438	.534	.006	−4.048	−.827
(Cleft side)	T1	T2	−1.253	.466	.082	−2.657	.152
Outer lateral height	T0	T1	−2.202	.309	.000	−3.134	−1.270
(Non-Cleft side)	T1	T2	−2.537	.554	.005	−4.208	−.867
Basal lateral height	T0	T1	−2.610	.414	.001	−3.859	−1.360
(Cleft side)	T1	T2	−1.361	.337	.011	−2.376	−.346
Basal lateral height	T0	T1	−2.786	.367	.000	−3.892	−1.679
(Non-cleft side)	T1	T2	−2.264	1.640	.926	−6.478	5.950
Columellar length	T0	T1	−2.331	.300	.000	−3.236	−1.425
	T1	T2	−.740	.159	.005	−1.219	−.262
Left philtrum length	T0	T1	−2.427	.335	.000	−3.437	−1.417
	T1	T2	−.956	.196	.004	−1.545	−.366
Right philtrum length	T0	T1	−2.361	.298	.000	−3.258	−1.463
	T1	T2	−.855	.233	.019	−1.558	−.152
Philtrum width	T0	T1	10.722	.474	.000	9.292	12.151
	T1	T2	1.088	.317	.027	.134	2.043
Angular measurements							
Nasal tip projection	T0	T1	−10.921	.739	.000	−13.151	−8.691
	T1	T2	2.568	.554	.005	.897	4.238
Nasal tip angle	T0	T1	7.370	1.283	.001	3.501	11.238
	T1	T2	2.194	1.148	.277	−1.268	5.656
Nasolabial angle	T0	T1	−16.836	1.008	.000	−19.876	−13.796
	T1	T2	4.153	.537	.000	2.534	5.772
Subnasal angle	T0	T1	−17.292	.882	.000	−19.950	−14.633
	T1	T2	9.336	.429	.000	8.043	10.630
Anterior nasal base	T0	T1	−8.288	.824	.000	−10.773	−5.804
triangle I	T1	T2	.500	.765	1.000	−1.806	2.807
Anterior nasal base	T0	T1	2.922	.672	.007	.896	4.947
triangle II	T1	T2	−2.733	.350	.000	−3.790	−1.677
Anterior nasal base	T0	T1	8.419	.516	.000	6.864	9.974
triangle III	T1	T2	1.335	.403	.032	.118	2.551
Anterior nasal root	T0	T1	15.899	.605	.000	14.075	17.723
Triangle	T1	T2	11.804	.327	.000	10.817	12.792
Columellar angle	T0	T1	−57.146	.287	.000	−58.011	−56.281
	T1	T2	−6.708	.326	.000	−7.690	−5.726

nasal height, outer lateral height (cleft side), basal lateral height (non-cleft side) and philtrum width as well as the nasolabial angle, anterior nasal base triangle III and anterior nasal root triangle measurements (Table 4).

Discussion

Nasolabial esthetics is the most well-researched outcome measure in most cleft studies. Many studies have used both

Table 4. Inter-group Comparison of Measurements (Linear and Angular).

Measure	(I) group	(J) group	Mean difference (I-J)	Std. error	Sig.	95% Confidence interval for difference	
						Lower bound	Upper bound
After NAM therapy (After T1 time interval)							
Linear measurements							
Nasal Height	Grayson	Aligner	4.72504	.98231	.000*	2.66128	6.78880
Intercanthal distance	Grayson	Aligner	−.98763	.65429	.149	−2.36225	.38699
Outer lateral height (Non-Cleft side)	Grayson	Aligner	−.25163	.77900	.750	−1.88824	1.38499
Outer lateral height (Cleft side)	Grayson	Aligner	1.96871	.71852	.013*	.45916	3.47827
Basal lateral height (Non Cleft side)	Grayson	Aligner	2.61642	.87089	.008*	.78674	4.44610
Basal lateral height (Cleft side)	Grayson	Aligner	.18356	.69091	.794	−1.26799	1.63510
Columella length	Grayson	Aligner	−.13740	.43497	.756	−1.05124	.77644
Left philtrum length	Grayson	Aligner	−.40967	.61983	.517	−1.71188	.89254
Right philtrum length	Grayson	Aligner	−.98897	.85435	.262	−2.78389	.80596
Philtrum Width	Grayson	Aligner	1.33021	.55471	.028*	.16481	2.49561
Angular measurements							
Nasal tip projection	Grayson	Aligner	2.37069	3.82703	.543	−5.66959	10.41097
Nasal tip angle	Grayson	Aligner	.36774	2.20344	.869	−4.26153	4.99700
Nasolabial angle	Grayson	Aligner	−6.30463	1.60436	.001*	−9.67526	−2.93399
Subnasal angle	Grayson	Aligner	.09379	1.99088	.963	−4.08889	4.27646
Anterior nasal base triangle I	Grayson	Aligner	−.79747	1.19256	.512	−3.30294	1.70800
Anterior nasal base triangle II	Grayson	Aligner	−.55395	1.32866	.682	−3.34537	2.23746
Anterior nasal base triangle III	Grayson	Aligner	−2.33637	.94095	.023*	−4.31322	−.35951
Anterior nasal root triangle	Grayson	Aligner	−2.98477	.95287	.006*	−4.98669	−.98286
Columellar angle	Grayson	Aligner	−1.57733	1.14992	.187	−3.99322	.83855
After lip repair surgery (T2 time interval)							
Linear measurements							
Nasal Height	Grayson	Aligner	3.233	.977	.004*	1.171	5.296
Intercanthal distance	Grayson	Aligner	−1.133	.554	.056	−2.301	.035
Outer lateral height cleft non side	Grayson	Aligner	−.161	.586	.787	−1.397	1.075
Outer lateral height cleft side	Grayson	Aligner	1.103	.501	.042*	.046	2.160
Basal lateral height Cleft side	Grayson	Aligner	.066	.538	.903	−1.068	1.201
Basal lateral height Non cleft side	Grayson	Aligner	−3.717	6.014	.545	−16.406	8.972
Columellar length	Grayson	Aligner	−.225	.373	.555	−1.012	.562
Left philtrum length	Grayson	Aligner	.031	.535	.955	−1.098	1.160
Right philtrum length	Grayson	Aligner	−.753	.742	.325	−2.319	.814
Philtrum width	Grayson	Aligner	.864	.388	.040*	.045	1.683
Angular measurements							
Nasal tip projection	Grayson	Aligner	.640	3.071	.837	−5.840	7.120
Nasal tip angle	Grayson	Aligner	.608	1.689	.723	−2.954	4.171
Nasolabial angle	Grayson	Aligner	−3.564	1.021	.003*	−5.719	−1.410
Subnasal angle	Grayson	Aligner	2.462	1.615	.146	−.945	5.868
Anterior nasal base triangle I	Grayson	Aligner	−1.650	.807	.057	−3.353	.052
Anterior nasal base triangle II	Grayson	Aligner	−.620	1.308	.642	−3.380	2.140
Anterior nasal base triangle III	Grayson	Aligner	−2.326	.803	.010*	−4.020	−.632
Anterior nasal root triangle	Grayson	Aligner	−1.808	.731	.024*	−3.351	−.266
Columellar angle	Grayson	Aligner	−.312	.616	.619	−1.612	.987

*Significant at $P < .05$.

direct and indirect anthropometric measurements majorly on 2D photographs or direct measurements on the patient, with only a few studies having used 3D stereophotographs, 3D scans of the nasal and facial casts.[9] For the assessment of nasolabial esthetics, quantifiable parameters such as comparative (like facial symmetry), objective (like columella length and nasal tip projection) and photometric rating (like Asher-McDade and other rating systems) have been previously used.[10–13] Amongst them, the studies with high-quality of evidence and low risk of bias have reported better nasolabial esthetics in patients with NAM protocol both in short and long term. In the humble knowledge of the authors, there have been no studies conducted to compare the two NAM techniques (modified Grayson technique and AlignerNAM with Dynacleft) using 3D facial scans based upon true depth technology.

The modified Grayson technique advocated nasal moulding when the alveolar gap has become less than 5 mm with the moulding vector in an outward and forward direction.[3] On the other hand, nasal moulding in Dynacleft system starts simultaneously with alveolar moulding, with the force vector in an upward and backward direction.[8] Upon a comparative assessment of treatment outcome, it has been noted that there is no significant difference between the two techniques, apart from the fact that the frequency of visits are reduced by 75% with AlignerNAM.[14] The current standard modified Grayson technique calls for weekly visits, adding up to an average of 16-20 visits over the course of treatment with conventional methods. In contrast, treatment with AlignerNAM and Dynacleft Nasal Elevator aims to reduce these patient visits to about one-fourth (4-6 visits), resulting in an overall reduction in the burden of care, after accounting for lost wages and additional costs incurred during these visits. It has also been postulated that AlignerNAM enables treatment in patients who are located in remote places leading to reduced attrition and burden of care. However, these studies have evaluated dental treatment outcomes and preliminary facial assessment based on 2D photographs for nasal symmetry.

The evaluation of the facial morphology is essential for the assessment of treatment outcomes and growth in patients with cleft deformities. 3D anthropometric assessments (linear and angular) provide an objective assessment of the treatment changes and have proven to be superior for overall nasolabial and alveolar outcome assessment post-NAM in patients with CLP when compared to 2D assessment.[15–18] The emergence of newer non-invasive, non-radiographic techniques such as photogrammetry, stereophotogrammetry, laser beam scanning and structured light scanning has proven advantageous due to high resolution, economical and faster scans, especially when working with young patients.[19]

In the present study, the changes in nasolabial and facial morphology were quantified with a clinically acceptable, standardised and validated method of 3D image capture. This technique enables capturing the topographical features of the face and most importantly the nasolabial region to three-dimensionally assess the changes in the nasal and lip projection with PNAM and the following primary lip repair surgery. Mancini et al.[9] showed that there was a significant improvement in the columella length, nasal symmetry and nasal projection after nasoalveolar molding and primary surgery when compared to noncleft controls, using 3D facial scan. They also noted that a significant change in the nasal form was due to the overcorrection of the nasal projection and columella angle. Piedra-Cascon also reported that an iPhone-based App Bellus 3D face scanner which uses structured face scanning technology, identified the landmarks accurately and precisely.[20] However, this technology uses a non-standardized method of image capture especially with respect to the orientation of the infant's head inside the focal trough (area of interest), thereafter rotating the smartphone device (iPhone) to the right and left in coordination with the command given by the application. To overcome this problem, the use of an innovative frame made up of a stainless steel rod of 150 cm in length, hydraulically bent to a semicircle of radius 42.5 mm was reported.[21] The infant's head was positioned to lie at the centre of the semicircular frame. The same frame was used in the present study. Moreover, a significant benefit of utilising 3D scans for evaluation is that the landmark selection process implies the selection of a vertex from each triangle that makes up the facial surface mesh. As a result, the programme calculates the distance between the two vertices/ plotted landmarks, and the measurement becomes independent of change in angulation/ view as present traditionally in error-prone 2D views (worm- and bird-eye views). This approach is especially helpful in situations when measuring nasal projection and symmetry is required.

In the present study, amongst the Modified Grayson and AlignerNAM with Dynacleft no statistically significant difference was noted in facial parameters except in the outer lateral height and basal lateral height of the non-cleft side and philtrum width. This may be due to the effect of growth on the non-cleft side. All the linear and angular values showed statistically significant differences after the PNAM therapy and after the surgery with the groups. This implies that both methods are effective in carrying out Naso-Alveolar Molding. However, there was no statistically significant difference between the groups except nasolabial angle, anterior nasal base triangle III, and Anterior nasal root triangle. This may be due to the difference in the mechanism of action and vector of forces acting at subnasale area. The nasal moulding in the modified Grayson Technique is attributed to the push provided by the acrylic nasal stent. The force and direction of the push are controlled by the care provider by adjusting the nasal stent angulation on each NAM visit. The nasal stent pushes the lateral wall of the nasal septum, medial crus and lateral crus medially and in an outward direction. The cleft nostril anatomy is reshaped to resemble that of a normal contralateral nostril by this upward force.

In Aligner NAM (with DynaCleft nasal elevator) technique, the nasal molding force vector is provided by the separate extraoral nasal elevator. This elevator works on pull mechanics. The lateral crus, medial crus, and nasal septum are all pulled upwards and to the opposite side by the nasal elevator. As a result, the nasal septum is elongated and straightened, thus the lateral crus is lifted upward in the direction of the pull force i.e., upward, backward and medially. It is pertinent to note that even though this group required fewer clinical visits, the magnitude and direction of the pull force is provided by the caretaker, which might vary at each application. Sound patient education therefore becomes mandatory for achieving optimal outcomes in patients undergoing nasal molding with nasal elevators.

The results of the present study are in agreement with previous studies comparising the nasolabial esthetics of PNAM techniques. Abhinav et.al has compared the intra-oral effects of modified Grayson and Dynacleft technique on 3D digital models and facial photographs. The authors found no significant difference between the two techniques in reduction of cleft defect and improvement of nasal anatomy.[22] Based on the results of the present study, both the PSIO methods can be considered as effective to improve and alter the nasolabial esthetics of the patients with UCLP.

Limitation

The shortcomings of this study include a small sample size and lack of a long-term follow-up of facial changes especially pertaining to the nostril symmetry. A method should thus be innovated to assess and control the force application and magnitude of nasal elevators remotely in the Aligner NAM (with DynaCleft nasal elevator) group as well as the modified Grayson Group at regular follow-ups. 3D analysis of changes in nasal labial region as well as long-term growth changes in these patients needs further follow-up and investigation. There is also a need for discovering a 4D material that changes shape over time adapting to the continuous change in nostril symmetry as NAM therapy proceeds further.

Conclusion

Within the limitations of the study, it can be concluded that:

1. Both methods are effective in Naso-Alveolar Molding. Hence, the Aligner NAM can be used as an effective alternative to the conventional NAM technique, since it requires less clinical visits.
2. There was a statistically significant difference in Pre- and post-PNAM facial measurements (linear and angular) in both groups, which reiterates the advantages of PNAM therapy.
3. After lip repair surgery, no significant difference between the groups with different PNAM techniques was observed for the linear parameters (except in the outer lateral height of the non-cleft side, the basal lateral height of the non-cleft side and philtrum width); for the angular parameters (except in nasolabial angle, anterior nasal base triangle III, and anterior nasal root triangle)

Declaration of Conflicting Interests

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Case Report

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Orthodontic management of a growing skeletal class II case with functional appliance and atypical extractions: A case report

Monis Raza, Payal Sharma, Shubhangi Jain and Piush Kumar

Abstract

Extractions are commonly used to alleviate moderate to severe crowding, retract protrusive incisors, or correct anteroposterior inconsistencies in the maxillomandibular area. The choice of which teeth to be extracted requires a thorough assessment of the dentition of the patient, taking into account treatment objectives, dental and periodontal properties as well as ease of mechanics with minimum iatrogenic effects. This case report discusses the successful treatment with myofunctional appliance of a growing patient with skeletal Class II malocclusion followed by fixed mechanotherapy involving atypical teeth extraction.

Keywords:

Atypical extraction, skeletal malocclusion, transposition

Introduction

The primary goal of orthodontics as a discipline is to maintain the functional, structural, and esthetic integrity of teeth and their supporting structures. Every dental unit, according to Dr. Edward H. Angle, must provide optimal skeletal, soft tissue, and dental health, as well as facial esthetic harmony. Different malocclusions, asymmetries, transposed teeth complexities, midline anomalies, and extreme arch length differences, however, necessitate the sacrificing of certain dental units—mainly premolars, but also atypical teeth such as lower incisors or even the cornerstone canines.[1,2] While premolars are most commonly extracted in case of tooth material arch length discrepancy as it is usefully sited to relieve anterior crowding and to correct molar relationship, canines are rarely extracted.

The mechanical, esthetic, and practical aspects of canine extraction have been explored by Saa dé and O Ghougassian.[3] Canine rise in lateral excursive movements has received a lot of attention in the past. Thornton[4] discovered, however, that there is no scientific evidence for the practical superiority of one occlusal scheme over another. The evidence-based literature does not support the need to develop a canine-protected occlusion in orthodontic patients. As a result, group function or premolar guidance will safely replace canine guidance.

Orthodontic treatment aims to restore proper occlusion and facial aesthetics, while also preserving joint and periodontal stability, as well as the health of tooth support systems. However, in a number of situations, a multidisciplinary clinical approach is needed in order to achieve all objectives.[5]

The aim of this case report is to discuss a comprehensive treatment of a growing

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patient with skeletal Class II malocclusion along with transposition between the canine and lateral incisor in the lower left quadrant.

Case Report

Male patient 13 years old, sought orthodontic treatment with chief complaint of having forwardly positioned upper front teeth and irregularly placed lower front teeth.

The clinical examination revealed the patient in good general health. In the frontal view, the patient presented a symmetrical face, increased lower facial third dimension, dolicofacial pattern, and absent lip seal with increased incisor display at rest.

In the lateral view, he presented a convex profile, a recessive chin due to retro-positioned mandible, acute nasolabial angle, and obtuse cervico-mandibular angle. The smile was asymmetric due to the crowding and was non-consonant.

The functional pattern analysis evidenced mixed breathing, despite being predominantly oral, in addition to phonation and deglutition with anterior interposition of tongue. The tonsils, adenoids, and temporomandibular joint were normal, with hyperactivity of both upper and lower lips.

The intraoral examination revealed mild upper arch crowding, severe lower arch crowding, lack of adequate overbite, 8 mm of overjet and increased axial inclination of maxillary incisors. There was a Class I molar relationship on the left side, half unit Class II on the right side with Class I canines and the left lower quadrant tooth #32 was partially transposed with #33; which was totally blocked out of the arch buccally. [Figure 1]

The dental cast assessments revealed a tooth material excess in both maxillary and mandibular arches. The panoramic radiograph showed overlapping images of tooth #32 and #33. The trabeculae contour was normal and the lamina dura was intact for all teeth with developing third molars also evident.

The skeletal pattern was assessed by means of lateral cephalogram and revealed a combination of orthognathic maxilla and a retrognathic mandible thus evidencing a Class II skeletal pattern (SNA = 81°, SNB = 75°, and ANB = 6°), with facial vertical growth (SN.GoGn = 33° and Y-axis = 64°). The dental pattern revealed increased axial inclination and protrusion of maxillary incisors (1-NA = 7.5 mm and 39.5°). Lastly, a convex profile was found, with the upper lower lip positioned 7 mm forward relative to the S line [Figure 2].

Treatment objectives

- Address the chief complaint, i.e., to correct the inclination and positioning of upper anteriors and proper alignment of lower teeth.

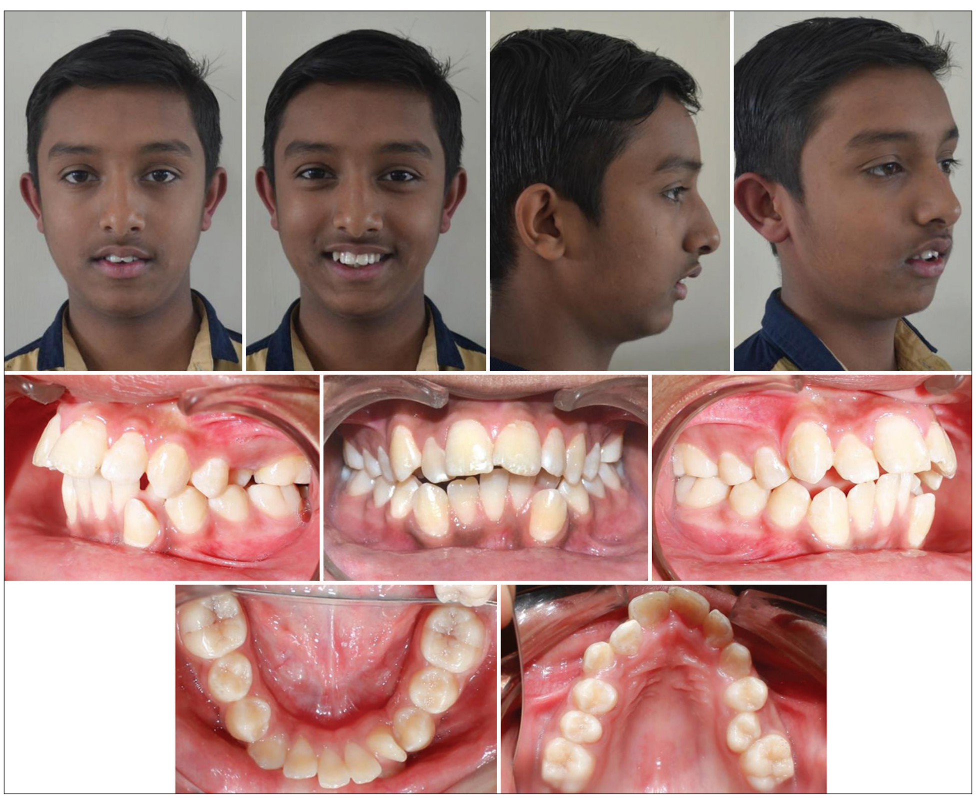

Figure 1: Pretreatment extra-oral and intra-oral photographs

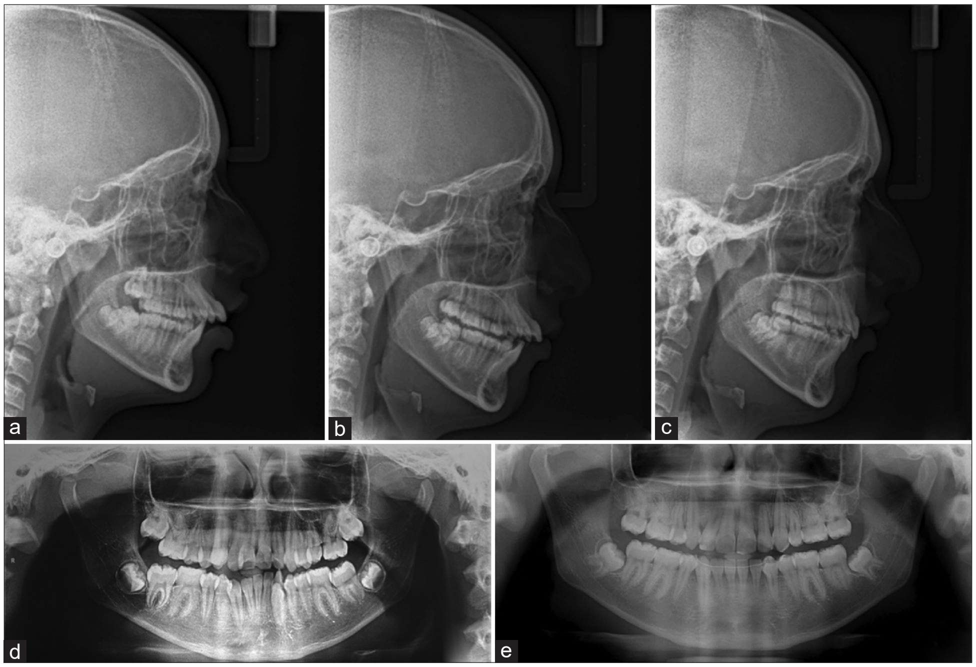

Figure 2: Pretreatment Lateral Cephalograms & Orthopantomogram (a & d), Mid-treatment Lateral Cephalogram (b) and Post-treatment Lateral Cephalograms & Orthopantomogram (c & e)

- Correction of increased overjet and reduced overbite.
- Correct the molar relation on the right side and obtain proper canine relationships bilaterally.
- Correct the skeletal Class II relation.

Improve the smile and soft tissue profile.

Treatment alternatives

With the list of objectives defined for this case, multiple treatment plans were taken into consideration:

1. To address the skeletal malocclusion with myofunctional appliance in phase 1 followed by extractions of all first premolars during phase 2, that is fixed mechanotherapy.
2. To address the skeletal malocclusion with myofunctional appliance in phase 1 followed by asymmetric extractions during phase 2, which would be tooth #14, #24, #33, and #44.
3. To treat this case by camouflaging the skeletal malocclusion via extractions and fixed mechanotherapy.

The second treatment plan was chosen for this particular case because we wanted to take advantage of the growth left in the patient to correct the skeletal disproportion as well as to correct the position of the teeth by fixed mechanotherapy. Extraction of tooth #33 would have aided us in creating simpler mechanics with minimal side effects and some anchorage preservation in the lower arch.

TREATMENT PLAN AND MECHANICS OF CHOICE: The orthodontic planning consisted of addressing the skeletal Class II by myofunctional appliance; twin block in this case, with an expansion screw so as to correct the posterior cross-bite that would develop after mandibular advancement. An occipital-pull headgear was used to control sagittal and vertical growth. Following the active and supporting stage of the twin block appliance, the patient underwent fixed mechanotherapy with MBT 0.022″ X 0.028″. Based on a comprehensive space analysis, extraction of all first premolars was decided, but to correct the partial transposition and for the ease of mechanics, tooth #33 was chosen for extraction instead of #34. Following a phase of leveling and alignment, retraction of anterior teeth was carried out on 19 x 25 SS wires keeping maximum anchorage in both arches. The occipital headgear was modified to fit into the headgear tube and continued for anchorage preservation. Following space closure, Intermaxillary elastics were used for settling the occlusion.

Results

The treatment objectives were fulfilled, as shown by the assessment of results achieved after the orthodontic treatment was carried out over a period of 24 months. The facial profile improved due to the mandibular advancement and decreasing protrusion of the maxillary incisors. In terms of tooth positioning, there were significant uprighting and retraction of maxillary incisors, in addition to the correction of the anterior open bite. Proper occlusion was achieved from a functional perspective, with incisal guidance during protrusive movement of the mandible and disocclusion of canines on the right side (working occlusion), without balancing interference during lateral guidance. On the left side, group disocclusion was aimed due to tooth #34 replacing tooth #33. Therefore, functional occlusion and esthetic outcomes were achieved. Subsequently, the patient was subjected to a minor restorative procedure to develop the anatomy of the canine on the premolar in the third quadrant [Figures 3 and 4].

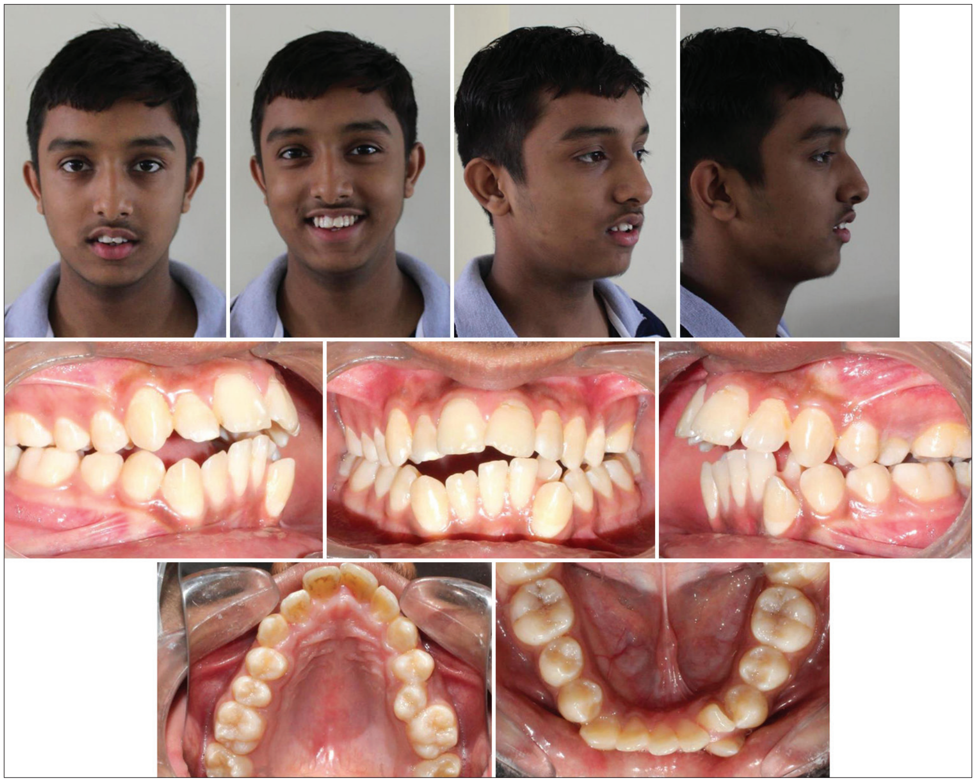

Figure 3: Mid-treatment extra-oral and intra-oral photographs after treatment with twin block appliance

Figure 4: Post-debond extra-oral and intra-oral photographs

The skeletal pattern assessment revealed, although the patient no longer presented facial growth, the ANB angle decreased to 3°. This occurred not just because of mandibular advancement but also due to retraction of incisors and considerable decrease in axial inclination [Table 1].

The total cephalometric superimposition revealed slight clockwise rotation of the mandible, very slight opening of mandibular plane, decrease in protrusion of maxillary and mandibular incisors, and improved lip position. The partial maxillary superimposition revealed mild extrusion and decreased protrusion of maxillary incisors, with a more significant palatal movement of the crown. The partial mandibular superimposition revealed mild extrusion and decreased protrusion of mandibular incisors, with less significant movement of the crown lingually, probably because it was a case of mandibular anterior crowding. By the end of fixed mechanotherapy, the patient had well-aligned arches, Angle`s Class I molars, Class I canines, and proper overjet and overbite with significant improvement in the overall facial appearance [Figure 5].

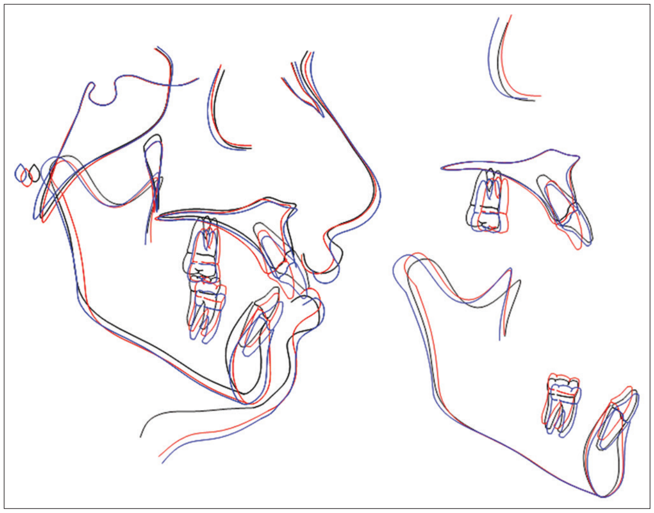

Figure 5: Treatment Superimposition (Black: Pre-treatment, Blue: Mid-treatment/ Post-functional & Red: Post-treatment)

Discussion

The adult dentition is prone to asymmetrical and awry complications, necessitating unusual extractions and treatment preparation. The decision to extract should be made in order to achieve equilibrium between the upper and lower arches, with no deficiency or excess space remaining. Soft-tissue breakdown, which manifests clinically as gingival recession, is often associated with an ectopically placed tooth. When teeth are relocated orthodontically into a new location, they lose their attachment and more bone is lost.[2]

Although these extractions may seem to be incongruous, they were necessary for this case to achieve an acceptable esthetic and structural target. When done correctly, atypical extractions can produce very satisfactory results. Before preparing any extraction, it is important to consider the midline of the dentition, periodontal health of the teeth in question, mechanics, and overall benefit to the patient with minimum iatrogenic damage.

Table 1: Pre-treatment, post functional appliance therapy and post debond Cephalometric analysis

Parameter	Normal Value/Range	Pre-treatment	Post-functional	Post-treatment
SNA	82°	81°	81°	81°
SNB	80°	75°	78°	78°
ANB	2°	6°	3°	3°
Upper 1 to NA	22°, 4 mm	39.5°, 7.5 mm	38.5°, 7 mm	25°, 4.5 mm
Lower 1 to NB	25°, 4 mm	25°, 4.5 mm	26°, 5 mm	24°, 4 mm
Upper 1 to SN	102±2°	119°	118	104°
IMPA	90°	92°	94°	92°
Inter-incisal Angle	135°	109°	110°	131°
Upper 1 to A-Pog	2.7 mm, 1-5 mm	+10 mm	+9.5 mm	+3.5 mm
Lower 1 to A-Pog	1+3 mm	+2 mm	+3 mm	+1 mm
SN-MP	32°	33°	33°	33°
PP-MP	25°	26°	26°	26°
Jaraback Ratio	62-65%	62%	61%	60%
Maxillary length		80 mm	80 mm	80 mm
Mandibular length		95 mm	96.5 mm	96.5 mm
LAFH		59 mm	60 mm	61 mm
Naso-labial Angle	102±4°	93°	93°	103°
N Perpendicular to point A	0±3.7 mm	+3 mm	+3 mm	+3 mm
N Perpendicular to pogonion	4-6 mm	-11 mm	-5 mm	-6 mm
Wits Appraisal	0 mm	4.3 mm	0.5 mm	0.5 mm
E Line	-2 mm	+3 mm	+3 mm	-1 mm

IMPA: Incisor mandibular plane angle, SN-MP: SN-Mandibular plane angle, PP-MP: Palatal plane-mandibular plane angle, LAFH: Lower anterior face height

No dental unit should be compromised unless the need for extraction is clearly justified.[6,7]

Whatever the treatment plan may be, the only goal that it should abide by should be to provide a stable occlusion along with a pleasing facial profile.

Treatment options are influenced by a number of factors, including the dental arch, affected teeth, crown and root position, degree of resorption, malocclusion, clinician experience, and patient motivation.[8,9] As for the patient reported herein, malocclusion hindered aesthetics which was impaired due to the excessively recessive mandible, incompetent lips, presence of anterior open bite, protruded maxillary incisors, and severe mandibular dental crowding.

In addition to the problems mentioned, the case was further complicated by the partial transposition present between tooth #32 and #33. In view of the treatment options available in the literature, alignment of transposed teeth would not be recommended. This is because the reported case presented with a partial transposition affecting the canine in labial version without enough space for alignment. Despite reaching less favorable outcomes when the order of teeth is not corrected, a number of clinicians opt for such orthodontic therapy, which is rendered simpler. They, thus, recommend correction of pseudo or incomplete transposition only so as to prevent root resorption, recession, and hard-to-control mechanics.[5] In the case reported herein, significant root resorption was absent at treatment completion, with only generalized rounding of root apices being found.

Additionally, the approach demands longer treatment time as well as meticulous torque and direction of force control, so as to move the transposed teeth while preserving the buccal bone cortex. Therefore, lack of space and unfavorable position of canine and preservation of anchorage in the lower arch were decisive in opting for extraction of one transposed tooth. Thiruvenkatachari[10] did a study to assess the esthetic perceptions of patient smiles among dental professionals and laypeople with respect to maxillary canine extractions. It was concluded that no statistically significant difference was found in the smile attractiveness between canine extraction and premolar extraction patients as assessed by general dentists, laypeople, and orthodontists.

A positive visual treatment objective, increased overjet, and patients's age were the key factors that propelled us to treat this case initially with a twin block appliance with an expansion screw; although certain factors like vertical growth pattern and lower anterior crowding were not the most favorable points. But the final decision was based on the idea of taking advantage of the growth that was left; even if we could obtain mild skeletal and dental changes, it would help in reducing the overjet and give some definition to the chin area. Some amount of intrusion of the first premolar was also performed in order to achieve optimal marginal gingiva levels along with a conservative buildup of premolar. This was the treatment of choice aimed at enhancing aesthetics and function, in addition to allowing shorter treatment time.

Conclusion

When done correctly, atypical extractions can produce very satisfactory results. Factors like treatment time, ease of mechanics, avoidance of any iatrogenic damages as well as the periodontal health of the teeth in question are key points in determining which tooth to extract. As shown in this case report, however, satisfactory esthetic and functional outcomes can be achieved by doing atypical extractions like canine in selected cases where the benefits outweigh the risks.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the legal guardian has given his consent for images and other clinical information to be reported in the journal. The guardian understands that names and initials will not be published and due efforts will be made to conceal identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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3-D assessment of skeletal and dentoalveolar bilateral dimensions in unilateral impacted palatal canine cases – A CBCT study

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Abstract

Background: The aim of this study was to compare skeletal and dentoalveolar dimensions in subjects with maxillary unilateral impacted palatal canines versus the unaffected contralateral side using CBCT.

Material and Methods: Skeletal and dentoalveolar variables (Anterior alveolar ridge height, Anterior dentoalveolar height , nasal cavity width, basal nasal width, Lateral angulation of long axis of the incisors and canines with respect to the nasal horizontal plane, premolar to median raphe width, dimensions of lateral incisor and canine, root resorption of lateral incisors, crown-root angulation of lateral incisor, and sector classification of canine) were compared between the impacted and the contralateral sides. As the data had normal distribution, means were compared using students t test. The significance was set at $p<0.05$. The root resorption in lateral incisor was compared using Chi square test.

Results: Lateral angulation of long axis of canines, nasal cavity width, basal lateral width, and premolar to median raphe width were found to be significantly different. Maximum number fell in sector 4 ($n = 23$, 38.3%) in sector classification. Root resorption of lateral incisor on impacted side was insignificant.

Conclusions: Skeletal and dento-alveolar dimensions vary between the impacted and non-impacted sides in unilateral palatal canine impaction cases. Canines on the impacted side were more mesially angulated compared to the non-impacted side. The nasal cavity width, basal lateral width and premolar to median raphe width were significantly less on the impacted side compared to the non- impacted side.

Key words: *Impacted canine, CBCT, skeletal dimensions, diagnosis, orthodontic treatment.*

Introduction

Canine impaction can be defined as an infra-osseous position of the canine after the expected eruption time (1,2). The prevalence of maxillary canine impaction ranges from 1% to 5%.6 Impacted canine in the palatal position occurs 3 to 6 times more often than the buccal position. Impacted canines are twice as common in women as in men, and the incidence in the maxilla is more than double compared to the lower jaw (3,4).

Disturbance in the dental lamina, precocious development of the canine in the maxilla and microform of the cleft lip and palate may lead to impaction of maxillary canines (4). Palatally displaced canines have been found to have an autosomal dominant trait with low penetrance and variable expressivity. Palatal canine impactions are related to excessive space in the dental arch, whereas buccal canine impactions have insufficient space to erupt in the dental arch (5). Although there is no consensus about the exact etiology of palatally impacted canines, it appears that the adjacent lateral incisor demonstrates an important role, either because its eruption and dimensions are controlled by the same genes that control the eruption of the canine (genetic theory) or because its position in the arch influences the eruption path of the canine (guidance theory) (6)

Becker *et al*. (7) related palatal canines to congenitally missing lateral incisors, late formation of the dentition, small lateral incisors, peg-shaped laterals, and short rooted laterals and reported a highly significant relationship between anomalous or absent lateral incisors and palatally displaced canines. In another study, palatally displaced canines were reported to be associated with other impacted and missing teeth, and deep bite with retroclined maxillary incisors. Becker *et al.* found that approximately half of their subjects with palatally displaced canines had delayed dental development (7,8).

Eruption is a physiologic process that influences the normal development of alveolar bone, whereas impaction (impacted tooth) may hinder the regional development of alveolar bone (9,10). Impaction can lead to reduced bone dimensions, or affect dental angulations of the nearby teeth. A few studies (6,10) have compared the impacted area with the contra-lateral area that had adequate canine eruption in the same individual. Kanavakis *et al*. (6) concluded that the root of lateral incisors adjacent to palatal impacted canines is angulated more mesially compared to that of lateral incisors adjacent to normally erupted canines.

With the advent of cone-beam computed tomography (CBCT), more specifically, by rendering three-dimensional (3D) views of teeth and bone at high resolution, detailed characteristic of alveolar bone dimensions can be obtained at the impacted side (10). Finding specific morphological differences in patients with palatally displaced canines could help to revise and maybe add to the accepted interceptive measures: extraction of the deciduous canine (11).

The aim of this study was to compare skeletal and dentoalveolar dimensions in subjects with maxillary unilateral impacted palatal canines versus the unaffected contralateral side using CBCT.

Material and Methods

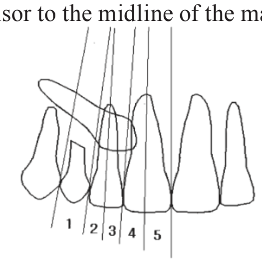
This retrospective cross-sectional split mouth design study was approved by the Ethics and Research Committee of the Institution. The sample consisted of full maxillary CBCT scans of 60 patients with unilateral maxillary impacted palatal canines (full FOV of 10 x 10 cm) sourced from the archives of an imaging centre specialising in CBCT imaging. The minimum sample size required was 20 impacted canines per group, determined by a formula to compare 2 means, with a 95% confidence level and 80% test power, when the average difference of RR between groups was 0.5 mm (data from a previous pilot test), and with a standard deviation of 0.64 mm. The inclusion criteria for selection were CBCTs of subjects over 15 years old of both sexes, with canines fully calcified, with a unilateral maxillary canine impaction, complete eruption of the contra-lateral canine and no prior orthodontic treatment. We included impacted canines located in all sectors.17 Exclusion criteria were subjects with previous orthodontic treatment, dento-maxillary traumas, maxillary canine transpositions, agenesis, craniofacial malformations, odontogenic pathologies, and CBCTs of bilateral impacted and bucally impacted canines.

All the CBCT images were taken with the NewTom 3G (QR SRL, Giona,Vila Silverstrini, Verona, Italy) device (90 kV, 10 mAs, 36 sec exp, voxel size 180 µ) with the patient in maximum intercuspation and Frankfort horizontal plane parallel to the floor following common CBCT imaging protocols. All the data sets were exported as Digital Imaging and Communications in Medicine (DICOM) images. Then these data sets were incorporated to the interactive CBCT analysis software. CS 3D Imaging v 3.5.7(Carestream Health) software was used for measurement on Dell Precision T1700 workstation with Dell P2214H monitor with a resolution 1920 X 1080 @ 60 Hz in a dimly lit room. All the measurements were performed on the multi-planar reconstruction (MPR) mode of the CBCT software. The parameters measured are defined in Table 1.

All CBCT measurements were done by two people, an Oral and Maxillofacial radiologist and one postgraduate student who were trained for the procedure before interpretation. Ten scans per day were evaluated and all the scans were evaluated twice at an interval of ten days.

On the anteroposterior projections derived from the CBCT volume in maximum intensity projections (MIP) in coronal view, parameters (Table 1) were measured

Table 1: Variables measured on CBCT images.

	VARIABLES	DEFINITION
1)	Anterior alveolar ridge height (AARHCI/ AARHLI)	Measured in millimetres from the bony ridge of upper incisors by drawing a straight line parallel to the midsagittal plane till the nasal floor on the side of impacted canine and side without impaction
2)	Anterior dentoalveolar height (ADARHCI/ ADARHLI)	Measured in millimetres from the incisal edge of upper incisors by drawing a straight line parallel to the midsagittal plane till floor of the nasal floor on side of impacted canine and side without impaction
3)	Nasal cavity width(NCW)	Measured in millimetres from the mid sagittal plane to the lateral wall of the nasal base on the side of impacted canine and the canine without impaction
4)	Basal lateral width(BLW)	Measured in millimetres from the mid sagittal plane to the outermost dentoalveolar rim on the side of impacted canine and the canine without impaction
5)	Lateral angulation of long axis of the incisors with respect to the nasal horizontal plane(LACI/LALI)	Value of the external angle of the longitudinal axis of the incisors of both quadrants with respect to the tangent of the nasal floor
6)	Lateral angulation of long axis of canines with respect to the nasal horizontal plane(LAC)	Value of the external angle of the longitudinal axis of the impacted canine and which has no impaction with respect to the tangent of the nasal floor
7)	Premolar to median raphe width(PWTMR)	Distance in millimetres from the middle palatine raphe to proximal alveolar bone crest between the canine (deciduous or permanent) and first premolar on each side, measured in the axial cut at bone crest level
8)	Width of crown of lateral incisor(LICW)	Mesiodistal width of crown measured from the widest point of the crown
9)	Width of crown of canine(CCW)	Mesiodistal width of crown measured from the widest point of the crown
10)	Height of crown of lateral incisor(LICL)	Anatomic height of the crown measured from the lowest buccal CEJ point to the incisal tip in the lateral view image
11)	Height of root of lateral incisor(LIRL)	Length of the root measured from the lowest buccal CEJ point to the root apex in the lateral view image.
12)	Root resorption of lateral incisors(RR)	Root resorption based as absent(intact root surfaces) or present (distorted root apex)
13)	Crown-root angulation of lateral incisor(LICRA)	Angle between the long axis of the crown and the long axis of the root of all the lateral incisors
14)	Sector classification of canine (Ericson and Kurol)	Mesiodistal position of the canine tip in relation to adjacent teeth : (1) Corresponds to the deciduous canine; (2) indicates the distal aspect to the midline of the lateral incisor; (3) indicates the midline of the lateral incisor to the distal aspect of the central incisor; (4) indicates the distal aspect to the midline of the central incisor; and (5) indicates the midline of the central incisor to the midline of the maxillary arch 

keeping a uniform standardized base thickness of 22.1 mm. In the sagittal section views, keeping a uniform standardized base thickness of 180 μ, three horizontal lines were projected, two tangents passing through the apex of the root tip and the crown tip and the third line passing through the buccal CEJ point towards the palatal part of the tooth dividing it into two halves. Length of the crown and root of the lateral incisor (Fig. 1) were measured. Resorption of the lateral incisor caused by the impacted canine was appraised on the volumetric images in multiplanar views on sagittal slice after triangulation of the lateral incisor along the long axis (Fig.

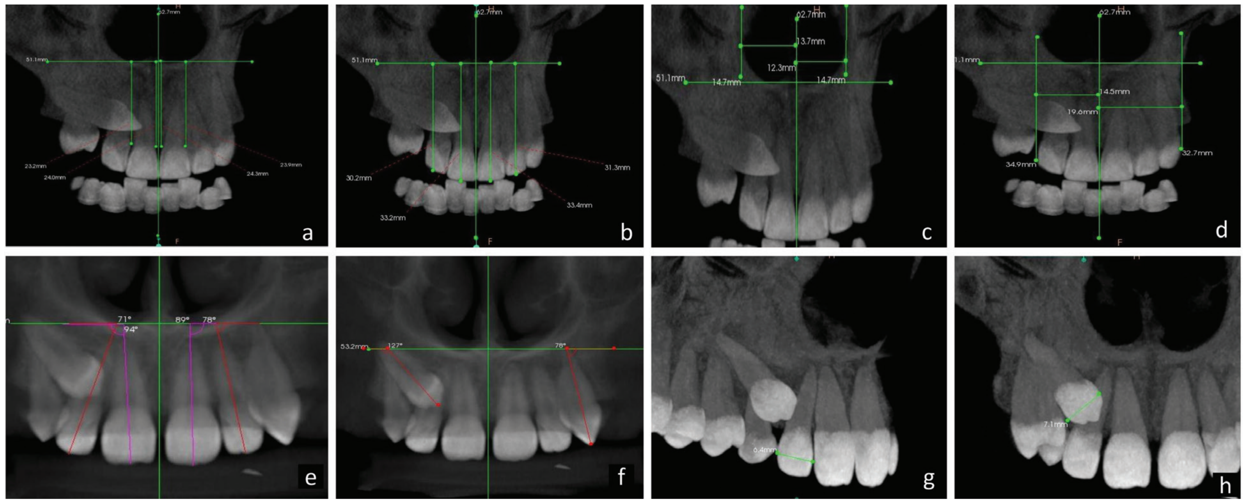


Fig. 1: a) Anterior alveolar ridge height measurement. b) Dentoalveolar ridge height measurement. c) Nasal Cavity width measuremet. d) Basal lateral width measurement. e) Lateral angulation of Incisor measurement. f) Lateral angulation of long axis Canine measurement. g) Width of lateral incisor in coronal section. h) Width of canine in coronal section.

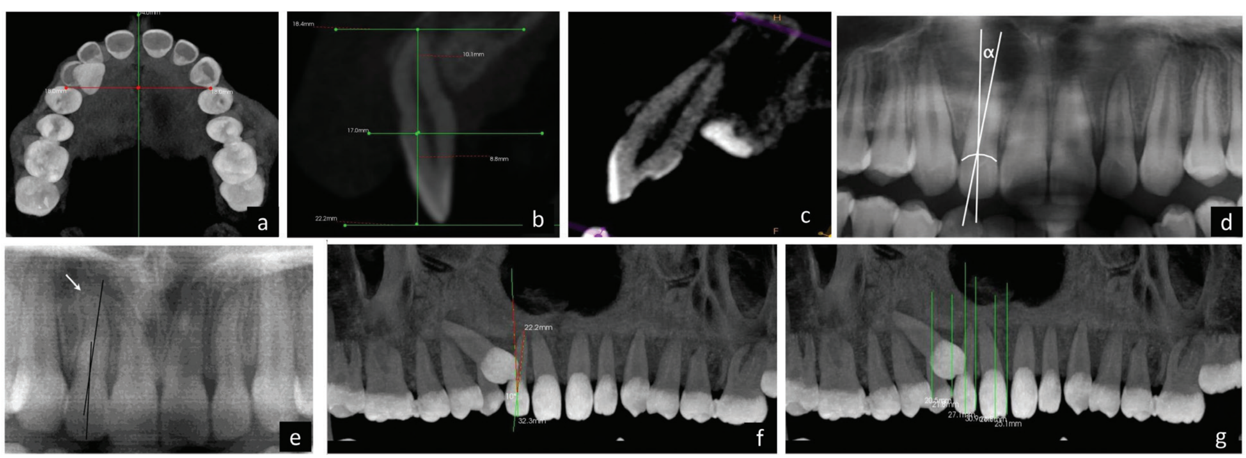


Fig. 2: a) Measurement of Premolar to median raphe width. b) Crown and Root Height evaluation on sagittal slice. c) Assessing root resorption of lateral incisor adjacent to canine. d) Angle α used to measure mesio-distal crown root angulation of the lateral incisor. e) Dilaceration of root apex (not regarded when defining the long axis of the root). f) Medially angulated lateral incisor with α > 0. g) Evaluation of Sectors classification in panoramic image reconstructed from axial view of CBCT images.

2). Root resorption was evaluated based on the presence of intact (Grade 0) or distorted root surfaces (Grade 1). In the curved slicing mode on the axial image, a manual arc was drawn following the midpoints of the teeth, at a level where both buccopalatal cortices were evident and a reconstructed panaromic view was obtained. Crown-root angulation of the lateral incisor and sector classification of the canine according to Ericson and Kurol were evaluated. When defining the long axis of the lateral incisor root, dilaceration at the root apex was not considered so as to obtain a better representation of the direction of the long axis (Figs. 1,2).
The data was computed and analysed statistically to determine differences between the impacted and non-impacted sides.

-Statistical analysis
The data was subjected to statistical analysis using SPSS version 20.0. The descriptive statistics including the mean, standard deviation, minimum and maximum values were calculated for each of the variables in both the groups. The Shapiro-Wilk test was assessed to determine whether the data had normal distribution. As the data had normal distribution, means were compared using students t test. The significance was set at $p<0.05$. The root resorption in lateral incisor was compared using chi square Test. Reliability between repeat observations was tested by Cronbach's Alpha and found to be 93.8% which indicated a strong agreement.

Results

Table 2 shows the descriptive statistics and comparison for all the variables measured at the impacted / non impacted sides. There was no statistical difference between the variables ADARHCI, ADARHLI, AARHCI, AARHLI, LACI, LALI, LICL, LIRL, LICW, CCW and LICRA between the impacted and non-impacted sides. LAC, NCW, BLW and PWTMR variables were found to be significantly different (Table 2).

Chi-Square Test was done to evaluate frequencies of root resorption of lateral incisor on impacted side. The difference was insignificant (Table 3).

Chi-Square Test was done to evaluate frequencies of root resorption of lateral incisor on both the sides. The difference was insignificant. 55% cases showed root resorption on impacted side.

The palatal impacted canines were classified into five sectors according to the method of Erricson and Kurol as stated in Table 1 (Table 4).

Out of 60 impacted canines, the maximum number fell in sector 4 (n = 23, 38.3%), followed by sector 3 (n = 13,21.6%), sector 5 (n = 11,18.3%) and sector 2 (n = 7, 11.6%). Sector 1 showed the least frequency (n = 6,10%).

Table 2: Comparison of variables between impacted and non-impacted side by T-test.

VARIABLES	SITE	n	Mean ± SD	Sig.	95% Confidence Interval of the Difference	
					Lower	Upper
ADARHCI (in mm)	IMPACTED	60	32.45 ± 3.87	.93	-1.35	1.48
	NON IMPACTED	60	32.38 ± 3.95	.93	-1.35	1.48
ADARHLI (in mm)	IMPACTED	60	30.25 ± 3.60	.69	-1.06	1.60
	NON IMPACTED	60	29.9 ± 3.76	.69	-1.06	1.60
AARHCI (in mm)	IMPACTED	60	22.96 ± 3.65	.91	-1.24	1.39
	NON IMPACTED	60	22.89 ± 3.61	.91	-1.24	1.39
AARHLI (in mm)	IMPACTED	60	22.41 ± 3.60	.70	-1.03	1.53
	NON IMPACTED	60	22.15 ± 3.49	.70	-1.03	1.53
LACI (in deg)	IMPACTED	60	87.97 ± 5.23	.87	-2.01	1.71
	NON IMPACTED	60	88.12 ± 5.08	.87	-2.01	1.71
LALI (in deg)	IMPACTED	60	78.57 ± 11.01	.51	-2.23	4.43
	NON IMPACTED	60	77.47 ± 6.98	.51	-2.24	4.44
LAC (in deg)	IMPACTED	60	122.97 ± 15.58	.00	35.77	45.03
	NON IMPACTED	60	82.57 ± 9.26	.00	35.76	45.04
NCW (in mm)	IMPACTED	60	11.90 ± 1.65	.04	-1.16	-.02
	NON IMPACTED	60	12.49 ± 1.52	.04	-1.16	-.02
BLW (in mm)	IMPACTED	60	14.58 ± 1.77	.00	-5.02	-3.66
	NON IMPACTED	60	18.92 ± 2.00	.00	-5.02	-3.66
LICL (in mm)	IMPACTED	60	9.03 ± 1.18	.82	-.45	.36
	NON IMPACTED	60	9.08 ± 1.06	.82	-.45	.36
LIRL (in mm)	IMPACTED	60	12.41 ± 1.67	.17	-1.02	.19
	NON IMPACTED	60	12.83 ± 1.67	.17	-1.02	.19
LICW (in mm)	IMPACTED	60	6.24 ± .76	.80	-.30	.23
	NON IMPACTED	60	6.28 ± .69	.80	-.30	.23
CCW (in mm)	IMPACTED	60	7.36 ± .62	.06	-.00	.41
	NON IMPACTED	60	7.15 ± .55	.06	-.00	.41
PWTMR (in mm)	IMPACTED	60	16.10 ± 1.98	.00	-1.78	-.38
	NON IMPACTED	60	17.18 ± 1.91	.00	-1.78	-.38
LICRA (in deg)	IMPACTED	60	4.90 ± 3.15	.26	-1.83	.49
	NON IMPACTED	60	5.57 ± 3.26	.26	-1.83	.49

Means were compared using students t test. The significance was set at $p<0.05$.

Table 3: Descriptive statistics to show frequencies of root resorption of lateral incisor on impacted and non-impacted sides.

			RR		Total
			No	Yes	
Tooth	Impacted	Count	27	33	60
		% within Tooth	45.0%	55.0%	100.0%
	Non-Impacted	Count	36	24	60
		% within Tooth	60.0%	40.0%	100.0%
Total		Count	63	57	120
		% within Tooth	52.5%	47.5%	100.0%

Table 4: To compare the test values – Chi square test.

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	2.70	1	.10	.14	.07

Discussion

Early diagnosis of ectopic erupting permanent canines could lead to early interceptive treatment with the goal of preventing impaction and reducing the need for later costly surgical exposure and subsequent orthodontic treatment (11). The relationship between maxillary canine impaction and the morphologic characteristics of the palate was examined in this study. Skeletal and dentoalveolar dimensions in subjects with unilateral maxillary palatal impacted canines were compared between the impacted and non-impacted sides.

On comparing anterior alveolar ridge height and anterior dentoalveolar height of central and lateral incisor between both the sides, the present study showed an insignificant difference. The study by Oleo-Aracena *et al*. (4) showed the same results. They reasoned that the incisor heights should not be affected because the sequence of eruption of incisors is prior to canines. Although their study had subjects of Latin American origin their findings were similar to our study which had subjects of Indian origin.

Our study showed significant differences in nasal cavity width and basal lateral width values, with reduced dimensions on impacted sides as compared to non-impacted sides. This result was in contrast with the findings of Oleo-Aracena *et al*. (4) and Miresmaeili *et al*. (12) who found no difference in these variables between the impacted and non-impacted cases. Saiar *et al*. (13) also found no relationship between the nasal width and PDC. Sar *et al*. (14) found significant differences were observed in the canine angulation, premolar width and basal lateral width between the impacted vs. contra-lateral sides. The disparity in results may have been due to the difference in the sample of the studies; our study and that of Oleo-Aracena *et al*. (4) took cases of unilateral impaction and compared impacted vs non-impacted sides whereas Miresmaeili *et al*. (12) included cases with bilateral and unilateral impacted canines along with a control group. The method of measurement also differed; Oleo-Aracena *et al*. measured nasal cavity width on each side from the anterior nasal spine whereas in this study, the measurement was made from the mid-sagittal plane (4).

Significant differences were observed in premolar to median raphe widths on comparing both the sides, measured as the distance from the mid-palatine raphe to the first premolar. The premolar width on the affected side was significantly lower than on the non-impacted side. This was similar to results of study by Oleo-Aracena *et al*. (4) As they explained, this was because the side of the impacted canine had not been sufficiently developed, compared with the unaffected side where canine erupted normally. Naoumova *et al*. (11) found significantly smaller arch width in the canine region in both unilateral and bilateral canine impaction cases compared with a control group. McConnell *et al*. (15) used dental casts to measure maxillary widths and concluded that patients with PDC have transverse deficiencies.

Narrower arches on the impacted side have been reported by many authors (McConnell *et al*. (15) and Kim *et al*. (16)) whereas some others have reported no difference in arch width (Langberg *et al*. (17), Saiar *et al*. (13) and Anic-Milosevic *et al*. (18)). The reason for these disparities may be due to different methods of measurement; Naoumova *et al*. (11) and Mucedero *et al*. (19) used 3D scans of models whereas this study and some other recent studies (Miresmaeili *et al*. (12), Tadinada *et al*. (10), Oleo-Aracena *et al*. (4), Hong *et al*. (20)) have preferred to measure on CBCT scans to enhance accuracy of measurements in three dimensions. The measurements of arch width have also been made at different levels; Naoumova *et al*. (11), Al-Khateeb *et al*. (21)

and Mc-Connell *et al*. (15) measured inter-canine width, Naoumova *et al*. (11) and Al Khateeb *et al*. (21) also measured inter-premolar width, Miresmaeili *et al*. (12), Al Khateeb *et al*. (21) and Kim *et al*. (22) measured inter-molar width whereas Tadinada *et al.* (10) measured bucco-palatal width at 2, 6 and 10 mm. They found that BP width at 2mm above the alveolar crest was significantly less on the side where the canine was impacted but there was no difference at 6 and 10 mm due to presence of the impacted canine (19).

McConnell *et al*. (15) advocated expansion therapy in patients with PDC. However, Naoumaova *et al*. (11) suggested that the absence of atleast one permanent canine in the dental arch is probably the cause of the narrow arch width found in the canine region rather than the narrow arch width being the cause of impaction. Therefore, they did not recommend expansion therapy based solely on the decreased inter-canine or inter-premolar widths. The presence/ absence of the deciduous canine may also affect the arch width measurements. Hence it may be recommended that the clinician should correct the transverse discrepancy where present (11).

In this study, no difference was found in the lateral angulations of the long axis of incisors between the impacted and non-impacted sides. In contrast, statistically significant differences were observed by Oleo-Aracena *et al*. (4) and Liuk *et al*. (23). Oleo-Aracena *et al*. (4) found that the lateral angulation of the long axis of the incisors was lower on the impacted side, presenting disto-angulated incisors on the side of impacted canine and mesio-angulated incisors on the non-impacted side. The variation in the angulation of the incisors may have been due to difference in the vertical level as well as the horizontal overlap (sector) of the impacted canines in the sample of the other studies compared to this study.

In our study the lateral angulation of the long axis of the canines showed significant difference on comparison between impacted and non-impacted side. The impacted side showed a greater angulation of the canine with mesial tipping compared to the non-impacted side. This was similar to results presented by Oleo-Aracena *et al*. (4) and Hanke *et al*. (24).

On assessing the crown-root angulation of lateral incisors, no statistical difference was seen. This result was not in accordance with the study by Kanavakis *et al*. (6) where the long axis of the root of the lateral incisors adjacent to palatal impacted canines formed a more mesial angle to the crown (approximately 2.5°) compared to the lateral incisors adjacent to normally erupted canines.

In the present study, we found no significant differences in the shape of the crown and root of the maxillary lateral incisors between the two sides.

Previous studies have reported significant associations between the morphology of lateral incisors and the presence of a palatally impacted canine. Some tend to support that an abnormally shaped, peg, or missing lateral incisor will cause the adjacent canine to impact by not guiding it into the correct position in the arch (3,16). On the other hand, there are numerous studies (3,4) suggesting that abnormally shaped lateral incisors and palatally impacted canines are both phenotypic expressions of specific genes and therefore tend to occur concomitantly. Results from the present investigation could not be potentially used to support either of the two prevailing theories.

The width of the crown of the maxillary canine was slightly greater on the impacted side but the difference was not statistically significant. This finding was in contrast to the results of the study done by Kim *et al*. (22) who found that the size of the maxillary canine was greater on the impacted side. Their results suggest that there is a possibility that normal eruption might be impaired due to insufficient space in patients with greater crowns of the maxillary canine. According to Jacoby (3) lack of space is associated with buccal impaction of canine whereas there is 'excessive space in the maxillary arch' in case of palatally impacted canines. As stated previously Kim *et al*. (22) included both buccal and palatal impacted canines in their sample unlike the present study.

In our study, 55% of the adjacent lateral incisors showed root resorption adjacent to the impacted canines compared to 40% on the non-impacted side. The difference in root resorption incidence was not statistically different. Other studies (6-8) have shown root resorption to vary from 38% to 67%. Our study supports previous studies showing that ectopic eruption of the impacted canine may cause root resorption of the maxillary incisors, most commonly the lateral incisors. Although CBCT allows visualization of the roots in all projections and is presumed to yield a more accurate assessment, it is possible that we have underestimated root resorption because the large FOV diminishes the resolution of the image (pixel size 0.377 in a 12-inch scan vs 0.292 in a 9-inch scan), as stated by Oberoi *et al*. (7). Thus in our study, the lack of significant difference of root resorption of lateral incisors between the impacted and non-impacted sides was probably because of the low resolution of the images, which did not allow for clear depiction of resorption craters.

In the present study, the palatal impacted canines were classified into five sectors according to the method of Erricson and Kurol (25,26) as stated in Table 1. Out of the 60 palatal impacted canines, the maximum number fell in sector 4(n = 23), followed by sector 3 (n = 13), sector 5(n = 11) and sector 2 (n = 7). Sector 1(n = 6) showed the least frequency.

The study by Oleo-Aracena *et al.* (4) included only impacted canines located in sectors 2 and 3; they did not include Sector 1 because according to them, this condition was less frequent than the other two. Due to the unequal distribution of the canines, they could not be evaluated according to sectors.

The limitation of this study was that the palatally displaced canine group from the radiology practice cannot represent the general population. There is a tendency for clinicians to refer only patients with more severely impacted canines or more complicated situations to a radiology practice for further investigation with CBCT. This makes subject selection somewhat biased and any similarity with the general population should be made with caution.

Also, in this study, the most prevalent gender was females confirming that the impacted upper canines are produced twice as common in women than in men. Oleo-Aracena *et al*. (4) found a similar ratio of 2 or 3 to 1, with women being more prevalent in this sample added to etiological factor, is probably the mere fact that women are esthetically more oriented to get orthodontic treatment.

Conclusions

1. There was a significant difference in some skeletal and dento-alveolar dimensions of the maxillary arch between the impacted and non-impacted sides in cases of unilateral palatal canine impaction.
2. The canines on the impacted side were more mesially angulated compared to the non-impacted side.
3. The nasal cavity width, basal lateral width and premolar to median raphe width were significantly less on the impacted side compared to the non- impacted side.
4. There was no significant difference in the anterior alveolar ridge height of the central incisor, anterior alveolar ridge height of the lateral incisor, anterior dentoalveolar height of the central incisor, anterior dentoalveolar height of the lateral incisor, lateral angulation of long axis of the central incisors , lateral angulation of long axis of the lateral incisors, width of crown of lateral incisor , width of crown of canine, height of crown of lateral incisor, height of root of lateral incisor, root resorption of lateral incisor and the crown-root angulation of lateral incisor between the two groups.

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Conflict of Interest
None.

Effect of Perioperative Steroid, Bupivacaine and Tetracycline on Post Operative Sequelaeof Impacted Mandibular Third Molar Surgery

Abstract:

Aim: To study the effectiveness of perioperative steroids, bupivacaineandintra-socket tetracycline on post-operative sequelae after impacted mandibular third molar surgery.

Materials and Methods: Twenty patients of age group 20-40 years were randomly selected who underwent extraction of non-carious impactedmandibular third molars. In group I (10 Patients):Dexamethasone 8 mg intravenously 1 hour before surgery was given and then intraoperative nerve block was given with 0.5% bupivacaine plus placementof tetracycline gel in the socketand post operatively NSAIDafter surgery was prescribed. Group II served as control (10 Patients) wherein intraoperative nerve block was given with 2% lignocaine with 1:80,000 adrenaline andpost operatively antibiotics (Cap. Amoxicillin)along withNSAIDs(non-steroidal anti-inflammatory drugs) but no steroid and tetracycline were given.

Visual analogue scale (VAS) for Pain, swelling and mouth openingwas assessed post- operatively onfirst, third andseventh day. Any other post-operative complications like alveolar osteitis and wound dehiscence were determined on seventh day. The data obtained were examined usingMaan-Whitney U-test andWilcoxon testfor pain and independent t-test was applied for evaluating mouth opening and swelling via SPSS, version 20.

Results: Twenty patients were analyzed out of which each group included ten patients. Thepost-operativemean VAS score of group I at first post-surgery day was low as compared to group II, which was statistically highly significant (P= 0.001). Swelling and mouth opening were comparatively same in both groups which was not significant statistically (P> 0.005). There were nopost-operative complications occurred in both groups.

Conclusion: The modified protocol for third molar surgery is as equally effective as standard method with an added advantages of: (1) no fear of antibiotic resistance development, (2) no excessive use of antibiotics and NSAIDS, (3) less patient discomfort both in terms of pain, swelling, trismus and in remembering large number of medicine that he/she has to take after surgery. Multicenter studies with more sample size are required to confirm its efficacy.

Key-words: Third molar, steroids, tetracycline

Introduction:

Mandibular third molar removal is frequently performed operation in oral and maxillofacialsurgery. These should be considered for removal when there is clinical, radiographic, or evidence of acute/chronic periodontitis, caries, deleterious effects on second molars, or pathology.[1] Complications after third molar surgery include dry socket, pain, swelling, trismus, sensory nerve damage, infection and hemorrhage.[2]

Although this surgical procedure requires good surgical skills of operator and accurate pre-operative evaluation, still

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complications arise often inspite of surgical competence on the part of surgeon. Pain, trismus, post-operative swelling is almost universal after third molar surgery and lead to significant deterioration of quality of life in immediatepost-operative period. Joseph F. Piecuch did aliterature review on various topics to identify the methods of improving outcomes after third molar removal[3].

Based on his recommendations, we have proposed a modified protocol for third molar surgery. The aim of this study was to investigate whether the use ofperi-operative steroids, bupivacaine andintra-socket tetracycline has any beneficialoutcome on post-operative sequelae of impacted mandibular third molar surgerywhen compared to the standard protocol.

Materials And Methods:

A total of 20 patients were randomly selected for prophylactic removal of impacted mandibular third molars and randomly divided into two groups: group I (Test) and group II (Control) with 10 patients randomly selected in each group. Randomization was performed using sealed opaque envelopes to prevent selection bias.

Inclusion criteria consisted of patients with no medical history of any illness or prolonged medication that could influence the course of post-operative wound healing, patients with healthy dental and periodontal status with no evidence of local inflammation or pathology at the time of removal of impacted tooth were selected. Pre-operatively, intraoral periapical, and panoramic radiographs were obtained. An informed consent was duly signed by the participants. Ethical grant for the study was provided by the Institutional Ethical Committee (Ethical Committee Approval Number was ITSCDSR/L/2018/150).Post-operative sequelae of surgical removal of impacted molars are influenced by the level of difficulty of the impacted tooth, amount of bone guttered and operatory time of the procedure, hence these were standardized (by taking Pell & Gregory's Position B & Class II cases)during selection of cases and during the procedure.

In the group I, Dexamethasone 8 mg intravenously 1 hour before surgery was given. After that local anaesthesia was administered at the site with 0.5% Bupivacaine (Inj. Anawain 0.5%). A ward's incision was made starting about 6 mm inferiorly in the buccal sulcus at a point corresponding to the junction of anterior 2/3rd and distal 1/3rd of mandibular second molar. The cut was then taken vertically upwards to the neck of the second molar, passing around the gingival margin of posterior 1/3rd of the tooth and continuing cervically on the distal aspect upto approximately the midpoint of the tooth. From this point, the incision was extended posteriorly and buccally along the line of external oblique ridge. Then a mucoperiosteal flap was elevated using molts periosteal elevator.

After exposing the surgical site, osteotomy was carried out using a bur technique and the tooth was sectioned as necessary and was removed. Tetracycline gel was placed in the extraction socket. The flap was approximated with interrupted 3-0 silk suture. NSAID (combination of ibuprofen and paracetamol) thrice daily was prescribed for 3 days.

In the group II, Lignocaine 2% with 1:80000adrenaline was used for inferior alveolar nerve block along with long buccal nerve block and lingual nerve block. Removal of tooth was done similarly as done in Group I and after the removal extraction socket was closed with 3-0 interrupted silk sutures without placing tetracycline gel in to the extraction socket. Post operatively cap. Amoxicillin 500mg and NSAID (combination of ibuprofen and paracetamol) thrice daily was prescribed for 3 days. No Steroid and intra-socket tetracycline used in this group.

The patients were recalled after first, third and seventh day postoperatively for follow up. For each patient, the operator obtained the visual analogue scales (VAS) for pain. Trismus was assessed by measuring the maximum inter-incisal opening- the distance between the incisal margin of the upper and lower central incisors- using a standard ruler.

For the objective evaluation of swelling, five distances were measured: (a) the distance from mandibular angle to lateral corner of mouth; (b) the distance from the mandibular angle to the nasal curvature; (c) the distance from the mandibular angle to the lateral canthus of eye; (d) the distance from the tragus to the lateral corner of the mouth. Any other post-operative complications like alveolar osteitis and wound dehiscence were determined on seventh day.

Results:

A total of 20 patients (12 Males and 8 Females), aged between 20-40 years (25.5± 2.72 years)with non-carious impacted mandibular third molars participated in this study. The average time taken to perform surgery was 20.41±3.97

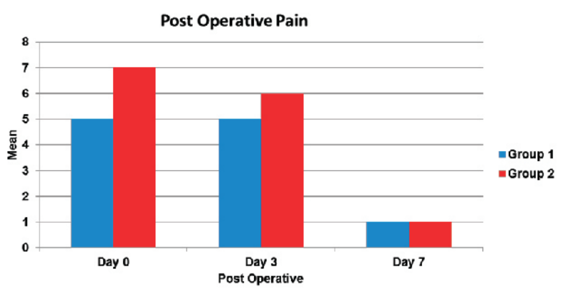
minutes for group I and 18.23 ±6.17 minutes for group II. (Table 1)

Table 1 Demographic data.

Variables	Data
Total Number of sample (N)	20
Gender	
Male	12
Female	8
Age (Years)	
Maximum age	40
Minimum age	20
Mean age	25.5± 2.72
Average Time taken for surgery (Minutes)	
Group 1	20.41±3.97
Group 2	18.23 ±6.17

Wilcoxon test and Maan-Whitney U-test was applied for statistical evaluation of pain and Independent t-test was applied for statistical evaluation of mouth opening and facial swelling.When compared to standard method (Group II) ,the modified method (group I) exhibited the following: (1) lower mean VAS score at first post-surgery day, which was statistically highly significant (P= 0.001); (2) lower mean VAS score at third post-surgery day, although this was not statistically significant (P= 0.178); (3) there was no statistically significant difference between pain on seventh post-surgery day (P= 0.744) (Table 2) (Graph 1); and maximal inter-incisal mouth opening in group I was slightly reduced by third day which was statistically not significant (P=0.360) which get stabilized by seventh day(Table 2) (Graph 2). Also, there is no statically difference between both the group for mouth opening and, in both group, means are comparably equal.

Graph 1: Graphical representation of post-operative pain.



Mean facial swelling was mild on first post-operative day (statistically not significant; P>0.005 in first post-operative day as compared to group II) followed by slight increase in swelling on third day then a reduction on seventh post-operativedaywhereas there was marked increase in swelling on first three days followed by decrease in swelling increase in group II which was statistically not significant (Table 2) (Graph 3).

Graph 2: Graphical representation of post-operative mouth opening.

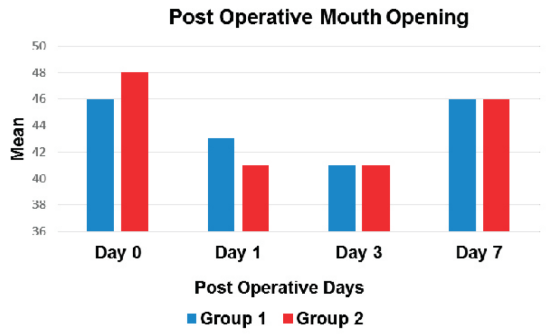
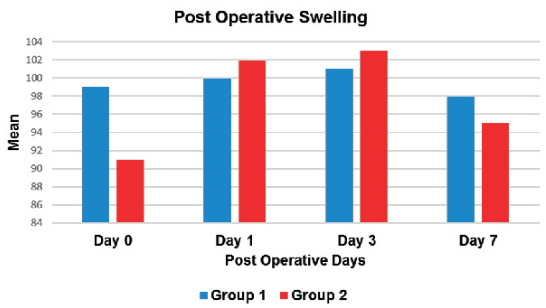


Table 2 Parameters and statistical analysis.

PARAMETERS	PRE-OPERATIVE	DAY 1	DAY 3	DAY 7
	Mean ± Std. Deviation (Std. Error Mean)	Mean ± Std. Deviation (Std.Error Mean)	Mean ± Std. Deviation (Std. Error Mean)	Mean ± Std. Deviation (Std. Error Mean)
PAIN				
Group 1	-	5.20 ± 0.63 (0.20)	5.20 ± 0.79 (0.24)	0.70 ± 0.82 (0.26)
Group 2	-	6.50 ± 0.70 (0.22)	5.80 ± 1.03 (0.32)	0.80 ± 0.78 (0.24)
P-value	-	0.001 (Highly Significant)	0.178	0.744
MOUTH OPENING				
Group 1	46.30 ± 6.67 (2.11)	43.10 ± 5.97 (1.89)	40.70 ± 5.83 (1.84)	45.50 ± 6.59 (2.08)
Group 2	48.30 ± 7.62 (2.41)	41.30 ± 7.60 (2.40)	41.40 ± 8.07 (2.55)	46.30 ± 9.46 (2.99)
P-value	0.694	0.374	0.360	0.311
FACIAL SWELLING				
Group 1	98.74 ± 5.08 (1.60)	100.04 ± 5.57 (1.76)	101.32 ± 4.75 (1.50)	98.16 ± 4.97 (1.57)
Group 2	90.52 ± 5.24 (1.66)	102.09 ± 2.52 (0.79)	103.06 ± 2.82 (0.89)	94.68 ± 5.61 (1.77)
P-value	0.673	0.143	0.637	0.407

Number of rescue NSAIDS required by the patient apart from the given medication in group I was 42 tablets average of 4.2 per patient where as in group II is 8 tablet, average 0.8 per patient.

Graph 3 : Representation of post-operative swelling.



Discussion:

The role of corticosteroids in preventing postoperative morbidity has been addressed in hundreds of articles, beginning in the 1950s. By the early 1950s, steroids were being used as adjuncts to surgical procedures, although concerns were raised as to potential problems with wound healing if steroids were administered.

Despite of the lack of knowledge of the methods of their action, in the 1950s dentists and oral & maxillofacial surgeons rapidly began to use steroids, initially in comparison with antihistamines to decrease edema and postoperative discomfort.[4-7] Some investigators noticed a degree of "rebound" swelling when the steroid was discontinued.[5]

Patients are usually afraid of having their wisdom teeth removed because of the fear of pain. Postoperative pain could be managed with analgesics, which reduce pain to a bearable level. Although the role of corticosteroids has mainly been of reducing postoperative swelling and limited mouth opening, corticosteroids also have analgesic properties if administered at the right time of the procedure and via an ideal route of drug administration.[27]

Corticosteroids act by suppressing each phase of the initial inflammatory response, thereby decreasing cellular permeability and capillary dilatation by inhibiting the production of vasoactive substances and diminishing the number of cytokines. Furthermore, the generation of prostaglandin is repressed by corticosteroids, resulting in an analgesic effect.[27]

Williamson et al. noted that the hypothalamic-pituitary-adrenal axis returned to normal in 7 days in 10 consecutive patients who received dexamethasone 8mg intravenously immediately after oral surgical procedures.[8] Hooley and Francis[9] used the dose recommendations of Nathanson and Seifert[10] for their prospective RCT of 476 patients who underwent surgical extraction of an impacted mandibular M3. For the experimental side, they received 2 tablets of betamethasone 0.6mg the evening before surgery and then 2 tablets 4 times/day the day of surgery and 2 tablets 4 times/day for the next 2 days. Tetracycline cones were placed into extraction socket. Their findings showed that the controls had 6 as much edema, 2 times as much trismus, and required 2 times as much pain medication as the controls.

In our study pre-operatively 5mg prednisolone was given 12 hours before surgery and Dexona(8 mg) intravenously 1 hour before surgery that result in less postoperative swelling although it was not statistically significant.

Nayyar and Yates[11] performed a randomized controlled trial (RCT) of the pre-emptive effects of bupivacaine on M3 (third molars) surgery. Bilateral M3 removal was performed under general anesthesia. Bupivacaine 0.5% with epinephrine 1:200000 was used on one side and nothing on the other side. This study found a significant decrease in pain at the bupivacaine surgical site at 6, 12,72 hours and 7 days. In our study 0.5% Bupivacaine was used and the post-operative pain was reduced which was statistically significant.

The role of antibiotics in the prevention of inflammatory complications after M3 surgery has long been debated.[12-13]The 1966 study by Kay[14] showed that the extraction of third molars in the presence of infection without antibiotics resulted in a 71% incidence of AO (alveolar osteitis) versus 8% when antibiotics were used. This study also reported on M3 extraction in 2,265 patients after infection was controlled. The 1341 patients treated without an antibiotic cover had an incidence of alveolar osteitis of 24%. The 924 other patients who underwent M3 extraction with an antibiotic cover (preoperatively) had an incidence of AO of 2.9%.

Curran et al[15], Happonen et al[16], Goldberg et al[17]and Capuzzi et al[18] each recommended against antibiotic prophylaxis. However, in the study by Curran et al, the antibiotic group actually had a higher incidence of postoperative infection than the non-antibiotic group. Happonen et al[16] and Capuzzi et al[18] saw no difference with or without antibiotics.

Mitchell[19] reported a 4% SSI incidence in the antibiotic group and a 45%SSI (surgical site infection) incidence in the placebo group, and Mitchell and Morris[20] subsequently confirmed these results. In the 1995, there was strong support in the literature for the prevention of AO by the use of antibiotics placed directly into the socket during surgery. In our study we placed tetracycline (topically) in the socket and no systemic antibiotics were prescribed. It showed that the efficacy of topically placed antibiotic is similar to postoperatively prescribed antibiotics. Results of our study corroborated with previous studies[26] which stated that systemic antibiotics did not benefit patients undergoing maxillary third molar surgery alone. However, topical tetracycline significantly decreased the infection rate for erupted mandibular third molars. Systemic antibiotics and topical tetracycline reduced postoperative infections for mandibular partial and full bony third molars, but topical tetracycline was more effective.

In 1995, Joseph Pieuchet al[12] retrospectively analyzed 2134 patients who underwent extraction of 6713 M3s.In this study full bony impacted M3 extracted without antibiotic prophylaxis had 26.5% risk of postoperative infection; if topical tetracycline was used, the risk decreased to 6.6%. Hence showed that topical tetracycline was more effective than systemic antibiotics. Our study also confirms the same. Some investigations showed tetracycline induced neuritis[21-25], however no such incidence was seen in our study.

Conclusion:

The results of this study suggest that the modified protocol for third molar surgery i.e.,combination of corticosteroid, topical antibiotic and NSAID is as equally effective as standard method.The intra-socket placement of tetracycline eliminates the risk of antibiotic resistance and systemic toxicity. Thismodified protocol for third molar surgery could be considered a suitable approach in 3rd molar surgery as it leads to less patient discomfort both in terms of pain, swelling, and trismus; and hence improves patient's recovery. A split mouth prospective randomized control design with similar difficulty of impacted teeth bilaterally, assessed with a standard difficulty index in a significantly larger number of patients would have enhanced the level of evidence of the results.

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Time-dependent force depreciation of intraoral orthodontic elastics of variable force and lumen sizes -An in vitro study

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Original Research Article

Time-dependent force depreciation of intraoral orthodontic elastics of variable force and lumen sizes – An in vitro study

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ABSTRACT

Objective: To evaluate force decay of elastics of different dimensions and different force values over 48-hours.

Materials and Methods : Steps included extension and immersion of elastics in artificial saliva and measurement of force levels at a specified point of time. A model with vertical pins placed at in the oral cavity. The initial force measurement was done using Universal testing machine before the elastics were engaged onto the pins 37°C in artificial saliva. The reading was taken after this in the Universal testing machine for the samples. The elastics were then placed back into the static simulation for the next 23 hours and again into the dynamic simulation for the next 1 hour.

Results: Statistically significant difference (P<0.05) was observed between force depreciation between rest and maximum stretch of the elastic. Statistically significant difference was observed in force depreciation with varying time intervals of a particular elastic sample. Lumen size and pre-determined force values affect the overall force decrease pattern of elastics.

Conclusion: Elastics with higher force and smaller lumen size show comparatively higher loss of force than the lighter elastics with larger internal diameter. The maximum force loss of a particular elastic happens within the first 24 hours of elastic stretch.

Clinical Significance: The study would help provide information about how an elastic's lumen size and initial force are interdependent, giving clinicians a better understanding of how to prescribe the right elastics for the force they need to apply for treatment.

1. Introduction

Mechanotherapy in orthodontics often involves the use of interarch latex elastics to correct sagittal discrepancies or improve the interdigitation of teeth. Whereas these auxiliaries are replaced daily, a concern associated with their use pertains to the force relaxation of the materials.[1] Elastics used in Orthhigh flexibility and relatively enduring force.[2] A light contfor orthodontic tooth movement and minimal patient discomfort. Elastics are usually used forces to increase or supplement the force provided by the arch wire.[3] Proffit et al. listed 2 ideal forces for elastics depending on the size of the wire. When using large rectangular wire, he suggested approximately using 250 g force for inter arch correction and force levels of 125 g for lighter round wires.[4]

Elastics are used to achieve orthodontic tooth movement like tooth retraction, space closure, cross-bite correction

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or inter-maxillary traction.[5] When placed in the mouth, elastics are not subjected to static forces alone.[6]

Intermaxillary tension of elastics varies with the distance during jaw movement.[7] given for patient talks, eats, The loss of force delivery and degradation of orthodontic elastics affect their clinical effectiveness.[8] In inconstant force expression with considerable maintain the required force.[3] It has been a common finding that rubber elastics in a watery or oral environment lose between 10% and 40% of their initial force between 30 minutes and 24 hours after they are applied.[7]

Mechanical degradation effects are considered to be the primary cause for degradation of orthodontic elastics when in use.[3] Many studies have shown a high force decay rate having 2 slopes: initial rapid force relaxation and latent decay of decreased slope. Orthodontic rubber elastics are supplied based on standard force index. This means if the elastic is stretched to 3 times the listed diameter, it will exert a tensile force approximately equal to the listed force.[7] Force gauges have been used traditionally to evaluate the force decay shown by the orthodontic elastics.[5]

A recent study in 2018 compared force degradation of non-latex and latex elastics over a duration of 48 hours. They reported that both showed similar trends of degradation however latex showed insignificant reduction in 12-48 hours while for non-latex this occurred during 28-48 hours.[2,9]

This study aimed to compare latex elastics depending upon the initial force and lumen size over the period of 48 hour show an elastic's lumen size and initial force are interdependent, giving clinicians a better understanding of how to prescribe the right elastics for the force they need to apply for treatment.

2. Aim and Objectives

This study aimsanalyze the rate of force degradation of orthodontic elastics of different force levels and lumen sizes in a simulated static and dynamic oral condition over a period of 24 hours and 48 hours respectively

3. Clinical Significance

The loss of force delivery and degradation of orthodontic elastics are major defects that affect clinical choice. This m akes it difficult for the clinician to determine the actual force applied to the dentition. Clinicians, hence, should be aware of the forces applied to the teeth when elastics are applied to the: lentition at a given elastic extension and how the force declines over time.

4. Materials and Methods

The study was conducted in the Department of Orthodontics and Centre for Advanced Research at a Dental College & Hospital in Ghaziabad. Ethical clearance was obtained from Institutional Ethical Committee (IIEC/RP/2021/002).

Steps included extension and immersion of elastics in artificial saliva and measurement of force levels at a specified point of time. Vertical pins were used for the purpose of simulating the various distances in the oral cavity. The first pair of vertical metal pins was placed in a cold cure resin plate and at a distance of 25mm to simulate the distance of molar and canine in the rest position in the oral cavity. Second pair of vertical pins was inserted in the resin at the distance of 40 mm to simulate the maximum occlusal distance in the oral cavity.

The initial force measurement was done using Universal testing machine before the elastics were engaged onto the pins. The person measuring was blinded to the knowledge of groups and subgroups to avoid any bias. The elastics of each sub-group were stretched and placed onto the static oral conditions for 23 hours and the second set of pins for dynamic oral simulation for one hour (corresponding with 20 minutes per meal in a day).

The entire acrylic plate was immersed into the glass container containing artificial saliva (ICPA mouth rinse) and then the entire assembly was placed into a water bath with the temperature maintained at 37°c to simulate normal oral cavity temperature.

The reading was taken after this in the Universal testing machine for the samples. The elastics were then placed back into the static simulation for the next 23 hours and again into the dynamic simulation for the next 1 hour. The reading was again taken after this and the comparison was made among the force levels. (Table 1) (Figure 1)

The readings per subgroup was recorded for the following time intervals:

1. T0 - At time zero.
2. T1- after 24 hours (23 hours of 25mm stretch and 1 hour of 40 mm stretch).
3. T2- after 48 hours (next 23 hours of 25mm stretch and 1 hour of 40 mm stretch) Readings were standardized in Gram milli force (GmF).

5. Results

Intergroup comparison was carried out by ANOVA test and Post hoc Bonferroni test with $P \leq 0.05$ indicated significant difference. The force values between the maximum and rest range within groups were compared using independent 't' test. The tables show the comparison within group between forces at rest extension and maximum extension of the same samples over a period of 48 hours. It showed that the same elastic sample has different force levels depending on the length of extension i.e. more will be the extension of the elastic, more will be the force applied by it. Maximum force depreciation seen in the group B3 at maximum extension. (Tables 2, 3, 4 and 5)

In this study, the first group consisted of 3 subgroups. Group with 3.5 Oz force and 3/8" lumen showed 12% loss in 24 hours and 13% in 48 hours at simulated rest distance and 12% in 24 hours and 16% in 48 hours for maximum extension.

Group with 3.5 Oz force and 5/16" lumen showed 3% force loss at 24 hours and 9% loss at 48 hours at rest and 2% at 24 hours and 8% at 48 hours for maximum extension. Group with 3.5Oz force and 3/16" lumen size showed 18.6% force loss at 24 hours and 19% loss at 48 hours at rest and 29.3% force loss at 24 hours and 31.3% force at 48 hours at maximum extension.

The second group consisted of 3 subgroups. Group with 4.5Oz force and 3/16" lumen size showed 5.7% force loss at first 24 hours and 16% after 48 hours at rest and 15% at 24 hours and 29% 48 hours at maximum extension. Group with 3.5Oz force and 3/16" lumen showed 9% loss at 24 hours and 14% 48 hours at rest extension and 18% force loss at 24 hours and 25% force loss at 48 hours at maximum extension.

Table 1: Group-wise sample allotment

Group	Subgroup 1	Subgroup 2	Subgroup 3
Group A (constant force)	3.5 oz – 3/8" lumen	3.5 oz – 5/16" lumen	3.5 oz – 3/16" lumen
Group B (constant lumen size)	4.5 oz – 3/16" lumen	3.5 oz – 3/16" lumen	6 oz – 3/16 " lumen

Figure 1: Testing of the elastics in universal testing machine

6. Discussion

Although an in-vitro testing is unable to represent actual clinical applications, This study's test results aid in providing ideas of interrelation of elastic force and lumen size. This also provides guidelines for choosing elastics for clinical use.

It was observed in this study that the elastics with a smaller lumen size, even if the force was kept constant showed more force degradation compared to other larger lumen sizes (3/16"> 5/16"> 3/8") and maximum loss was seen in first 24 hours. When the lumen sizes were kept constant, the maximum force reduction was seen in the group with maximum inherent force levels which was 6oz force with 3/16" lumen size.

Dynamic extension showed more loss of force compared to the static extension indicating the length of extension is one of the factors that affect the force loss. This result is similar to most of the studies in literature.[1,4]

Group with 6Oz force and 3/16" lumen showed 12.5% force loss at 24 hours and 17.8% at 48 hours and 18% force loss at 24 hours and 24.1% at 48 hours at maximum extension. The results of subgroup 6Oz – 3/16" and 3.5Oz – 3/16" are similar to the results of a study by kersey et al.[3] Their study also indicated that dynamic testing led to faster force decrease but was not clinically significant compared to static testing.

A study done by Bales concluded that lesser is the lumen size (higher is 3 x lumen size) more force would be generated by the elastic.[10] This result is similar to the results of present study as 3.5 Oz – 3/16" lumen has the smaller lumen size compared to other subgroups of the group A with the same initial force. Bales et al. cited Bertram in 1931 as having first reported that one third of an elastic's developed force is lost per day and further suggested that, clinically, elastics should be changed on a daily basis.[10]

Results of this study also coincides with that of Yogosawa et al that larger is the extension, more is the force loss experienced. However, this study found that the higher the force levels observed, the greater the force loss observed.[11]

Force loss percentage of 3.5Oz- 3/16" lumen at maximum extension at first 24 hours is similar to the force loss observed by Hwang and Cha.[12] There was about 4-6% more of force loss when compared from 24 hour reading to 48hour reading and this observation is supported by the study done by Wang.[13]

One of the major drawbacks of the methodology of this study, as also discussed in the literature, was the repeated testing of the same sample over different time frames which leads to additional force depreciation leading to some

Table 2: Comparison of force within group A

	Groups	T0	T1	T2	p value	Intergroup comparison
	A1	114.25 ± 7.98	102.42 ± 8.39	99.58 ± 10.05	0.002*	T0 vs T1 = 0.039* T0 vs T2= 0.003* T1 vs T2 = 1.000
At rest	**A2**	110.33 ± 8.42	106.08 ± 8.82	100.92 ± 8.76	0.024*	T0 vs T1 = 0.625 T0 vs T2= 0.011* T1 vs T2 = 0.558
	A3	204.33 ± 39.04	166.42 ± 16.85	165.58 ± 23.02	0.012*	T0 vs T1 = 0.056 T0 vs T2 = 0.042* T1 vs T2 = 1.000
		A1 vs A2 = 1.000 A1 vs A3 = 0.001* A2 vs A3 = 0.001*	A1 vs A2 = 1.000 A1 vs A3 = 0.001* A2 vs A3 = 0.001	A1 vs A2 = 1.000 A1 vs A3 = 0.001* A2 vs A3 = 0.001*		
	A1	155.58 ± 9.86	136.58 ± 11.04	130.75 ± 11.22	0.001*	T0 vs T1 = 0.001* T0 vs T2 = 0.001* T1 vs T2 = 0.149
Maximum	**A2**	149.42 ± 13.50	145.25 ± 7.62	137.67 ± 10.53	0.016*	T0 vs T1 = 1.000 T0 vs T2 = 0.025* T1 vs T2 = 0.084
	A3	399.25 ± 61.72	282.75 ± 31.73	274.42 ± 35.00	0.001*	T0 vs T1 = 0.001* T0 vs T2 = 0.001* T1 vs T2 = 1.000
		A1 vs A2 = 1.000 A1 vs A3 = 0.001* A2 vs A3 = 0.001*	A1 vs A2 = 0.881 A1 vs A3 = 0.001* A2 vs A3 = 0.001*	A1 vs A2 = 1.000 A1 vs A3 = 0.001* A2 vs A3 = 0.001*		

Repeated measure ANOVA test; * indicates significant difference at $p \leq 0.05$
Post hoc Bonferroni test; * indicates significant difference at $p \leq 0.05$

Table 3: Comparison of force within group B

	Groups	T0	T1	T2	p value	Intergroup comparison
	B1	210.42 ± 14.44	198.33 ± 17.46	176.58 ± 5.07	0.001*	T0 vs T1 = 0.266 T0 vs T2 = 0.001* T1 vs T2 = 0.010*
At rest	B2	195.42 ± 19.87	177.58 ± 13.84	166.83 ± 9.82	0.001*	T0 vs T1 = 0.069 T0 vs T2 = 0.009* T1 vs T2 = 0.083
	B3	320.75 ± 44.46	280.75 ± 25.51	263.33 ± 16.99	0.001*	T0 vs T1 = 0.013* T0 vs T2 = 0.006* T1 vs T2 = 0.128
		B1 vs B2 = 0.657 B1 vs B3 = 0.001* B2 vs B3 = 0.001*	B1 vs B2 = 0.042* B1 vs B3 = 0.001* B2 vs B3 = 0.001*	B1 vs B2 = 0.148 B1 vs B3 = 0.001* B2 vs B3 = 0.001*		
	B1	414.33 ± 30.54	351.17 ± 34.56	290.92 ± 16.33	0.001*	T0 vs T1 = 0.001* T0 vs T2 = 0.001* T1 vs T2 = 0.001*
Maximum	B2	380.75 ± 38.93	309.92 ± 43.68	284.33 ± 16.99	0.001*	T0 vs T1 = 0.002* T0 vs T2 = 0.001* T1 vs T2 = 0.173
	B3	531.25 ± 38.90	435.33 ± 32.08	403.75 ± 31.00	0.001*	T0 vs T1 = 0.001* T0 vs T2 = 0.001* T1 vs T2 = 0.005*
		B1 vs B2 = 0.091 B1 vs B3 = 0.001* B2 vs B3 = 0.001*	B1 vs B2 = 0.031* B1 vs B3 = 0.001* B2 vs B3 = 0.001*	B1 vs B2 = 1.000 B1 vs B3 = 0.001* B2 vs B3 = 0.001*		

Table 4: Comparison of force among rest and maximum within group A

	Rest	Maximum	Difference	t value	p value
T0 (A1)	114.25 ± 7.98	155.58 ± 9.86	-41.33	-11.29	0.001*
T1 (A1)	102.42 ± 8.39	136.58 ± 11.04	-34.17	-8.534	0.001*
T2 (A1)	99.58 ± 10.05	130.75 ± 11.22	-31.17	-7.168	0.001*
T0 (A2)	110.33 ± 8.42	149.42 ± 13.50	-39.08	-8.508	0.001*
T1 (A2)	106.08 ± 8.82	145.25 ± 7.62	-39.17	-11.645	0.001*
T2 (A2)	100.92 ± 8.76	137.67 ± 10.53	-36.75	-9.295	0.001*
T0 (A3)	204.33 ± 39.04	399.25 ± 61.72	-194.18	-9.245	0.001*
T1 (A3)	166.42 ± 16.85	282.75 ± 31.73	-116.33	-11.217	0.001*
T2 (A3)	165.58 ± 23.02	274.42 ± 35.00	-108.83	-9.000	0.001*

Independent t test; * indicates significant difference at $p \leq 0.05$

Table 5: Comparison of force among rest and maximum within group B

	Rest	Maximum	Difference	t value	p value
T0 (B1)	210.42 ± 14.44	414.33 ± 30.54	-203.92	-20.912	0.001*
T1 (B1)	198.33 ± 17.46	351.17 ± 34.56	-152.83	-13.673	0.001*
T2 (B1)	176.58 ± 5.07	290.92 ± 16.33	-114.33	-23.164	0.001*
T0 (B2)	195.42 ± 19.87	380.75 ± 38.93	-185.33	-14.689	0.001*
T1 (B2)	177.58 ± 13.84	309.92 ± 43.68	-132.33	-10.004	0.001*
T2 (B2)	166.83 ± 9.82	284.33 ± 16.99	-117.50	-20.741	0.001*
T0 (B3)	320.75 ± 44.46	531.25 ± 38.90	-210.50	-12.344	0.001*
T1 (B3)	280.75 ± 25.51	435.33 ± 32.08	-154.58	-13.078	0.001*
T2 (B3)	263.33 ± 16.99	403.75 ± 31.00	-140.42	-13.761	0.001*

Independent t test; * indicates significant difference at $p \leq 0.05$

change in the readings.

However, in a study done by Kanchana and Godfrey, it was mentioned that to gain a more complete and empirical understanding of the physical properties of elastic materials under clinical conditions, it would be useful to include pre stretching, thermal cycling, using artificial saliva as the immersion medium, and cyclic stretching and relaxation to simulated chewing during the use of orthodontic elastics.[7] The present study fulfils most of the above-mentioned methodology.

Timing for changing elastics is also a clinical issue as some authors suggest changing elastics every hour. In real practice, elastics are exposed to numerous intra oral factors. The mechanical properties of elastomers are influenced by the rate and duration of loading as well as environmental conditions.[14] Hence clinical decisions cannot be made on the basis of an *in-vitro* experiment. The intraoral environment exerts greater effects on the elastic. This occurs because the oral cavity includes a wide array of potent aging factors such as pH fluctuations, temperature and enzymatic and microbial action.

Kersey reported 17% force degradation at 24 hours for 20 mm with the statically stretching method.[15] Fernandes stated although water immersion and temperature are significant in the degradation of force because of interference in secondary elastics bond sites perhaps transitory hardening of material could explain the force increase.[16] Filho et al.[13]

Veeroo et al. identified barriers to compliance with recommendations concerning the wearing of elastics during orthodontic treatment and tested the use of implementation intentions to enhance compliance. They observed that barriers to wearing elastics included the discomfort associated with the elastics. Much like fixed appliances in general, the participants found that the discomfort was worse when they initially started wearing elastics.[17] This observation may be linked to the initial high value of forces present in the elastics which induce initial discomfort. As the forces degrade, the pain and discomfort felt by the patient reduces. Klabunde and Grünheid[18] evaluated the force decay over time of latex and non-latex orthodontic elastics subjected to either static or dynamic stretching under simulated intraoral conditions and found that latex elastics retained significantly more force over time than their non-latex equivalents. Because of the higher force decay in a dynamic environment, it is important that non-latex elastics be changed more frequently. These findings are similar to the ones we found in our study.

The method in the present study also suffered from another major weakness: it failed to allow for the collection of continuous data because the force was only periodically recorded; thus, non-continuous data were used to construct the force relaxation curves, inducing some unavoidable approximation. Nevertheless, this limitation was in general agreement with the approach of other studies.[2,13,14]

It would be reasonable for the manufacturers to expect clinicians to use their judgment in prescribing the use of particular elastics for their patients according to force requirements to be applied at specific intraoral elastic stretch distances. Nevertheless, the clinician has to rely on reasonable constancy of working properties for any elastic type; this requires quality control in manufacturing.

7. Conclusion

The maximum force loss of a particular elastic happens within the first 24 hours of elastic stretch. The distance of extension would alter that rate of force depreciation, more would be the elastic extension, more would be the loss of force. Elastics with higher force and smaller lumen size show comparatively higher loss of force than the lighter elastics with larger internal diameter. The force levels of the elastics vary from the prescriptions provided by the manufacturer. Also, the elastic forces vary within the same lot of elastics provided by the manufacturer.

8. Source of Funding

None.

9. Conflict of Interest

None.

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Original Article

Evaluation of Pain Perception During Orthodontic Debonding of Metallic Brackets with Simultaneous Application of TENS Therapy

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Main Points

- The application of transcutaneous electrical nerve stimulation (TENS) therapy results in pain reduction during the debonding procedure.
- Female subjects experienced more pain than the male subjects during debonding.
- Higher pain scores were recorded for the mandibular anterior teeth than for the maxillary teeth.
- Patients displayed good acceptance and satisfaction with TENS therapy for pain control during the debonding of fixed appliances.

ABSTRACT

Objective: The objective of the present study was to evaluate the effectiveness of transcutaneous electrical nerve stimulation (TENS) therapy on pain during the debonding procedure.

Methods: A placebo-controlled, randomized split - mouth study was conducted on 30 orthodontic patients. The right and left anterior teeth in the maxilla and mandible were randomly allocated to the control and experimental groups (EG) and were stimulated. TENS application was made through a modified electrode probe that was used from an ammeter. The control group (CG) received the mechanical application of the device with no current, whereas the EG received progressively increasing current from 0.1 mA to the point where the patient experienced a mild tingling sensation for 60 s for each tooth. This was followed by a debonding procedure using an orthodontic debonding plier. Pain perception was recorded on a numerical rating scale after debonding each tooth.

Results: The mean pain score was higher in the CG than in the EG, and the difference between the two groups was significant (p=0.001). The pain score was higher in the mandibular teeth than in the maxillary teeth, and the difference between the two groups was also significant (p=0.021). Pain score was higher in female subjects than in male subjects, and the difference between the two groups was significant (p=0.015).

Conclusion: The application of TENS therapy results in pain reduction during the debonding procedure. The female subjects experienced more pain. Higher pain scores were recorded for the mandibular anterior teeth than for the maxillary teeth.

Keywords: Debonding, randomized controlled clinical trials, transcutaneous electrical nerve stimulation

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INTRODUCTION

A frequent adverse effect of many orthodontic procedures is pain. Pain is subjective and is expressed both verbally and non-verbally.[1] It has been noticed that pain is typically felt during or immediately after the adjustment of an orthodontic appliance and may even last for 2 to 4 days, despite there being no quantitative documentation. From a slight soreness when clenching to a constant, throbbing pain, the level of pain varies.[2] Orthodontic pain is a result of pressure, ischemia, inflammation, and edema at the periodontium level. 95% of orthodontic patients feel some level of pain or discomfort during or after various orthodontic operations. The insertion of separators, activation or placement of archwires, use of miniscrews, and debonding of fixed appliances are among the orthodontic operations that are most likely to cause pain or discomfort.[1]

Techniques used to control pain are broadly classified into pharmacological and non-pharmacological methods. Pharmacological methods include local anesthesia, general anesthesia, pharmacologic sedation, nitrous oxide relative analgesia, and hypnosis. Bite wafers, chewing gum, low-level laser therapy (LLLT), vibratory stimulation, transcutaneous electrical nerve stimulation (TENS), application of ice/cryotherapy, acupuncture/acupressure, and psychological interventions such as a structured phone call to patients during treatment are examples of non-pharmacological methods for pain control. TENS has found its greatest use with physical therapists in rehabilitation and chronic pain control.[2-4]

Greeks were the first to document the use of electricity to ease pain in writing. Walsh and Cavendish provided the first written account of the numbing effects of electrical generators in the 1770s. The first person to mention the use of electricity to treat tooth discomfort was Francis in the 19th century.[3,4] TENS is used to treat the symptoms of mild to moderate pain from any source, including neuropathic, musculoskeletal, and nociceptive pain.[5] TENS has been used previously for the treatment of myofascial pain dysfunction, trigeminal neuralgias, and temporomandibular joint pain.

Bond strength is crucial for maintaining the effectiveness of orthodontic treatment, but quick debonding of the brackets is preferable at the end of the procedure.[6,7]

A thorough review of the literature found no studies evaluating the effect of TENS during the debonding procedure. Therefore, the objective of this study was to evaluate the analgesic effect of a single application of TENS on pain during the debonding procedure. Therefore, the aim of the present study was to evaluate and compare the effectiveness of TENS therapy on pain during the debonding procedure.

METHODS

This study was approved by the I.T.S. Institutional Ethics Committee with protocol number: ITSCDSR/IIEC/RP/2019/014 and date: 22.11.2019. Sample size was estimated using the data obtained from a previous study conducted by Roth and Thrash[2] where the mean and standard deviation of visual analog scale scores were 4.77±6.96 for the treatment group and 15.22±15.86 for the control group (CG). This data revealed that, for an effect size of 0.85, a total sample size of 60 sites would provide an adequate statistical power of 95% to detect a significant difference.

This placebo-controlled, randomized split - mouth study was conducted on 30 orthodontic patients aged between 12 and 27 years in whom fixed orthodontic treatment had been performed using conventional metallic MBT brackets and in whom debonding was scheduled. Patients who had no missing teeth except the first premolar and who had not undergone any tooth transplantation were selected. Patients using antibiotics or analgesics, pregnant or breastfeeding, and those with a history of systemic diseases such as seizures, cardiac arrhythmia, or pacemakers were excluded. Patients with treated or untreated apical bone lesions, parafunctional habits, temporomandibular dysfunction, or smokers and alcoholics were also not included in study.

All patients meeting the inclusion criteria were given oral and written information by the operator and consented to participate in the study. Before starting the procedure, 30 opaque envelopes were made, out of which 15 envelopes were from the experimental group (EG) and 15 were from the CG. Allocation concealment was performed via unmarked envelopes. When the operator was about to start the procedure, patients were instructed to choose one envelope, and subsequently, the right maxillary and left mandibular teeth were given the same intervention as mentioned in the envelope. The left maxillary and right mandibular teeth were subjected to the opposite intervention. Both groups were informed that they would be evaluating a pain reduction device that would administer a mild electric current and that the strength of the stimulation could range from sub-sensory to negligible tingling.

The brackets on the anterior teeth in the maxilla and mandible were deboned in the study for pain evaluation. Immediately before the debonding procedure, a conductive gel was applied to the labial surface of the anterior teeth. The teeth allocated to the EG received stimulation from the TENS device on the incisal edges of the anterior teeth (Figure 1a). The device used was a modified electrode probe that was derived from an ammeter. It was selected because it had a detachable metallic head that could be autoclaved (Figure 1b). It generated a biphasic, symmetrical pulse with a net neutral charge and a maximum current of 10 mA. The current was progressively increased from 0.1 mA to the point where the patient experienced a mild tingling sensation (Figure 2). From this stage, the current was delivered for 60 s to each tooth. The teeth in the CG group received the same mechanical application of the device with no current. After delivery of the current for 60 s, the dental operator started the debonding procedure. The elastomeric modules, ligature ties, e-chains, and any other accessories were removed to separately record the pain score of each tooth. Debonding was performed with debonding pliers by placing the blades of the plier at the bracket-adhesive interface, and gentle squeezing action was applied until bond failure occurred.

Pain intensity was scored on a numerical rating scale after debonding in both the EG and CG groups immediately after the debonding procedure. A score of 0 indicated no pain, whereas a score of 10 indicated maximum pain. The patients were asked to rate the pain levels separately for each tooth. Acceptance of TENS therapy was assessed after the debonding procedure using a questionnaire provided to the patients.

Statistical Analysis

Data were analyzed using SPSS v20.0 software (SPSS Inc, Chicago, Il, USA). The level of significance was maintained at 5%. The data were subjected to normality testing using the Shapiro-Wilk test, which showed that the data deviated from the normal distribution. The demographic details of the study participants were presented using descriptive statistics. Pain scores between the control and EG groups were compared using the Mann-Whitney U test. Pain scores were also compared between gender and arch using the Mann-Whitney U test.

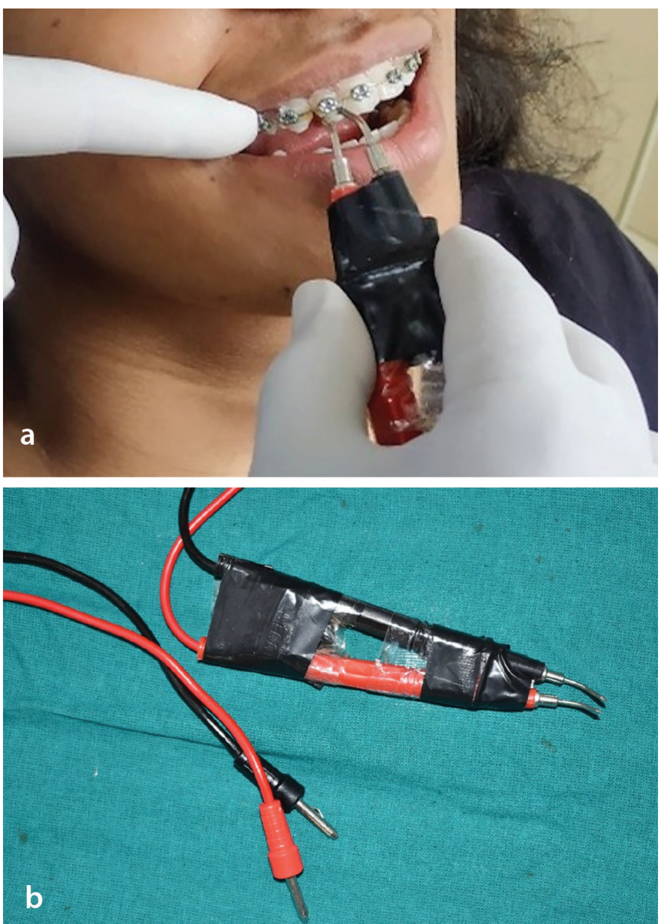

Figure 1. a) Patient receiving tens application. b) Modified electrodes for intraoral application

RESULTS

The mean age of the sample was 19.63±3.11 years. The sample size was 30 out of which 13 participants were male and 17 participants were female (Table 1). The Mann-Whitney U test revealed that the mean pain score was higher in the CG than in the EG, and the difference between the two groups was significant (p=0.001). A significant difference was also observed when comparing pain score in individual arches in the CG as compared to EG (p=0.001) (Table 2). Also, the pain score was higher in mandibular teeth as compared to maxillary teeth in control (p=0.021) and EG, and the difference between the two groups was significant (p=0.012).

Female subjects had a higher score than male subjects in both groups, and the difference between the two groups was significant (Table 3).

The pain score was higher in the CG than in the EG in female and male subjects, and the difference between the two groups was significant (p=0.001) for females and non-significant for males (p=0.064) (Table 4).

For individual teeth pain scores, the maximum mean pain score was recorded for the lower right central and lateral incisors and the minimum for the upper right central incisor in the CG. For the EG, the maximum mean pain score was recorded for the lower right central incisors and the minimum mean pain was recorded for the upper left central incisors (Table 5).

The questionnaire regarding their experience with TENS therapy revealed that 50% of patients expected the debonding procedure was painful, whereas 76.7% reported mild pain. Thirty percent of patients had excellent responses, and 60%

Figure 2. TENS machine
TENS, transcutaneous electrical nerve stimulation.

reported excellent responses with TENS therapy. 93.3% patients agreed to use the same therapy as needed. Almost all the patients 100% agreed to recommend this therapy to friends and family, and only 13% of patients were aware of the TENS machine/therapy (Table 6).

DISCUSSION

Modern dentistry has increasingly prioritized minimizing patient pain and discomfort during dental procedures. However, in orthodontics, research in this area is relatively limited compared to other fields within orthodontics.[8] Pain remains a significant concern as it can impact patient decisions and treatment acceptability.[9] Management of orthodontic pain includes both pharmacological and non-pharmacological interventions. Pharmacological therapeutic therapies, however, may have some side effects and limitations. For these reasons, non-pharmacological treatments for orthodontic discomfort have also been explored, including chewing gum, bite-sized wafers, LLLT, vibratory stimulation, and TENS.[10]

TENS, approved by FDA in 1972, delivers a pulsed electrical current via electrodes on the skin to stimulate superficial nerves for pain relief.[4] It offers advantages such as non-invasiveness and safety, but its use in dentistry, particularly in orthodontics, has received only limited attention.

The analgesic action of TENS is mediated by two mechanisms: it stimulates the A-delta and A-beta fibers, which blocks the transmission of painful stimuli by the small unmyelinated C-fibers in the spinal cord; this is in accordance with Melzack and Wall's "gate control" theory. The endogenous opioid theory is an alternative explanation for this and was given by Reynolds. According to this theory, TENS stimulates the activation of local circuits within the spinal cord or from the activation of descending pain-inhibitory pathways, which results in the release of endogenous opioids in the spinal cord.[4] The present study evaluated the efficacy of TENS application to control pain during the debonding procedure in fixed orthodontic patients. The results showed that the pain score was higher in the CG than in the EG, and the difference between the two groups

Table 1. Demographic details of study participants

Variable	Category	Mean±SD/n (%)
Age	--	19.63±3.11 years
Gender	Male	13 (43.3%)
	Female	17 (56.7%)

SD, standard deviation

Table 2. Comparison of pain score between control and experimental groups of maxilla and mandible

Groups (n=30 each)	Mean±SD	Difference (95% CI of difference)	Maxilla	Mandible	P value Maxilla vs mandible	p value
Control	3.11±2.08	2.01 (1.16-2.85)	2.35±1.88	3.60±1.97	0.021	0.001*
Experimental	1.10±0.96		0.76±0.96	1.49±1.38	0.012*	

*p<0.05 indicating a statistically significant difference. SD, standard deviation; CI, confidence interval

Table 3. Comparison of pain score between maxillary teeth and mandibular teeth in the two study groups

Groups	Gender	n	Mean	SD	Difference (95% CI of difference)	p value
Control	Female	17	3.91	2.00	1.84 (0.40-3.27)	0.015*
	Male	13	2.07	1.76		
Experimental	Female	17	1.38	1.07	0.63 (-0.02-1.28)	0.094 (NS)
	Male	13	0.75	0.66		

*p<0.05 indicating a statistically significant difference. SD, standard deviation; CI, confidence interval

Table 4. Comparison of pain score between males and females

Groups	Gender	n	Mean	SD	Difference (95% CI of difference)	p value
Female	Control	17	3.91	2.00	2.53 (1.41-3.65)	0.001*
	Experimental	17	1.38	1.07		
Male	Control	13	2.07	1.76	0.63 (0.25-2.40)	0.064 (NS)
	Experimental	13	0.75	0.66		

*p<0.05 indicating a statistically significant difference. SD, standard deviation; CI, confidence interval

Table 5. Descriptive statistics of pain scores in different teeth in the control and experimental group

		Control group			Experimental group		
Tooth no	N	Minimum	Maximum	Mean±SD	Minimum	Maximum	Mean±SD
11	15	0	4	1.13±1.45	0	6	0.93±1.62
12	15	0	7	2.53±2.56	0	4	0.93±1.28
13	15	0	7	2.07±2.55	0	2	0.73±0.88
21	15	0	7	2.87±2.53	0	2	0.2±0.56
22	15	0	9	3.13±2.61	0	3	0.87±1.18
23	15	0	5	2.4±1.88	0	4	0.93±1.48
31	15	0	8	2.93±2.76	0	5	1.8±1.56
32	15	0	6	2.47±2.35	0	9	1.87±2.41
33	15	0	8	2.07±2.25	0	3	0.8±0.94
41	15	1	9	5.2±2.1	0	6	2.07±2.08
42	15	3	9	5.47±1.60	0	5	1.6±1.45
43	15	1	6	3.47±1.50	0	4	0.8±1.26

SD, standard deviation

Table 6. Descriptive table of responses of questionnaire to assess acceptance of TENS therapy by patients

	No pain	Mild	Moderate	Severe
1. What type of pain did you expect in the postoperative period?	1 (3.3%)	5 (16.7%)	15 (50%)	9 (30%)
2. What type of pain did you experience in postoperative period?	7 (23.3%)	23 (76.7%)	0	0
	Excellent	**Very good**	**Fair**	**Poor**
3. What was the quality of pain relief after TENS therapy?	9 (30%)	18 (60%)	3 (10%)	0
4. How was your overall experience with pain management/TENS therapy?	13 (48.3%)	14 (46.7%)	3 (10%)	0
	Yes		No	
5. Would you use the same analgesia modality again if required?	28 (93.3%)		2 (6.7%)	
6. Would you recommend the same modality to your family/friends?	30 (100%)		0	
7. Were you aware of this treatment modality prior to its application?	4 (13.3%)		26 (86.7%)	

TENS, transcutaneous electrical nerve stimulation

was significant (p=0.001) which indicated that the patients experienced less pain when subjected to TENS therapy.

This result is in accordance with two studies that have previously reported the use of TENS therapy for pain control in orthodontic patients. Roth and Thrash[2] demonstrated reduced pain in orthodontic patients receiving TENS therapy, while Haralambidis[7] found pain relief for up to 48 hours post-TENS application. Additionally, TENS therapy has also been reported to be effective for pain control in different dental procedures. Suzuki suppressed pain during cavity preparation using 4 to 10 AA through the bur.

Christensen and Radue[11] provided updates on TENS use for dental anesthesia, reporting a 50% success rate in 1987. Clark et al.[12] treated fifty patients, with an 80% effectiveness rate in the active group. Six hundred patients were examined by Hochman[13], with 76% experiencing pain relief. Jensen examined 35 people using three different waveforms and three different frequencies. Patients' expectations of pain were positively correlated with success. Malamed et al.[14] achieved an 86% success rate in 109 patients treated with H-Wave equipment.

Electrodes are crucial for TENS equipment. Intraoral electrodes come in sponges, conductive fabrics, and adhesive materials.[14] Different types of electrodes have been used in previous studies, such as through burs, and on the lip and mucosa, and extraoral pads. In this study, a modified electrode probe was used directly on the tooth's incisal edge. Roth and Thrash[2] noted rapid onset of analgesia with TENS, lasting for several hours. Therefore, in the present study, the current intensity was gradually increased until a mild tingling sensation was felt, then delivered for 60 seconds per tooth.

Debonding process should be swift, painless, and safe. Previous research analyzed the pain and discomfort during appliance implantation, but debonding pain remains process poorly understood.[6] According to Williams and Bishara[15] the mobility of the tooth and the direction of force application have a considerable impact on the threshold of patient discomfort at debonding. Patients have been found to be far more able to endure intrusive forces than mesial, distal, facial, lingual, or extrusive forces at the moment of debonding.[15] Applying a biting force stabilizes teeth and balances debonding pressures applied to the periodontal ligament. In addition, increased pressure on the periodontal ligament can induce proprioceptive stimulation that lessens discomfort.[1] Therefore, in this study, debonding was performed mesio-distally with a plier, while applying intrusive force on the incisal edge of the tooth. The study found significant differences in pain scores between mandibular and maxillary teeth, with mandibular teeth exhibiting higher pain scores in both study groups. Additionally, females experienced higher pain levels compared to males, consistent with previous findings.

Study Limitations

The present study had some limitations, such as a small sample size and unequal number of males and females. It is recommended that more procedures should be evaluated at different time periods to evaluate the duration of pain control and follow-up. To test various electrodes, electrode placements, wave patterns, frequencies, and combinations with other pain control methods, a pain model that mimics the discomfort of surgical operations is required.

CONCLUSION

Within the limitations of this study, the following conclusions may be drawn:

• The application of TENS therapy results in pain reduction during the debonding procedure.

• The female subjects experienced more pain than the male subjects during debonding.

• Higher pain scores were recorded for the mandibular anterior teeth than for the maxillary teeth.

Patients displayed good acceptance and satisfaction with TENS therapy for pain control during the debonding of fixed appliances.

Ethics

Ethics Committee Approval: This study was approved by the I.T.S. Institutional Ethics Committee with protocol number: ITSCDSR/IIEC/RP/2019/014 and date: 22.11.2019.

Informed Consent: All patients meeting the inclusion criteria were given oral and written information by the operator and consented to participate in the study.

Author Contributions: Concept - A.R., P.S.; Design - A.R., P.S., C.S.R.; Supervision - A.R., P.S., C.S.R., S.J., M.R., K.T.; Fundings - A.R.; Materials - A.R., C.S.R., S.J.; Data Collection and/or Processing - A.R.; Analysis and/or Interpretation - A.R., P.S., S.J., M.R., K.T.; Literature Review - A.R., P.S., S.J., M.R., K.T.; Writing - A.R., P.S., S.J., M.R., K.T.

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Original Article

Comparative evaluation of different osteosynthesis modalities with respect to lingual splaying in mandibular interforaminal fractures using CBCT: A prospective study

ABSTRACT

Introduction: The management of interforaminal fracture can prove to be challenging because of its unique anatomy and muscular forces. Often, lingual splaying has been found either postoperatively or even during the procedures in such fractures and can be challenging when it comes to managing them. Various modalities such as miniplates, lag screws, and three-dimensional (3D) miniplates have been utilized to manage these fractures. This article compares these three modalities in the management of lingual splaying.

Material and Methods: Thirty patients were allotted randomly to either of the aforementioned modalities randomly in this prospective study. The patients were operated and followed up for the period of 6 months.

Results: It was found that no significant difference exists between the modalities in terms of reduction in lingual splay.

Conclusion: All three modalities have different ventures to offer. A larger sample size study may be warranted to elucidate the obtained results.

Keywords: 3D plates, lag screws, lingual splay, miniplates

INTRODUCTION

The management of interforaminal fracture can prove to be challenging because of its unique anatomy and muscular forces. One complication that surgeons regularly encounter is achieving an adequate lingual reduction. The possible reason for such lingual splay can be an inadequate reduction or opening up of the lingual cortices during hardware fixation. It is challenging to identify and recognize such lingual discrepancy intraoperatively, and even a small splay can lead to a significant increase in bigonial width. Fractures in this area of the mandible predispose the patients to malocclusion and widening of the face if not properly treated.[1,2]

The lag screw technique was first described by Brons and Boering in 1970 who postulated that it not only immobilizes the fracture fragments but also produces a constant compression of the fracture area. It is a safe and effective method of rigid fixation. Besides supplying compression between the fragments to support healing, fracture stabilization is firm, and tissue exposure is reduced.[3,4] In 1973, Michelet introduced miniplates via a transoral approach and Champy further refined and researched miniplates. The approach to rigid plate fixation was then modified with progressively smaller plates and less reliance on compression.[5] Because of the torsional forces generated during function, two miniplates are advocated to predictably

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maintain rigid fixation during healing. They provide better handling, higher stability, and less pressure on the bone.[6] The shortcomings of rigid and semi-rigid fixation like led to the development of 3D miniplates, consisting of 2 × 4-hole miniplates joined by four interconnecting cross-struts. Farmand and Dupoirieux (1992) presented this system of plates made of titanium. Easy use, good resistance against torque, and compact form of the plate were some of the advantages.[7-9]

This study was conducted to evaluate the efficacy of various techniques of osteosynthesis with respect to lingual splaying in mandibular interforaminal fractures using cone-beam computed tomography (CBCT). The objective was to evaluate the efficacy of 3D miniplates, standard miniplates, and lag screw and to compare the aforementioned osteosynthesis modalities in terms of stability of fracture and lingual splaying.

MATERIAL AND METHODS

This study was carried out to compare and evaluate 3D plates, miniplates, and lag screws and find out which one was better in reducing postoperative lingual splay. All dentate patients of the age group of 20 to 60 years with confirmed clinical or radiographical interforaminal mandibular fractures reporting to the Department of Oral and Maxillofacial Surgery were included in this study. Patients with infected fractures, comminuted fracture, atrophic mandible, pathological fractures, and American Society of Anesthesiologists (ASA) III and IV criteria patients were excluded. The selected patients were then divided randomly into three groups: group A: 3D stainless steel miniplates (3D plates), group B: two stainless steel conventional miniplates, and group C: two stainless steel lag screws. Ethical clearence was obtained from Ethical committee with Ref no. IDST/IEC/2020-23/17 dated 18th January 2021.

Preoperative records such as radiographs such as orthopantomagram (OPG) and CBCT along with clinical pictures of the patients were prepared. All patients were operated under general anesthesia. An intraoral vestibular approach was used to expose the fracture site and was reduced followed by intermaxillary fixation to immobilize the reduced fragments. Fixation was done depending on which group the patient was allocated to, that is, 3D plates (a and b), miniplates (c and d), or lag screws (e and f) [Figure 1]. The intermaxillary fixation was then released, and occlusion was assessed on the table. The wound was closed, and the patient was extubated uneventfully and shifted for post-op care under the regime of standard medications.

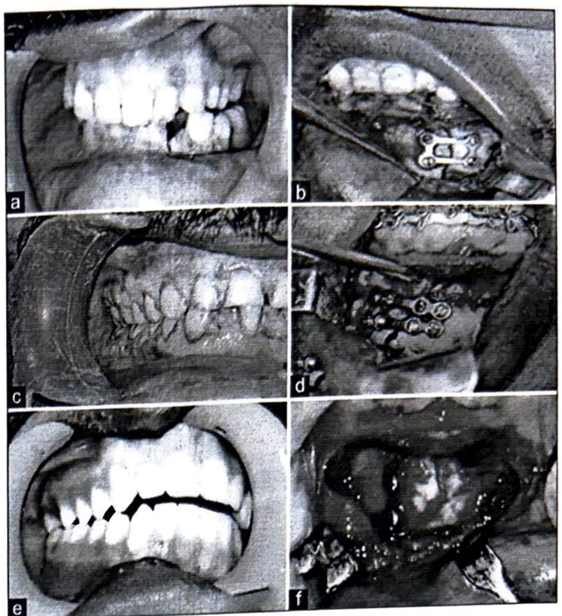


Figure 1: Pre-opertaive fracture sites various osteosynthesis modalities in place. (a) Right Parasymhysis #, (b) Right Parasymhysis # treated with 3-D plate, (c) Right parasymphysis fracture, (d) Right Parasymhysis # treated with convebntional miniplates, (e) Right Parasymhysis #, (f) Right Parasymhysis # treated with lag screws

Postoperative photographs were taken. Preoperative radiographs included OPG and CBCT. Postoperatively, these radiographs were also taken in the 1st week, 1st month, and 3rd month. The patients were assessed for lingual splay measurement and scoring, pain score according to the visual analog scale, occlusion discrepancy, stability of fracture fragments, need for postoperative maxillomandibular fixation (MMF), facial asymmetry, malunion of fragments, hardware failure, paresthesia, infection or swelling, plate removal operating time, and bite force.

RESULTS

Our study comprised a total of 30 patients of whom 22 were males (73.3%) and eight were females (26.7%). Patients were 18 to 70 years of age group with a mean age of 34.87 ± 12.091 years.

Road traffic accident was the most common cause of trauma, which accounted for 60% of cases followed by fall, which was 40% of cases.

Preoperatively, the mean lingual splay measurement was 1.805 ± 0.81 mm in the 3D plate group, 2.04 ± 0.85 mm in the lag screw group, and 2.07 ± 0.55 mm in the miniplate group. After 1 week, it was 1.01 ± 0.63 mm in the 3D plate group, 1.06 ± 0.54 mm in the lag screw group, and

1.11 ± 0.28 mm in the miniplate group. After 1 month, the mean lingual splay was unchanged, and at the 3rd-month follow-up, there was no splaying in the 3D and miniplate group and negligible in the lag screw group, which was 0.04 ± 0.084 mm. The difference between the groups showed no statistical significance.

The method for assessment of lingual splay was followed according to Prasad *et al.*,[9] which required evaluation by the operating surgeon using CBCT taken preoperatively and postoperatively. In our study, six of 10 patients of the 3D plate group have +1 score, while four of them have 0 score; six of 10 of the miniplate group patients have +1 score, while 1 patient has 0 and -1 scores each; and six of 10 of the lag screw group patients have scored +1, while 4 of them have scored 0. The results show no statistical significance among the groups.

The pain was evaluated based on the visual analog scale (0–10). All patients complained of mild pain after surgery, which lasted for one week. No difference in statistical significance was found between the three study groups.

Occlusal discrepancy persisted in only two patients each from the 3D plate group and miniplate group till the 1st-week follow-up, which subsided in subsequent follow-ups. There is no statistically significant difference among the study groups.

90% of patients from each study group had displaced fracture preoperatively. Only 20% of patients from the miniplate group showed some displacement radiographically in the 1st-week follow-up, which subsided during the subsequent follow-ups. No statistically significant difference was seen among the groups.

All the patients required postoperative MMF for 1 week after surgery, which was removed by 1st-month follow-up except for two patients in the 3D plate group and two patients in the miniplate group in whom it was removed after 1st-month follow-up. There is no statistically significant difference among the study groups.

There was no incidence of hardware exposure or failure or removal after surgery during any of the follow-up periods in any of the patients.

20% and 10% of patients from the miniplate group and lag screw group, respectively, had an infection or swelling preoperatively. At the first-week follow-up, 10% of patients had the presence of infection or swelling in both groups, which subsided in subsequent follow-ups. This result was statistically nonsignificant.

In our study, nerve paresthesia existed in 10% of patients in the 3D plate group and the miniplate group preoperatively, which persisted for 1 week after surgery and subsided in the subsequent follow-ups. The result is statistically nonsignificant.

In our study, none of the patients showed any signs of nonunion or malunion of fracture fragments when assessed radiographically in the postoperative phase.

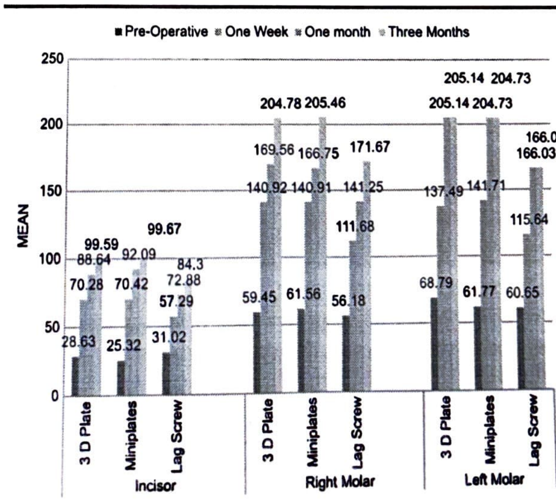
In our study, we found a significant statistical difference in the operating time of patients treated with lag screw having a mean operating time of 23.60 ± 2.17 minutes, patients treated with 3D plate having a mean operating time of 43.80 ± 3.25 minutes, and patients treated with miniplates having a mean operating time of 65.60 ± 5.33 minutes [Table 1].

The bite force measurement at the incisor, left molar, and right molar regions had increased progressively at each of the postoperative follow-up visits such as 1 week, 1 month, and 3rd month compared with the previously recorded preoperative value. The results show that the difference in the

Table 1: Comparison of operating time taken

Parameter	Modality	*n*	Mean	Std. deviation	One-way ANOVA *P*	Significance
Operating time	3D plate	10	43.80	3.259	0.000	Significant
	Miniplates	10	65.60	5.337		
	Lag screw	10	23.60	2.171		
	Total	30	44.33	17.829		

Figure 2: Comparison of bite force throughout the study duration between the three osteosynthesis modalities



three regions in each of the follow-up visits was significantly better in the 3D plate and miniplate groups compared with the lag screw group. [Figure 2].

DISCUSSION

The arduous pace of modern life with high-speed travel and an increasingly violent and dictatorial society has made trauma to maxillofacial complex one of the most important health problems worldwide. The mandible due to its prominent position is one of the most commonly fractured bone in the facial skeleton. It is a unique bone with a complex role in the esthetics of the face and functional occlusion. It has been reported that fractures of the mandible account for 36%–59% of all maxillofacial fractures. Fractures of the mandible cause both functional disabilities and social and cosmetic morbidities. The aim of mandibular fracture treatment is the restoration of anatomical form and function, with particular care to establish the occlusion and allow immediate return to the function.[10]

In the area of the mandibular symphysis, a small error in reduction can result in a large change in the position of the mandibular rami. When support for the mandibular symphysis is lost due to fractures of the condyle, angle, body, and/or symphysis, there is a tendency for the symphyseal region to move posteriorly and the rami to flare laterally due to the pull of the lingual musculature attached to the mandibular symphysis. Symphyseal fractures, especially those associated with condylar fracture and a poor dentition, are prone to facial widening. Even with an intact dentition, there is a tendency toward splaying of the gonial angles due to the application of the maxillomandibular wires on the buccal surface of the dentition, which causes the mandibular segments to tip lingually, even though the teeth appear properly interdigitated. In those symphyseal fractures treated by an open procedure, a gap in the line of fracture may be noted at the inferior border of the mandible even though the mandibular incisors are in approximation superiorly, which necessitates to loosen the wires slightly to obtain proper osseous reduction at the inferior border. A great amount of widening at the gonial angles can occur if the bones themselves are not inspected for approximation in cases of poor dentition. If the bone plate is not properly bent and/or overbent, the lingual cortices may not contact even though the buccal cortices appear perfectly reduced. In such cases, tightening the screws, especially if compression is applied, would cause the rami to move laterally. If the mandibular teeth are lingually inclined and upright to a more normal relationship with digital pressure at the gonial angles, open reduction in the symphyseal fracture must be considered. Post-op intermaxillary fixation, if applied, is most effective if placed bicortically so that the lingual cortices are also approximated by the wire.[11]

According to Bhargava *et al.*, the fracture fragments can be engaged in the reduced position using a lag screw of 12 to 14 mm after which the plates can then be adapted to the contour of the mandible. Fixation of all the screws is done as per Champy's principles, except for the screw passing through the inter-fragmentary screw path, which is removed before placement of the final screw. Thus, it is useful in ensuring the adequacy of lingual reduction and diminishing the chances of lingual splay due to errors in handling the reduction forceps besides reducing the chances of error incorporation in fracture reduction, while the fixation of the plate is carried out.[2,12]

Miniplates placed according to Champy's ideal lines should be placed within 10 mm of the superior border, but in the anterior part of the mandible, torsional and bending forces are greater and higher near the mandibular symphysis, which cause movement along the axis of the plate with buccolingual splaying and gap formation at the inferior border, respectively. So, it is advocated to overbend the plate as a way to get an accurate reduction of the lingual cortex and overcome the tendency of the fracture to remain splayed open, besides applying pressure at the gonial angles.

Jimson *et al.* studied and compared 3D plates and miniplates and found three times lesser number of patients with postoperative lingual splay than conventional miniplates. Ponvel *et al.* ascertained the correction of lingual splay during fixation of 3D miniplate in their study as it reduced stress distribution and negated the pressure related to resorption of bone, which may be clinically significant. Prasad *et al.* who placed 3D plates in 18 patients measured lingual splay of the fractured mandibles pre- and postoperatively using occlusal radiographs and found that 72.2% of them showed a significant reduction in lingual splay, 16.6% showed minimal or no change in lingual splay reduction, and 11.1% showed an increase in lingual splay.[2,9,13] Siddiqui *et al.* and more recently Mohammad *et al.* who both placed 3D and conventional plates in their studies did not find any postoperative lingual splay at any follow-up periods. Hatem *et al.* found similar results in their study using conventional miniplates where they measured the mesiodistal plane discrepancy in terms of the linear width of the inter-fragmentary gap and the linear depth of buccolingual gap in terms of lingual splay at the inferior border between the fractured mesial and proximal segments using CBCT.[14-16]

In this study, the lingual splay was measured in each of the cases preoperatively and postoperatively using CBCT. We found that 60% of patients treated with 3D plates showed a significant reduction in lingual splay, 80% of patients treated with conventional miniplates showed a significant reduction in lingual splay, and 60% of patients treated with lag screws had significant reduction in lingual splay. The increase in lingual splay seen in one patient was attributed to the fact that the patient had a concurrent condylar fracture, which worsened the splay and hence the occlusion initially, but with the application of elastics for two weeks, it was observed that the malocclusion subsided and radiographically the splay had decreased by the first-month follow-up.

In this study, the mean intraoperative time for the lag screw group was least followed by the 3D group and the maximum time was taken in the miniplate group. There was a statistically significant difference among the groups, which was similar to studies conducted by Mittal *et al.*, Tiwari *et al.*, Kaushik *et al.*, and Mohammad *et al.*[15,17-19] Post-op intermaxillary fixation was required in all patients for one week and two patients each in the 3D plate group and the miniplate group for one month. This was in contrast to study by Balakrishnan *et al.*, Malhotra *et al.*, and Agnihotri *et al.* In the study by Sehgal *et al.*, 40% of the 3D plate group and 73% of patients of the miniplate group required post-op intermaxillary fixation.[20-23] Some occlusal discrepancies that were seen in this study stabilized within the first month of the follow-up period. The results were similar to the studies conducted by Mittal *et al.*, while Malhotra *et al.* found that 30% of patients of the miniplate group and 10% from the 3D group had a occlusal discrepancy with no statistical significance, which was similar to Barde *et al.*[24] A study by Prasad *et al.* who treated with 3D plates showed only 11.1% of patients with loss of occlusal stability, which was corrected with intermaxillary fixation. Studies by Elhussein *et al.* and Jambhulkar *et al.* showed no occlusal discrepancies at any follow-up periods.[3,25] Infection or swelling in this study was observed one week postoperatively in one patient each from the 3D plate group and the miniplate group, which was statistically nonsignificant and correlated with studies performed by Jimson *et al.*, Prasad *et al.*, and Jain *et al.*[9,13,26]

CONCLUSION

There is a noticeable lack of studies showing lingual splay playing a role in the success of mandibular fracture treatment. The good old evaluation of occlusion has always been the go-to method to evaluate the success so far, so in this study we decided to take it up a notch by taking into consideration the less explored criteria, that is, lingual splaying, which is the main yet occult culprit behind flaring at the gonial angles and hence unesthetic facial widening. The final follow-up found that all of the modalities yielded good outcome in terms of reduction in splaying, occlusal discrepancies, and stability of fragments with no major complications. 3D plates were easy to maneuver and place in the anterior region compared with the other two, and their quadrangular shape is credited for the better stability of fragments. In terms of implant material, 3D plates, due to the lesser number of screws required than two miniplates and lag screw not requiring any additional component other than itself, have an advantage over conventional miniplates though this did not hamper the success of conventional miniplates. Lag screw placement was a significantly more time-conserving procedure compared with 3D plate and conventional miniplates though it required greater expertise in placement than the other two methods. It is safe to deduce that while one modality may have some advantages over another, all of them are equally good in terms of treatment outcome providing good stability, occlusion, and minimum or no complications.

With the availability of modern amenities such as CBCT and their rising relevance in our field, the evaluation and assessment of success of fracture treatment can be accomplished more beautifully by incorporating lingual splay as one of the primary parameters along with others. Although our study shows a good reduction in lingual splay in 60%, 80%, and 60% of the patients in the 3D plate group, the miniplate group, and the lag screw group, respectively, it has paved the way toward the same and we strongly recommend that more and more studies should be conducted in future with a larger sample size and longer study period including lingual splay as a vital parameter along with the other parameters to look out for in the field of Oral & Maxillofacial Trauma in India.

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Conflicts of interest

There are no conflicts of interest.

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Tobacco use and oral health related quality of life among Indian adolescents

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Abstract

Objectives: The present study was conducted to assess tobacco use and its effect on Oral Health-Related Quality of Life (OHRQoL) in Indian adolescents.

Methods: The present study was conducted on 1,600 13–14 year old adolescents from the schools of Modinagar, western Uttar Pradesh, India selected using stratified random sampling technique. OHRQoL was assessed using Hindi version of Child Perceptions Questionnaire (CPQ). Information regarding demographic, socioeconomic and oral health measures was also collected from the study participants. Tobacco use was assessed through questions derived from Global Youth Tobacco Survey (GYTS) questionnaire. Influence of predictor variables on tobacco use was evaluated using multilevel Poisson regression model.

Results: The tobacco use among the study population was 8.1 % and CPQ scores were 9.15±0.32. Adolescents who used tobacco had worse OHRQoL scores. Low socioeconomic status, presence of dental caries, absence of regular dental visits (last 6 months) were associated with increased regular consumption of tobacco products.

Conclusions: The findings of the present study play an important role in planning public health strategies to improve adolescent OHRQoL and reduce tobacco use.

Keywords: tobacco use; oral health; quality of life; adolescent

Introduction

Tobacco use has been the most common social cause of early loss of lives and economic and financial deprivement in youngsters. According to global youth tobacco survey, majority of adolescents get into this habit at an early age. Addictions developed early in life are likely to persist throughout life. However, if adequately controlled, they can be prevented for life as well [1].

Adolescence is the life stage which is significantly influenced by many factors particularly the psychosocial and behavioural factors in the community at large. Studies have also shown that the adolescents' psychosocial, environmental and cultural factors significantly influence the pathways leading to tobacco and other substance abuse which in turn is significantly associated with the occurrence of oral diseases among adolescents [2].

Psychosocial theory serves as a framework for understanding the impact of psychosocial factors on individual well-being. It explores how people perceive social inequalities and the consequent influence of these perceptions on their health. Within the realm of psychosocial variables, an adolescent's quality of life is closely linked to their resilience in facing life's obstacles, as well as their ability to cultivate health-promoting behaviors and establish positive interpersonal connections [3]. Today's youth which celebrate beauty magnifies the deleterious effects of facial disfigurement and tooth loss. Recommendations for further research include exploring the dimensions of oral health and well-being through a focus on the impact of oral conditions on youth's social functions, such as communication, social interactions, and intimacy. It is important to delve into the realm of oral-health-related quality of life to gain a deeper understanding of its effects [4].

Oral Health-Related Quality of Life (OHRQoL) refers to the impact of oral disorders on an individual's overall well-being, taking into account their self-perceived oral health measures and outcomes [5]. Previous studies have revealed a correlation between impaired OHRQoL and behavioral indicators, particularly the utilization of dental services in children. Additionally, individuals with poorer OHRQoL tend to experience diminished subjective well-being, which can negatively affect their behavioral habits [6]. The potential link between OHRQoL and tobacco use can be attributed to the physical and/or psychological distress caused by oral disorders, thereby influencing an individual's OHRQoL. This condition can contribute to heightened stress, anxiety, and the adoption of unhealthy behaviors, including alcohol and tobacco consumption [7, 8].

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Child oral health-related quality of life (OHRQoL) is commonly evaluated using self-administered questionnaires known as socio-dental indicators. Various questionnaires have been created to assess oral health and its impact on the quality of life of children and adolescents [9]. Among these self-perception measures are the Child-Oral Impacts on Daily Performances [10], the Early Childhood Oral Health Impact Scale [11], the Child Oral Health Quality of Life [12], the Child Perceptions Questionnaire (CPQ) [13], and the Child Oral Health Impact Profile [14]. Specifically, the CPQ designed for children aged 11–14 (CPQ 11–14) is one of these assessment tools [15]. While initially developed in Canada, subsequent studies have confirmed its satisfactory psychometric properties among schoolchildren in different regions worldwide. The CPQ 11–14 evaluates OHRQoL across four subscales, namely: (1) oral symptoms; (2) functional limitations; (3) emotional well-being; and (4) social well-being [9].

To the best of our understanding, there has been no prior examination of the impact of a subjective factor associated with dental clinical conditions on tobacco usage. This correlation holds significant significance, especially among adolescents, given that tobacco consumption can result in addiction and various health issues during this developmental phase and into adulthood. These health problems encompass non-communicable and infectious diseases, mental disorders, injuries, violence, and more. Hence, the purpose of this study was to assess the effect of Oral Health-Related Quality of Life (OHRQoL) on tobacco use among adolescents. Our hypothesis postulates that adolescents who engage in tobacco use are more likely to experience poorer OHRQoL.

Methodology

The present study was a cross-sectional study among 13–14-year-old adolescents attending public and private schools in Modinagar, Ghaziabad. The sample size was calculated based on the results of Pandey et al. [16] among adolescents in India allowing for a 5 % precision, a Z statistic of 1.96 for a 95 % confidence level, 80 % power of the study and a prevalence of 52 %. Based on the outcome, dental caries, and adjusting for an allowance of 10 % missing data, the sample size was rounded off to 1,600 study subjects.

The study commenced with obtaining official permission from the Block Education Officer, Bhojpur Block, Modinagar. Subsequently, consent was sought from the respective school authorities and parents of the selected schools' children for their participation in interviews and oral examinations. Furthermore, the study participants themselves provided their assent prior to the investigation. The research adhered to the ethical guidelines approved by the Institutional Review Board. To ensure a representative sample, a stratified random sampling technique was employed for the selection of schools and the sample size. The Office of the Block Education Officer, Bhojpur Block, Modinagar provided a comprehensive list of schools, along with the number of 13-year-old students enrolled. In Modinagar, a two-stage cluster random sampling technique was utilized. Initially, the city was divided into four geographical areas, from which an equal number of public and private schools were included. Each zone comprised two public schools and three private schools, except for one zone that housed four private schools. In order to ensure an equal representation of both school types, random sampling by lottery method was employed, resulting in the selection of one school from each type. Consequently, a total of eight schools were included in the study.

The study participants were selected using simple random sampling to ensure equal representation from both government and private schools. A total of 1,600 adolescents were included in the study, with 800 obtained from public schools and 800 from private schools in Modinagar. Careful attention was given to maintaining an equal number of boys and girls among the participants. To achieve this, 200 adolescents were selected from each of the eight schools comprising the study population. The inclusion criteria for the study were as follows: adolescents who were at least 13 years old but had not yet reached 15 years of age, willingness to participate in the study, and written informed consent from their parents or guardians. Only children with permanent dentition were included in the study. On the other hand, the exclusion criteria encompassed children who had medical conditions that could compromise their health, physical disabilities or deformities, and congenital defects. Additionally, children with acute infections in the oral cavity that could interfere with the oral examination were also excluded from the study.

While organising the survey, a time table was prepared and the study was systematically scheduled to spread over a period of six months. The respective schools were informed and their authorities obtained consent well in advance for the detailed weekly and monthly schedule. Prior to conducting the survey, the examiner underwent training and calibration at the Department of Public Health Dentistry, Manav Rachna Dental College, FDS. The training included the use of a structured proforma and intraoral examination techniques for assessing various oral health conditions in adolescents. Specifically, a group of 10 children aged 13–14 years were examined to practice and refine the procedures. Following this training, a total of 20 subjects were scheduled to be examined on two separate occasions over two consecutive days. The reliability of the examiner's observations was assessed using the kappa statistic, which yielded a value of 0.85, indicating a good level of agreement among the observers in their assessments.

While implementing the survey, a structured questionnaire was utilized to gather data on various sociodemographic factors, including name, age, gender, address, and family income. Additionally, family-related aspects such as the occupation and education of both parents, family income, birth order, number of siblings, and family structure were examined. Psychosocial factors such as perceived parental support, perceived parental punishment, the number of siblings, number of close friends, and habits like tobacco use or substance abuse (if applicable) were also assessed. Furthermore, general and oral health-related factors were considered, such as the frequency of sugar consumption, dietary habits, tooth brushing frequency, use of oral hygiene aids, sugar consumption, pattern of dental visits, and oral health preventive measures. The questionnaire incorporated a combination of open-ended and close-ended questions to gather the necessary information from the participants. To determine socioeconomic status, the Revised Kuppuswamy's scale of 2022 by Sood and Bindra [17] was employed for recording purposes which is based on education, occupation and income. The OHRQoL was assesses using Child Perception

Questionnaire which is created by Jokovic et al. in 2002, consisted of 37 items categorized into four conceptual domains: oral symptoms (OS, six items), functional limitations (FL, nine items), emotional well-being (EWB, nine items), and social well-being (SWB, 13 items). The children were instructed to indicate the frequency of specific experiences they had encountered within the past three months. A pre validated questionnaire among Hindi speaking population by Jain et al. [18] was used in the present research.

The tobacco use questionnaire was developed using Global Youth Tobacco Survey and adapted from the study by Singh et al. [19] The study utilized a structured, self-administered questionnaire comprising 20 items. These items were categorized to cover various aspects such as tobacco use, knowledge about the harmfulness of tobacco, tobacco accessibility, attitudes towards tobacco use, cessation behavior, exposure to tobacco advertisements, and attitudes towards tobacco control (refer to Table 1). Each participant's responses were evaluated based on the accuracy of their answers. Before conducting the study, the questionnaire underwent a pre-testing phase involving 20 individuals to ensure accurate translation, validity, and necessary modifications were made for field administration. The reliability of the questionnaire was assessed using Cronbach's alpha internal consistency coefficient, resulting in an average value of 0.82.

Adequate instruments were used per day for clinical examination. Each day, a maximum of 40 study subjects underwent examination. The children were seated on chairs as the oral assessment took place within their respective schools. Using a plain mouth mirror, explorer, and CPI probe, the examination was carried out under natural light conditions (Type 3). An explorer was used to remove debris from the tooth surfaces. A structured questionnaire was filled out by the study subjects before the clinical examination. The questionnaire was anonymous to maintain the confidentiality of the study subjects. The proforma filled by the study subjects were then checked to ensure completeness and minimize missing data. This was followed by the clinical examination of the study subjects which was filled in the proforma by the investigator herself. Dental Caries were recorded according to the Decayed, Missing, Filled Teeth Index (WHO criteria 1997) [20] to assess the 32 teeth (if present).

The data was entered into Microsoft Excel, and statistical analysis was conducted using IBM SPSS Statistics version 27.0. Categorical variables were expressed as numbers and percentages, while continuous variables were presented as mean and standard deviation. To examine relationships between variables, suitable statistical tests were applied. A significance level of 0.05 or lower was predetermined to determine statistical significance.

Table 1: Questions related to tobacco use.

Tobacco use questionnaire	Responses, %
Have you heard about tobacco?	Yes – 99.1 % No – 0.9 %
What are the forms you know of?	Gutka – 58 % Pan masala – 42 % Bidi – 5% Cigarette – 32 %
Knowledge regarding harmful effects of tobacco	Yes – 99.6 % No – 0.4 %
Sources of information for tobacco?	Television – 58 % Newspapers – 26 % Movies – 16 %
Factors influencing tobacco use?	Peer pressure – 100 %
Parents/siblings smoke or use tobacco products?	None – 34.3 Father – 34.8 Mother – 4.5 Siblings – 15.0 Dont know – 11.4
Has anyone discussed the harmful effects of tobacco use with you?	Yes – 67 % No – 33 %
Knowledge about anti-tobacco media messages?	Yes – 98 % No – 2 %
Have you ever used tobacco or its products?	Yes – 8.2 % No – 91.8 %
Reason for tobacco use	Curiosity – 25 % Fun with friends – 75 %
Pattern of tobacco use	Smoker – 5 (0.3 %) Chewer – 126 (7.8 %)
Age of initiation (year) of tobacco use	10.2 ± 1.68 years
Duration of smoking	1–3 years – 100 %
Frequency of smoking	Every month – 42 (2.6 %) Rarely – 89 (5.6 %)
Type of tobacco users	Current users – 90 % Ever users – 10 %
Procurement of tobacco products?	Bought them – 88 % Borrowed them – 12 %
Ease of getting tobacco products regardless of age?	Yes – 100 % No – 0 %
Place of tobacco use	Outside – 90 % Friends place – 10 %

Results

A total of 1,600 schoolchildren participated in the research, with an equal split of 800 from government and 800 from private schools. The average age of the participants was 12.3 ± 0.89 years. Among the study population, there were 828 students aged 13 and 772 students aged 14. The study included an equal number of boys and girls.

Among the 1,600 children, an overwhelming 99.1 % reported being aware of tobacco and its products, while only 0.5 % had no knowledge about them. The children demonstrated familiarity with various forms of tobacco, including bidi, cigarette, gutka, pan masala, and zarda. A total of 8.2 % of the schoolchildren acknowledged having used tobacco in some form. The primary reasons cited for tobacco use among the users were socializing with friends (75 %) and curiosity (25 %) [see Table 1].

The majority of tobacco products used by the schoolchildren were in chewable form, while a mere 0.3 % had used tobacco in the form of cigarettes. Among the tobacco users, 64.3 % purchased tobacco themselves, while 35.7 % borrowed it from others. Surprisingly, despite legislation prohibiting the sale of tobacco products to minors, age posed no barrier for the schoolchildren to obtain these products, and they predominantly used them in public places.

Television served as the primary source of information about tobacco and its products, cited by 58 % of the participants, followed by newspapers (26 %) and movies (16 %). Within the study group, 58 % of the children reported that their parents and/or siblings used tobacco products, while 42 % specifically mentioned that their fathers were tobacco users (Table 1).

There were no statistically significant differences between males and females in relation to any of the questions ($p>0.05$). The participants displayed a high level of knowledge about the harmful effects of tobacco, with 95 % of them being aware of the associated health risks. The prevalence of tobacco usage among the study subjects was found to be 8.2 %.

The mean overall CPQ scores among the study participants was 9.15 (0.32). The means for OS domain was 3.14 (SD 1.08), FL domain was 2.04 (SD 1.52), EW domain was 2.00 (SD 1.04), SW domain was 1.25 (SD 0.89). The adolescents were mainly belonging to middle socioeconomic status and lower middle socioeconomic status. The dental caries prevalence among the study population was 38.5 %, it was seen that adolescents with higher CPQ scores were found to have more dental caries, and also significantly associated with tobacco use.

Most of the tobacco users were boys who mainly belonged to lower and lower middle socioeconomic stats (61.8 and 26.7 % respectively). The majority of tobacco users had never visited a dentist and those who visited, did so only when in pain. The caries prevalence among the tobacco users was 42 % and the gingival health was also poor in 65.6 % of the tobacco users (Table 2).

The Poisson analysis showed that higher CPQ scores i.e. worse OHRQoL were found to be associated with higher tobacco use, lower socioeconomic status and lower dental attendance. The predictors of tobacco use were untreated dental caries and absence of dental attendance in the past six months. Gingival health did not show significant difference with tobacco use (Table 3).

Table 2: Sample characteristics of tobacco use according to demographic, socioeconomic and oral health variables.

	n=131	%
Gender		
Boys	105	80.2
Girls	26	19.8
SES		
Upper	10	7.6
Upper middle	2	1.5
Middle	3	2.3
Lower middle	35	26.7
Lower	81	61.8
Dental visits		
Yes	42	32.1
No	89	67.9
Dental caries		
Yes	55	42
No	76	58
Gingival health		
Good	45	34.4
Poor	86	65.6
OHRQoL (CPQ)		
Mean ± SD	9.15 ± 0.32	

Table 3: Unadjusted and adjusted association between variables for tobacco use.

	Unadjusted IRR	p-Value	Adjusted IRR	p-Value
Gender				
Girls	1	0.001	1	0.0001
Boys	1.85 (1.25–1.92)		1.76 (1.15–1.84)	
SES				
Upper	1	0.001	1	0.0001
Upper middle	0.85 (0.75–0.95)		0.78 (0.70–0.85)	
Middle	0.89 (0.72–0.98)		0.85 (0.68–0.95)	
Lower middle	2.10 (1.85–2.28)		2.05 (1.79–2.25)	
Lower	2.85 (2.36–3.42)		2.81 (2.24–3.32)	
Dental visits				
Yes	1	0.001	1	0.0001
No	1.98 (1.78–2.25)		1.55 (1.65–2.35)	
Dental caries				
No	1	0.01	1	0.003
Yes	1.56 (1.29–1.88)		1.42 (1.24–1.75)	
Gingival health				
Good	1	0.323	1	0.055
Poor	1.20 (1.12–2.35)		1.05 (0.95–1.40)	
OHRQoL (CPQ)	1.12 (1.10–1.15)	0.025	1.05 (1.02–1.08)	0.001

Discussion

The cross-sectional research was conducted to assess the influence of tobacco use on OHRQoL of adolescents. Tobacco use, whether in the form of smoking or smokeless tobacco, can cause severe oral health problems. The harmful constituents present in tobacco, such as nicotine, tar, and various carcinogens, directly affect oral tissues, leading to periodontal diseases, tooth decay, oral cancer, and compromised oral hygiene. Consequently, these conditions can significantly diminish an adolescent's OHRQoL by causing pain, discomfort, functional limitations, and aesthetic concerns. OHRQoL represents the subjective evaluation of an individual's oral health status and its impact on their daily functioning, psychological well-being, and overall quality of life. In the context of adolescents, OHRQoL is crucial as it influences their social interactions, self-esteem, and overall psychosocial development. Poor oral health resulting from tobacco use can negatively affect an adolescent's OHRQoL by impairing their ability to eat, speak, and maintain a positive self-image, thereby impacting their overall well-being [4–6].

The study also suggested that demographic factors such as sex, socioeconomic status and oral health behavioral variables such as dental visits, and untreated dental caries are related to tobacco use. There are very few studies focussing on oral health-related quality of life and tobacco use among adolescents throughout the world and no such study has been conducted in India. Moreover, the present study also assesses oral health behavioural variables and its influence on oral health related quality of life. The pattern of tobacco use in the present study comprised mainly of smokeless forms. Similar results were reported in a study by Singh et al. [19]. Most of the tobacco users were boys. These results were similar to those by Petkar et al. [21] who reported 92.8 % of the tobacco users to be males while 7.2 % were females. The most probable reason could be that in India, tobacco use among females is still considered a taboo especially in suburban areas where the study was conducted. Also, males are found to be more prone to tobacco use which can be easily attributed to familial patterns, customs and a macho factor among boys. However, other findings did not show gender differences or effect in adolescents regarding tobacco use. The main factors for tobacco use was stress followed by curiosity. Various studies have reported that development of stressful responses especially in early adolescent life can have effect on physical and mental health such as retarded growth, addictions etc. Individuals with bad stressful experiences are more likely to get involved into bad habits and develop nicotine dependence [22–25].

The present study showed that tobacco use was higher among adolescents belonging to lower socioeconomic status. Socioeconomic obstacles pose constraints on individuals' access to knowledge and health information, as well as contribute to the development of harmful oral habits. Nevertheless, the existing body of literature on this subject lacks consistent findings due to variations in research methodologies, cultural influences, geographic factors, and the diverse socioeconomic indicators utilized [26].

The concept of OHRQoL encompasses four subscales of oral symptoms, functional limitations, emotional and social well-being. The emotional and social wellbeing components are strongly associated with adolescents' tobacco use and nicotine dependence. It was also seen in the present study that stressed individuals with worse social well being were more strongly associated with tobacco use.

Oral disorders often tend to cause symptoms that affect the perception of oral health, thus compromising the OHRQoL. The present study showed that the individuals with more dental caries had a worse OHRQoL. This can be justified based on the fact that children with oral health problems have a physical and psychological impact of these conditions. Thus, the long term effects of oral disorders tend to affect physical, psychological and social development leading to worsening of OHRQoL.

The main limitation of the present study was self reporting of tobacco use and OHRQoL. Though the questionnaire was anonymous and confidentiality was ensured, this can underestimate tobacco use since adolescents may not report true consumption frequency. Another limitation of the study was memory bias especially related to questions on frequency and age of initiation.

However, the present study provided an insight into the factors associated with tobacco use and its influence on OHRQoL, an association which has largely been neglected. This has implications in identifying risk factors associated with adolescents' behaviour change and its effect on OHRQoL. Future interventions might be required with more longitudinal studies to generate evidence to improve adolescents' oral health and behaviour through OHRQoL. Interventions and Recommendations would include: (a) Comprehensive Tobacco Control Programs: Implementing evidence-based tobacco control programs that target adolescents can play a pivotal role in reducing tobacco use. These programs should incorporate components focused on oral health education, raising awareness about the consequences of tobacco use, and developing life skills to resist peer pressure. (b) School-Based Interventions: Schools serve as an ideal setting for interventions, including oral health education programs, peer support groups, and counseling sessions. Collaboration between oral health professionals and educators can foster a supportive environment for promoting positive oral health behaviors. (c) Role of Oral Health Professionals: Dentists and oral health professionals have a crucial role in assessing, diagnosing, and treating oral health conditions related to tobacco use. They can also provide guidance on tobacco cessation strategies and promote preventive oral health practices through routine dental visits.

Conclusions

The findings of the present study concluded that tobacco use is significantly associated with OHRQoL among adolescents. Adolescents with tobacco use presented with worse OHRQoL and more dental caries i.e. poor oral health behaviour. The study also showed that the socioeconomic indicators and clinical conditions are a strong predictors of tobacco use. Tobacco use poses a significant threat to the OHRQoL of adolescents, impacting their overall well-being and psychosocial development. Comprehensive efforts are required at individual, community, and policy levels to address this issue effectively. By implementing targeted interventions, raising awareness, and providing appropriate support, we can empower adolescents to make informed choices, reduce tobacco use, and improve their oral health-related quality of life.

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Comparison of the effect of zirconia and titanium abutments on peri-implant hard and soft tissues

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Abstract

Aim: The primary objective of this research was to assess and compare the impact of customized zirconia (Zr) and titanium (Ti) abutments, placed on early loaded dental implants, on both hard tissue (as measured crestal bone level) and soft tissue (as assessed by sulcular bleeding index [SBI], probing depth [PD], and Pink Esthetic Score [PES]), through clinical and radiographic evaluation.

Settings and Design: This research involved a sample of 15 patients who had partially dentulous mandibular arch. Within this group, a total of 30 implants were surgically placed. Specifically, each patient received two implants in the posterior region of the mandible, and the bone density in this area was classified as D2 type. In each patient, one implant was loaded with Zr abutment and the other was loaded with Ti abutment. The bone quality in the area of implant placement was Type D2. Two groups were created for this research. Each group consisted of 15 early loaded dental implants with customized Zr abutments and customized Ti abutments respectively.

Materials and Methods: Hard- and soft-tissue changes were evaluated in both the groups. Evaluation of crestal bone loss (CBL) with cone beam computed tomography and SBI, PD and PESs were evaluated by various indices at 2, 4, and 6 months postloading.

Statistical Analysis Used: After obtaining the readings, data were subjected to statistical analysis and comparison of quantitative data was done, paired *t*-test was used.

Results: The mean CBL in the Ti abutment is higher; the difference between the two groups was not statistically significant. SBI and PD for Zr were higher, but there was no statistically significant difference between the two groups. Zr had a higher PES than Ti abutment and the difference between the two groups was statistically significant. In the literature till date, the PES of Zr abutments were proven better for provisional restorations in implant prosthesis, but very few literatures support the same for the final implant restorations.

Conclusion: The study did not reveal a clear advantage of either Ti or Zr abutments over the other. Nevertheless, Zr abutments tended to produce a more favorable color response in the peri-implant mucosa and led to superior esthetic outcomes as measured by the PES.

Keywords: Customized zirconia abutment, hybrid abutment, titanium abutment

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INTRODUCTION

The field of dental implant has expanded significantly in the past few decades, bringing innovation with increasing the range of available treatments. One aspect of this advancement is specifically related to the prosthetic abutments. The prosthetic abutment attaches to the implant platform and serves as a connection point between the future superstructure or prosthesis and the fixture. In systematic reviews, titanium (Ti) has maintained a leading position as an abutment material. Due to their well-documented biocompatibility and mechanical characteristics, Grade 5 Ti alloys are typically used to create custom Ti abutments. However, the optical result may be harmed if the metallic color of Ti continues to shine through the mucosa. A dull gray shine through, even if placed sub gingivally, could make the soft tissue appear artificial.[1]

The development of tooth-colored ceramic and personalized implant abutments is a result of consumer demand for extremely esthetic restorations. From an esthetic standpoint, especially for patients with thin, mucosal tissues, and customized zirconia (Zr) implant abutments are advised. Zr is superior to Ti, having less plaque accumulation with similar soft-tissue response, probing depths (PDs), bleeding on probing, and marginal bone level.[2] Although, Ti abutments are still considered better mechanically and more reliable as compared to Zr when exposed to long term clinical function.[1]

Literature provides very limited evidence on comparative clinical evaluation of customized Zr and Ti abutments. Hence, this *in vivo* research aimed to compare and evaluate the hard- and soft-tissue response around early loaded dental implants with customized Zr and Ti abutments.

MATERIALS AND METHODS

The Institutional Ethical Committee gave its Clearance under number IDST/IEC/2020-23/28. The Clinical Trial Registry of India received the study registration. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp. Released 2012 was used to estimate the sample size. Fifteen partly edentulous individuals (male and female) between the ages of 30 and 50 years had 30 dental implants implanted. Two groups were created for the investigation. Fifteen early loaded dental implants in Group 1 had a customized Zr abutment, while 15 early loaded implants in Group 2 had a customized Ti abutment. An appointment for diagnosis marked the beginning of the trial regimen. According to the inclusion, exclusion, and laboratory investigation criteria, all 15 patients were chosen.

Inclusion criteria

- Age 30–50 years
- Partially edentulous sites
- Extraction socket that has healed
- No occlusal disharmony
- Sufficient height and quantity of bone for implant placement
- COVID-19 (reverse transcription polymerase chain reaction report) negative
- Having good dental and general wellness.

Exclusion criteria

- Immunocompromised state
- Chronic bone diseases
- Psychiatric disorders
- Uncontrolled diabetes
- Pregnant or lactating females.

A thorough clinical examination, radiographic assessment involving the cone beam computed tomography (CBCT) was done [Figure 1]. All treatment options were thoroughly discussed with the patients. The relative advantages and disadvantages of implant treatment were informed. The surgical procedure was adequately explained and thereafter, a written consent was taken from all the patients.

After making diagnostic impressions with alginate, Type 2 dental stone was used to pour the cast, bite registration was recorded and semi adjustable articulator was used to mount the cast. With the help of vacuum forming machine, thermoplastic material was applied to the cast, and stents were made to direct the surgical drills during surgery.

A presurgical prophylactic dose of 2 g Amoxicillin 1 h before the surgery was prescribed to the patient. The patient was instructed to do intraoral rinses with 0.12% chlorhexidine after the surgical site was prepped with 5% betadine paint.

Local anesthesia (2% Lignocaine with 1:100,000 adrenaline) was administered using disposable syringe and a mid-crestal incision was given in mandibular posterior region with no. 15 BP blade [Figure 2]. Two releasing incisions were placed on the mesial and distal aspect to raise a full thickness mucoperiosteal flap. Surgical guide was then placed in position, and the initial osteotomy was performed using pilot drill. The complete osteotomy was obtained after using all the required surgical drills in the progressively increasing diameter. The depth of the osteotomy site was measured with the help of implant depth gauge.

Then, using an implant driver and a torque wrench, implants were placed [Figure 3] at the site of the osteotomy with an insertion torque of 30–50 Ncm, according to the available bone density, healing abutments were attached and primary closure of the surgical site was achieved [Figure 4]. The healing abutments were then taken out and the closed tray impression copings were attached for making closed tray implant level impressions with the help of polyvinyl siloxane (putty and light body consistency) (Photosil DPI, India) impression material. At the end, healing abutments were reattached followed by postoperative instructions and medications were prescribed to the patient.

Final impression attached with lab analog was sent to the laboratory where the master casts were poured with Type IV Gypsum products and the scan bodies were attached to the cast followed by which the designing of the abutment was done according to the type of implants placed in the patient and milling of the abutments (Zr and Ti) were done with the help computer-aided-design/computer-aided-manufacturing software (3 Shape) [Figures 5 and 6]. The Porcelain Fused to Metal (DMLS) crowns were also fabricated in the laboratory.

In the next appointment, the sutures were removed and customized Zr and Ti abutments were attached to the implants and were loaded functionally within a week [Figures 7 and 8].

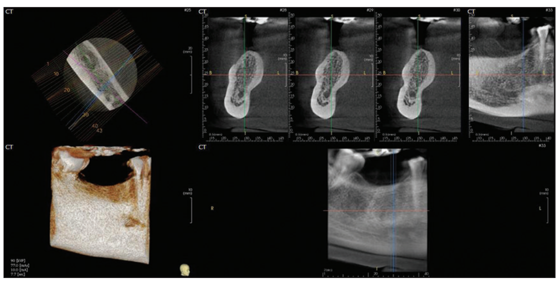


Figure 1: Preoperative cone beam computed tomography field of view

Figure 2: Mid crestal incision and flap raised wrt 46, 47 region

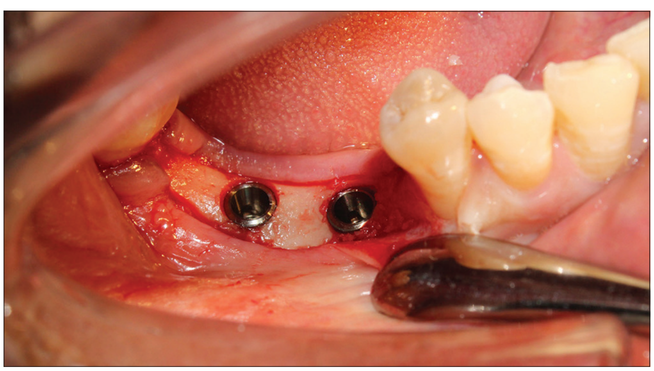


Figure 3: Implant placement done wrt 46, 47 region

Figure 4: Healing abutment attached and suturing done

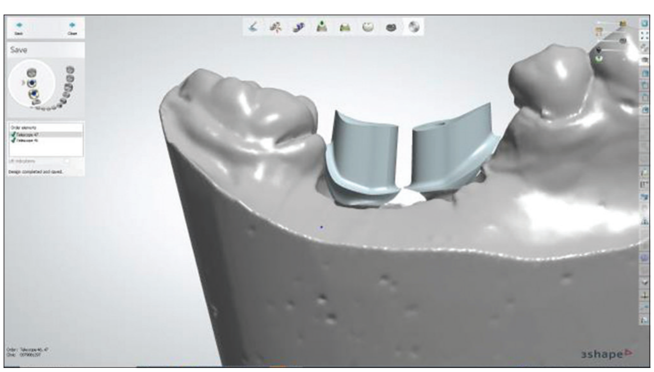


Figure 5: Designing of zirconia and titanium abutments wrt 46, 47

Figure 6: Zirconia and titanium abutments

At the 2nd, 4th, and 6th months after loading, standardized follow-up exams were planned to evaluate both hard- and soft-tissue changes [Figure 9].

Crestal bone loss was assessed with CBCT (Papaya 3D Plus, Genoray Korea Japan) postoperatively at 0, 2, 4, and 6 months to assess the hard-tissue changes for both the groups. At 2, 4, and 6 months postloading PD, bleeding index (BI), Pink Esthetic Score (PES), which includes the mesio-distal papilla, alveolar process deficiency, soft-tissue level, contour, color, and texture were all recorded to assess any change in both groups using the Hu-Friedy Colorvue plastic probe.

Figure 7: Zirconia and titanium abutment wrt 46, 47

Figure 8: Implant loading with porcelain fused to metal (DMLS) crowns wrt 46, 47

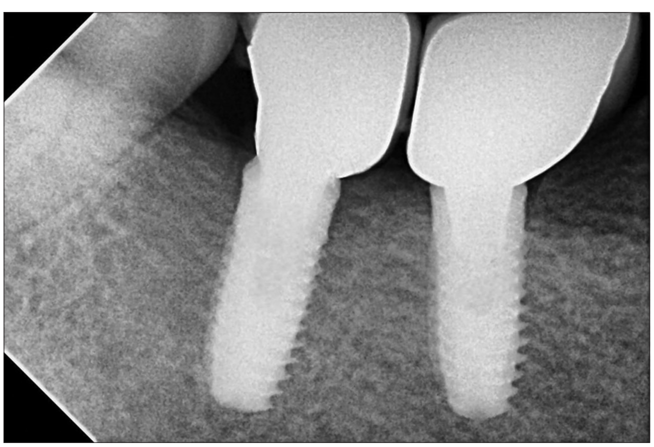


Figure 9: Postoperative IOPA X- ray wrt 46, 47

RESULTS

Data were collected and compiled methodically, converted from a pro forma with precoded fields to a computer, and a master table was created. The complete amount of data were thoughtfully distributed and displayed as separate tables and graphs.

Intergroup comparison of mean sulcular BI (SBI) at 2, 4, and 6 months was done using paired *t*-test. It was found that SBI for Group 1 is higher at recorded time intervals in comparison to Group 2. *P* value at 2 months was 0.650, at 4 months 0.825, and at 6 months 0.532, but the difference between the two groups was statistically not-significant [Table 1 and Graph 1].

Intergroup comparison of mean PD at 2, 4, and 6 months was done using paired *t*-test. It was found that PD for Group 1 is higher at recorded time intervals in comparison to Group 2. *P* value at 2 months was 0.906, at 4 months 0.748, and at 6 months 0.683, but the difference between the two groups was not statistically significant [Table 2 and Graph 2].

Intergroup comparison of mean PES at 2, 4, and 6 months was done using paired *t*-test. It was found that PES for Group 1 is higher at recorded time intervals in comparison to Group 2. *P* value at 2 months was 0.004, at 4 months

Table 1: Intergroup comparison of sulcular bleeding index

Groups	*n*	Mean	SD	*P*
At 2 months				
Group 1	15	0.7833	0.18581	0.650, NS
Group 2	15	0.7500	0.21129	
At 4 months				
Group 1	15	0.5333	0.18581	0.825, NS
Group 2	15	0.5167	0.22093	
At 6 months				
Group 1	15	0.2333	0.11443	0.532, NS
Group 2	15	0.2000	0.16903	

SBI: Sulcular bleeding index, NS: Not significant, SD: Standard deviation

Table 2: Intergroup comparison of probing depth

Group	*n*	Mean	SD	*P*
At 2 months				
Group 1	15	3.9500	0.33004	0.906, NS
Group 2	15	3.9333	0.42748	
At 4 months				
Group 1	15	3.4833	0.56273	0.748, NS
Group 2	15	3.4167	0.56432	
At 6 months				
Group 1	15	3.2500	0.60504	0.683, NS
Group 2	15	3.1667	0.49701	

PD: Probing depth, NS: Not significant, SD: Standard deviation

0.004, and at 6 months 0.008 and statistically significant difference was found in both the groups [Table 3 and Graph 3].

Intergroup comparison of mean crestal bone loss (CBL) at 2, 4, and 6 months was done using the paired *t*-test. It was found that mean CBL for Group 2 is higher at recorded time intervals in comparison to Group 1. *P* value at 2 months was 0.443, at 4 months 0.950, and at 6 months 0.170 and there was no significant difference in both the groups [Table 4 and Graph 4].

Obtained data showed bleeding on probing was higher for customized Zr abutment at recorded time intervals than customized Ti abutment, PD was less for customized Ti abutment compared to customized Zr abutment, PES was higher for customized Zr abutment at recorded time intervals and crestal bone loss was less for customized Zr abutment than customized Ti abutment.

DISCUSSION

The objective of this *in vivo* study was to examine and assess the hard- and soft-tissue response to early loaded dental implants with custom-made Zr and Ti abutments.

The CBCT was done to evaluate hard-tissue changes. The measuring tools used were provided within the Triana Software. Linear measurements were calculated using ruler tool to calculate distance on mesial and distal aspect to measure bone loss in coronal section and lingual and buccal aspect in sagittal section, respectively. Bone measurements calculated on 0, 2, 4, and 6 months postloading of implants were compared by using this tool to calculate bone loss at a given time. The soft-tissue changes were evaluated by using Hu-Friedy Colorvue plastic probe for the both groups.

According to the study's findings, Group 1 (customized Zr abutment) had higher mean SBI scores than Group 2 (customized Ti abutment) at the recorded time points of 2, 4, and 6 months; however, there was no significant difference in both the groups. Because of the young junctional epithelium around the dental implants, initial

Table 3: Intergroup comparison of Pink Esthetic Score

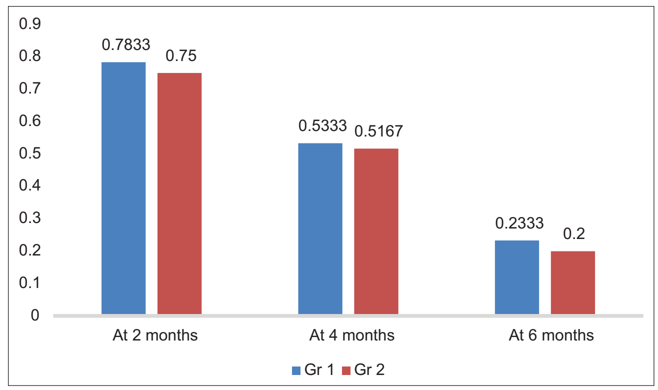
Group	*n*	Mean	SD	*P*
At 2 month				
Group 1	15	7.8667	1.12546	0.004 (significant)
Group 2	15	6.5333	1.18723	
At 4 months				
Group 1	15	9.8000	1.20712	0.004 (significant)
Group 2	15	8.4667	1.12546	
At 6 months				
Group 1	15	11.4000	0.91026	0.008 (significant)
Group 2	15	10.3333	1.11270	

PES: Pink Esthetic Score, SD: Standard deviation

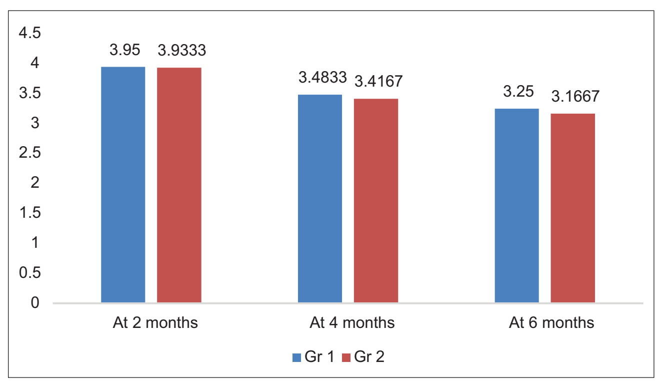
Table 4: Intergroup comparison of crestal bone loss

Group	*n*	Mean	SD	*P*
At 2 month				
Group 1	15	0.2340	0.16211	0.443, NS
Group 2	15	0.2823	0.17769	
At 4 months				
Group 1	15	0.4576	0.18525	0.950, NS
Group 2	15	0.4626	0.24331	
At 6 months				
Group 1	15	0.6829	0.20007	0.170, NS
Group 2	15	0.5706	0.23524	

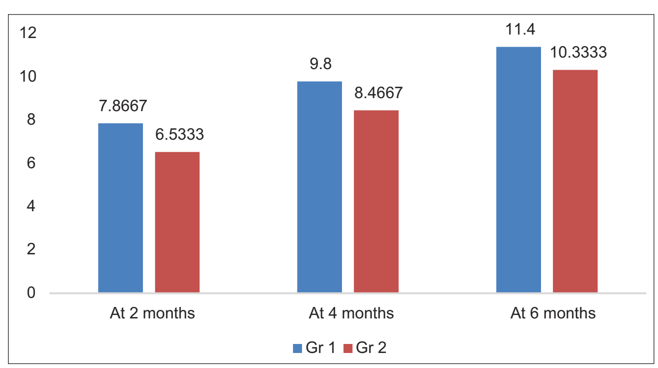
CBL: Crestal bone loss, SD: Standard deviation, NS: Not significant



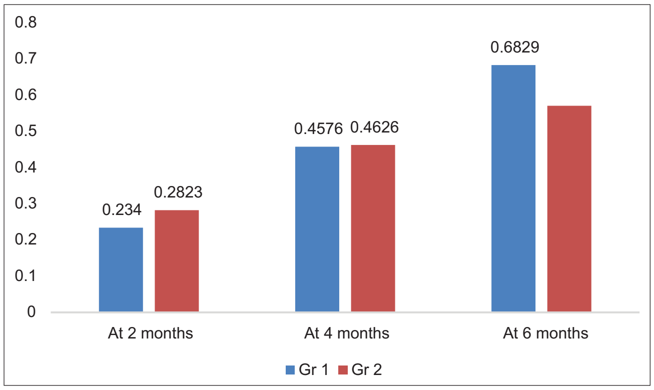
Graph 1: Intergroup comparison of sulcular bleeding index. SBI: Sulcular bleeding index



Graph 2: Intergroup comparison of probing depth



Graph 3: Intergroup comparison of Pink Esthetic Score. PES: Pink Esthetic Score



Graph 4: Intergroup comparison of crestal bone loss. CBL: Crestal bone loss

bleeding on probing was greater, although this gradually subsided over time.

The percentage reduction in the SBI decreased more quickly in Group 2 (Ti) than in Group I (Zr) from the 2nd to 8th months and from the 4th to 6th months, although the difference was not statistically significant.

Sailer *et al*. concluded that there was more bleeding on probing at the prosthesis supported by Zr abutment in comparison to Ti abutment.[3] However, Zembic *et al*.,[2] Lops *et al*.,[4] and Hosseini *et al*. (2013)[5] reported no significant difference in BOP around Zr and Ti abutments.

Payer *et al*. evaluated SBI around two-piece Zr implants with Ti abutments for 24 months and concluded that there was no statistical difference among both the groups.[6]

At the recorded time intervals of 2, 4, and 6 months, it was discovered that Group 2 (Ti) had lower mean scores for PD, but this difference between the two groups was once again not statistically significant. This may possibly be related to the initially immature junctional epithelium around the dental implants, which improve gradually overtime.

The percentage reduction in PD also showed a faster reduction from 2nd to 4th months and from 4th to 6th months in Group 2 (Ti) compared to Group 1 (Zr), but the difference was not statistically significant.

Sailer *et al*. and Carrillo de Albornoz *et al*. showed mean PD for Zr abutment (3.5 mm) was more than mean PD for Ti abutment (3.3 mm) at 1 year follow-up, but difference was not statistically significant between two groups.[3,7]

In contrast Lops *et al*. reported that mean PD for Zr abutment was less than mean PD for Ti abutment, but difference was not statistically significant between two groups.[4]

While considering the mean scores for PES, it was found that scores were considerably higher for Group 1 (Zr) at recorded time interval (2, 4, and 6 months) and there was a significant difference in both the groups.

The percentage increase in PES also showed a faster increase from 2nd to 4th months and from 4th to 6th months in Group 1 (Zr) compared to Group 2 (Ti) and the difference was statistically significant.

Payer *et al*. recorded PES to evaluate Zr and Ti abutments. The mean score for Zr abutments were higher after 24 months, showing a significant difference between the two.[6]

Zembic *et al*. - Papilla Index, Hosseini *et al*. (2013) - Copenhagen Index Score, and Carrillo de Albornoz *et al*. - Implant Crown Aesthetic Index reported that no significant difference was found between the two.[2,5,7]

Mean CBL was less for customized Zr abutment at recorded time intervals, but only for initial two follow-ups which were 2nd and 4th months. For the 3rd follow-up which was at 6th month, lesser CBL was found for customized Ti abutment than customized Zr abutment, but the difference between the two groups was nonsignificant.

Zembic *et al*., Lops *et al*., Hosseini *et al*. (2013), Payer *et al*., and Carrillo de Albornoz *et al*. reported on interproximal CBL. Studies that were included reported no significant differences in CBL among both the abutments.[2,4-7]

From observations, it can be deduced that the PD, bleeding on probing and CBL around implants were comparable with no statistical significant difference.

Significant difference was found in the PES among both the groups confirming the hypothesis that the Zr abutments can improve the esthetics around the dental implants compared to Ti abutment.

Furthermore, it was observed that the survival rate of early loaded implant was around 97% at 6 months. Occlusal loading 4–21 days after implant surgery is defined as "early loading."

Pigozzo *et al*. stated that the overall survival rates were 97.5% for early loading at 1 year and 97.6% at 3 years.[8] Ganeles *et al*. stated that implant survival rate is around 97% for early loading protocol at 12 months.[9] Several studies supported early loading and stated that it is a good treatment alternative more esthetic and less time taking procedure.[10]

Limitation of this study was the short follow-up period and sample size was small. Further investigations including a large sample size and a long follow-up period to enhance the significance of the conclusion concerning the use and predictability of the Zr abutment.

CONCLUSION

Following conclusions were made based on the limitations of this study:

1. SBI was higher for customized Zr abutment at recorded time intervals than customized Ti abutment, but there was no significant difference between both the groups
2. PD was less for customized Ti abutment at recorded time intervals than customized Zr abutment, but there was no statistically significant difference between both the groups
3. PES was considerably higher for customized Zr abutment at recorded time interval than customized Ti abutment with statistically significant difference among both the groups. It showed potential to improve the esthetics with Zr abutments and the overall quality of the soft tissue was also improved around implants
4. Crestal bone loss was less for customized Zr abutment, but only for initial two follow-ups which were 2nd and 4th months. At the 6th month, CBL was less for customized Ti abutment than customized Zr abutment, but the difference was statistically nonsignificant among both the groups.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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Denture Barcoding - The Clever Way

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Abstract

Forensic Odontology is the means to identify a person from their dental remains. Various methods are there for identifying an individual. In this study, the main aim is to identify an edentulous person making a positive identification by means of Barcode. A Barcode is a machine-readable code in the form of numbers and a pattern of parallel lines of varying widths, printed on a commodity. The study focuses on creating dentures with identification marks/labels using patient's identity proofs such as Aadhar Card, PAN card, Voter ID card. And these will be incorporated in the denture after acrylization using cost effective and minimally altering method. This is an attempt to incorporate identity marks in dentures that can be provided by a General Dental Practitioner on day-to-day basis.

Keywords: Denture; Barcoding; Human Identification; Aadhar Card; Pan Card; Voter Id Card; Forensic; Barcodes; Economical

List of Abbreviations

EPIC- Electoral Photo Identity Card; PAN - Permanent Account Number; SC- Schedule Caste; ST- Schedule Tribe; OBC- Other Backward Cast; RTA/RTO- Regional Transport Authorities/Offices

Background

The word forensic comes from the Latin word forensis, meaning “in open court” or “public.” When you describe something as forensic you usually mean that is has to do with finding evidence to solve a crime. It could also mean that it has to do with the courts or legal system. [1] The word Forensic is defined as relating to or denoting the application of scientific methods and techniques to the investigation of crime and Odontology means study of teeth. Thus, Forensic Odontology is the application of dental science onto legal investigations, which is primarily involving the identification of the offender by comparing dental records to a bite mark left on the victim or an object left at the scene of crime, identification of unidentified human remains based on by comparative identification of using ante mortem dental records.

Historically, the earliest case of dental identification is recorded in ancient Rome with the Agrippina who identified decapitated head of Lollia Paulina with her “distinguished teeth” [2]. In year 1775, Dr Paul Revere became first dentist who performed forensic dental identification in United States[3] using his dental records for identifying the body of the remains of Gen. Dr. Joseph Warren by finding the ivory dentures he crafted and wired to his Warren’s jaw, after his body was exhumed after nine months.[4] Since then identification using dental tissues has offered a new perspective in various aspects of identification of unclaimed human remains in mass disasters both man-made and natural scenarios.

This meant that identification using dental structures has gained more importance as these dental tissues are often preserved even if the deceased person is skeletonized, mummified [19], adipocered, burnt or dismembered. Dental tissues are often used to determine age, sex, and ethnicity of the person using comparative, reconstructive or profiling methods. The Comparative identification means to establish the remains of decedent and a person represented by ante mortem records are of the same individual while reconstructive identification is the Dental Profiling or Post Mortem Dental Profile which elicit race, gender, age and occupation of the dead individual. They are undertaken when ante mortem records are not available [5]. The methods can be expensive like Deoxyribo Nucleic Acid (DNA) printing to economical.

Weissenstein first proposed that denture should have some form of identifiable marking in 1931[6] and ideal characteristics of denture markers were described by Vestermark in 1975[7]. Denture Barcoding is a newer and an innovative technique to identify a patient with Complete Denture/RPD using a QR code just like the ones that come with Implants. A Barcode is a machine-readable code in the form of numbers and a pattern of parallel lines of varying widths, printed on a commodity. Barcodes are not limited to those white and black vertical printed lines these can also be made using some special numbers or codes.

In this article the study focuses on the economical method of denture barcoding using the patient’s own identity proof numbers (Aadhar Card, Voter Id card, PAN card).

Following are the Criteria Which Need to be Fullfilled for Barcoding a Denture [8,9]

The strength of the prosthesis must not be jeopardized.

Easy and inexpensive to apply

The identification system must be efficient.

The marking must be visible and durable.

The identification must withstand humidity and fire.

The identification mark should be aesthetics acceptable.

The identification mark should be biologically inert.

The marking should be permanent and resistant to everyday cleansing and disinfecting agents.

The advantages and disadvantages of Denture Barcoding is given in Table 1

ADVANTAGES [8]	DISADVANTAGES [8]
1.For identification of a person in case of accidents, state of unconsciousness, health issues like dementia or Alzheimer's, Natural calamities.	1. Patients need to carry their dentures wherever they go.
2. Allows entering of data, its tracking and verification.	2. Denture incorporated with a QR code if not in use should be thoroughly discarded on medicolegal grounds.
3. Less expensive	3. Residual ridge resorption pattern results in refabrication of denture over the years which may result in different identification marks.
4. Useful in forensic odontology and in medico-legal aspects.	

Table 1: Advantages & Disadvantages of Denture Barcoding

This study focuses on an economical method of denture barcoding using patient's identity proof. Following are the various identification proofs issued by the government of India:

- Aadhar card
- Passport
- Electoral Photo Identity Card (EPIC)
- Permanent Account Number (PAN)
- Driving license

Other Identity Proofs Issused:

- Ration card
- A Birth certificate
- SC/ST/OBC Certificates
- Transfer/School leaving/Matriculation Certificate

Aadhar Card

Aadhaar is a verifiable 12-digit identification number issued by UIDAI to the resident of India for free of cost. The UIDAI was established on 28 January 2009 after the Planning Commission issued a notification [10], and on 23 June Nandan Nilekani headed this project by the Government of India. The Aadhar Card comprises of the following [9].

12 Digit Number,

Face Photo,

Fingerprint,

Iris Scanner,

Body Identification Mark,

Demographic such as name, age, gender, address,

QR code,

2D QR code

The rationale and aim behind Government of India to introduce Aadhar Card was to provide an individual identity which would allow each person to avail social security benefits. Thus, allowing every individual to be will be financially inclusive and would also enable direct services delivery along with direct benefit transference. The government is able to communicate and govern its people using e-governance, preventing its people from identity fraud, ghost employee/voters and will in return reduce corruption [9]. It is thus rightly known as "Aam Aadmi ka Adhikar." (Figure 1)

Figure 1: Aadhar Card [14]

Voter Id Card

The Indian voter ID card is an identity document issued by the Election Commission of India to adult domiciles of India who have reached the age of 18, which primarily serves as an identity proof for Indian citizens while casting their ballot in the country's municipal, state, and national elections. It was first introduced in 1993 during the tenure of the Chief Election Commissioner T. N. Seshan [11]. (Figure 2)

Figure 2: Voter Id Card Old(left) & New (Right), Issued by Election Commission of India [15]

Pan Card

A permanent account number (PAN) is a ten-character alphanumeric identifier, issued in the form of a laminated "PAN card", by the Indian Income Tax Department, to any "person" who applies for it or to whom the department allots the number without an application [12]. In the year 1972, the concept of PAN was rolled out by the Indian government and was made statutory under section 139A of the Income Tax Act, 1961. Initially a voluntary process, PAN was made mandatory for all taxpaying individuals in 1976 [13]. (Figure 3)

Figure 3: Permanent Account Number (PAN CARD) [14]

Passport

A passport is a travel document, usually issued by a country's government to its citizens, that certifies the identity and nationality of its holder primarily for the purpose of international travel. Standard passports may contain information such as the holder's name, place and date of birth, photograph, signature, and other relevant identifying information [16].

Driving Licence

In India, a driving licence is an official document that authorizes its holder to operate various types of motor vehicles on highways and some other roads. It is administered by the Regional Transport Authorities/Offices (RTA/RTO) [17].

Aim and Objective

Positive identification through labeled Complete Denture using Personal Identity Proof without compromising the structural and functional integrity of the denture based on both post insertion assessments of dentist and patient.

Materials and Method

According to literature review, numerous methods have been previously used for denture identification namely Surface Methods which includes Scribing or Engraving, Embossing or writing using fibre tip. On the other hand, there are some Inclusion methods. In surface methods marks are laid on the denture surface area.[20] In this technique, letters, or numbers are engraved with a small round dental bur on the fitting surface of the complete denture [21] whereas, Embossing comprises initials of the name and the surname of the patient that are scratched with a dental bur on the master cast. On the other hand, Inclusion methods are more permanent as opposed to the relatively simple surface marking methods; however, these techniques require certain skills and are time consuming.[20] Other methods may include ID-Band, Paper strips, T-Bar, Laser etching, Electron microchips, Radio-frequency identification (RFID)-tags.[20]

Focus of our study was positive identification of a denture using identity proofs it also focuses on the idea for it to be feasible to a General Dental Practitioner as well as be economical to the patient.

The intent of this study was to establish an economical and feasible protocol which would enable a general dental practitioner can use on complete denture prosthesis on everyday basis. Thus, enabling a general dentist in creating a positive identification mark on the denture without distorting the prosthesis.

Here we are linking the denture marking system with Patient's Identity card, i.e citizen's unique identification card in India. This was done after patient's informed consent was obtained. The study was conducted at I.T.S Dental College, Muradnagar in the Department of Prosthodontics, on completely edentulous patients. For the purpose of sample collection, the completely edentulous patients reported to the department were taken into inclusion criteria (Table 2) to bring their identity proofs and along with this the informed consent of the patient was taken. The clinical sequence for the conventional method was performed in accordance with a standardized protocol consisting of the following steps:

First was making preliminary impressions using aluminum stock trays and impression compound (Y-Dents Impression Compound) and for Diabetic cases alginate impressions were made. Then, custom acrylic resin trays were prepared by followed by Border moulding using green stick (DPI Pinnacle Tracing Sticks) on their borders and then shaped by tongue movements and manipulation of labial and buccal soft tissues after which Definitive Impression (final Impression) using irreversible hydrocolloid material Algitex (Alginate Dental Impression Material) and Zinc Oxide Eugenol (DPI Impression Paste) was made using Selective Pressure technique. Third was occlusal plane orientation and maxillomandibular relationships using record bases. The position of maxillary rims was transferred to a mean value articulator. Dentures received anatomic teeth with cuspal inclination of 0 degrees (Premadent Teeth Set) were set. The fourth step was denture try-in. A methacrylate-based resin (Heat Cure Acrylic-DPI Heat Cure) was used, mixed, and packed according to the manufacturer's instructions and polymerized. On the day of insertion of the denture base during insertion of the denture a small area was removed using micromotor and then a printed slip of identity proof no. covered with scotch tape was placed in that area using clear acrylic (DPI-RR Cold Cure Acrylic Rapid Repair). (Figure 4). The barcodes were inserted using the process of Randomization and are shown in figure 5, 6, 7 and 8. Further appointments were scheduled within 15 days as necessary to check for any post denture insertion problems.

INCLUSION CRITERIA	Completely edentulous patientPatient with valid identity proof i.e Aadhar card, PAN card, Voter Id card.
EXCLUSION CRITERIA	Any physical or mental illness affects the patient's ability to cooperate during or after treatment.Patient who is hypersensitive to denture materials.Pathology eg. Pemphigus, cysts etc.Patient with bone necrosis or root stumps.Patients without a valid Id proof.
TOTAL NO. OF SAMPLES	Total number of 40 cases of Complete Denture were selected among which 20 were females and 20 males.
DISTRIBUTION OF SAMPLES	These samples were then distributed into 4 groups each with10 samples with Aadhar card no.,10 with QR code on Aadhar Card.10 with Voter Id card no., and10 with PAN card no.

Table 2: Inclusion & Exclusion Criteria

Figure 4: MATERIALS USED- DPI-RR Cold Cure Acrylic Rapid Repair, Scotch tape, Scissors, Denture Base, Identity proof.

Figure 5: Barcoding of the denture with Aadhar Card number

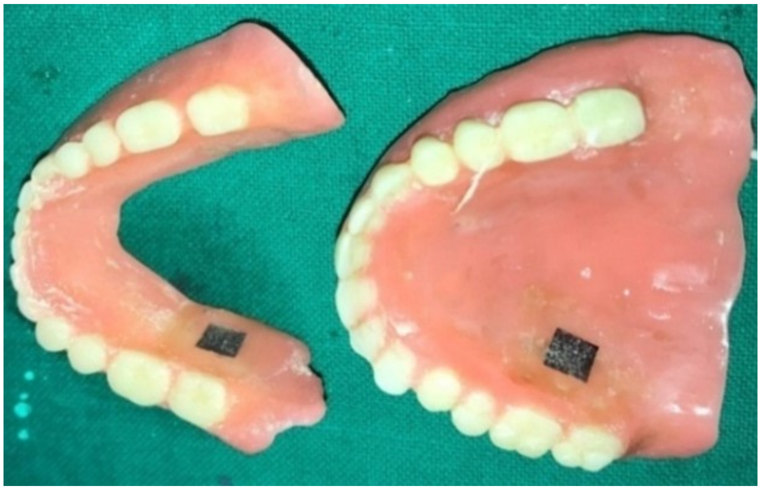

Figure 6: Barcoding of the denture with QR code on the Aadhar Card

Figure 7: Barcoding of the denture with Voter Id Card number

Figure 8: Barcoding of the denture with PAN Card number

Statistical Analysis

SPSS version 23 software was used for analysis of the data. The test applied was chi-square test to check the difference in responses among four categorical variables.

Results

Denture Barcoding was done using various identity proofs (Aadhar Card, PAN card, Voter ID card) of Complete Denture patients at I.T.S CDSR, Muradnagar. After processing of the denture a printed slip laminated with Scotch tape was inserted with clear self-cure resin. Barcoding of dentures during heat curing was not done to eliminate the error of misplacing of the slips and also to make the procedure feasible in day-to-day practice along with the corrections in post processing/insertion errors in the denture if any.

Group	Male	Female	Total
Aadhar card number	4 (40%)	6 (60%)	10 (100%)
Election card number	5 (50%)	5 (50%)	10 (100%)
Pan card number	6 (60%)	4 (40%)	10 (100%)
Aadhar barcode	6 (60%)	4 (40%)	10 (100%)

Table 3: Gender Details of Study Participants

Among the groups, after insertion of the dentures Post Insertion Evaluation of the denture along with the area on which Identity details were placed was done which comprised of asking the patients for any discomfort associated with the denture, checking for retention, stability, support or any other issues related to the denture. This Post Insertion Evaluation of the denture was subjected to naked eye visibility test. In group 1 (10 samples with Aadhar card no.), group 2 (10 samples with PAN card no) and group 3 (10 samples with Voter Id card no.) the font used was size 7 and the information printed was clearly visible and recognizable. Within group 4 (10 samples with QR code of Aadhar Card) QR Code was visible and recognizable yet no information was deciphered at this stage. By using the QR code which are “Quick Responses”, are square-shaped black and white symbols that are used to take a piece of information from a transitory media and put it in to your cell phone [25] which were scanned using the application “Aadhar QR Scanner” (for Android) and “Aadhar Card QR Scanner” (for IOS) [22]. It was noted that when Dentures with QR code on Aadhaar card is placed it resulted in jeopardizing its stability as it occupies more area and the once scanned the information retained in the QR code was scanned in 2 out of 10 successfully. This was followed by re-evaluation of the patient after 30 days and noting their feedback. For easier understanding we have included a flowchart to explain the process which we followed to get the results:

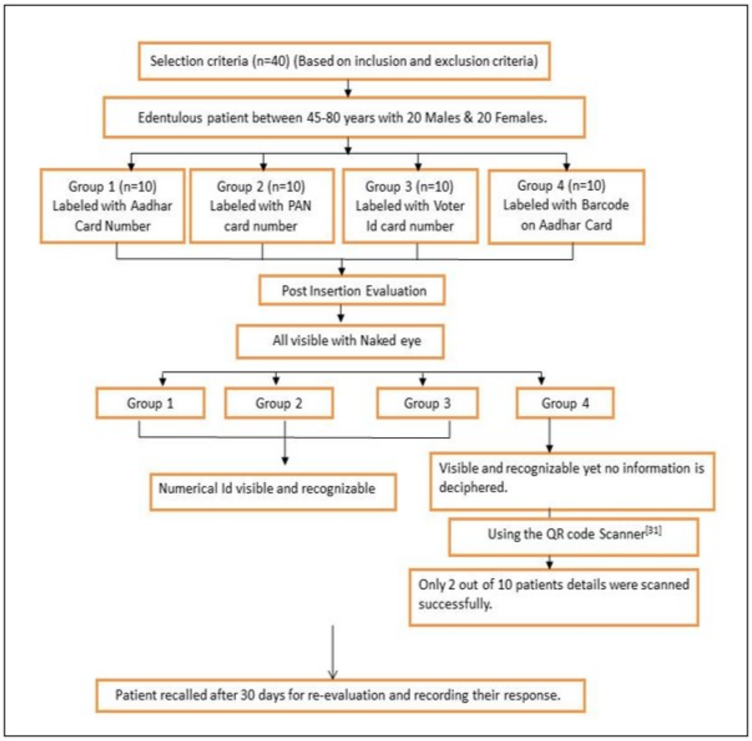

Figure 9: Result process flowchart

Criteria	Response	Aadhar card number	Election card number	Pan card number	Aadhar barcode	p value
Denture stability	**Yes**	10 (100%)	10 (100%)	10 (100%)	10 (100%)	--
	No	0	0	0	0	
Denture retention	**Yes**	10 (100%)	10 (100%)	10 (100%)	5 (50%)	0.001*
	No	0	0	0	5 (50%)	
Visibility of barcode	**Yes**	10 (100%)	10 (100%)	10 (100%)	2 (20%)	<0.001*
	No	0	0	0	8 (80%)	
Placement of barcode	**Easy**	10 (100%)	10 (100%)	10 (100%)	10 (100%)	--
	Tough	0	0	0	0	

Chi-square test; * indicates significant difference at $p \leq 0.05$

Table 4: Comparison of dentist opinion criteria among four groups

Denture stability was reported in all the dentures having aadhar card number printed on denture, election card number printed on denture, pan card number printed on denture, and aadhar barcode printed on denture.

Denture retention was reported in all the dentures having aadhar card number printed on denture, election card number printed on denture, and pan card number printed on denture; however, denture retention was reported in only 5 subjects who were given denture with aadhar barcode printed on it. There was a significant difference in denture retention reported among study groups.

Identity number was visible on all the dentures having aadhar card number printed on denture, election card number printed on denture, and pan card number printed on denture; however, aadhar barcode was visible only on 2 dentures and the difference was significant.

Placement of barcode was easy in all the methods reported and there was no difference.

Criteria	Aadhar barcode vs Aadhar card number	Aadhar barcode vs Election card number	Aadhar barcode vs Pan card number
Denture retention	0.033*	0.033*	0.033*
Visibility of barcode	0.001*	0.001*	0.001*

Chi-square test; * indicates significant difference at p≤0.05

Table 5: Pairwise Comparison

Pairwise comparison showed that dentures with aadhar barcode printed showed poor retention as compared to dentures with aadhar number printed, denture with election card number printed and dentures with pan card number printed. Also, visibility of barcode was significantly less on dentures with aadhar barcode printed as compared other methods.

Criteria	Response	Aadhar card number	Election card number	Pan card number	Aadhar barcode	p value
Denture satisfaction	**Yes**	9 (90%)	10 (100%)	10 (100%)	9 (90%)	0.551
	No	1 (10%)	0	0	1 (10%)	
Aesthetics	**Yes**	10 (100%)	10 (100%)	10 (100%)	7 (70%)	0.021*
	No	0	0	0	3 (30%)	
Retention	**Yes**	10 (100%)	8 (80%)	9 (90%)	9 (90%)	0.528
	No	0	2 (20%)	1 (10%)	1 (10%)	
Discomfort	**Yes**	4 (40%)	4 (40%)	2 (20%)	5 (50%)	0.567
	No	6 (60%)	6 (60%)	8 (80%)	5 (50%)	
Speech	**Yes**	7 (70%)	5 (50%)	8 (80%)	4 (40%)	0.244
	No	3 (30%)	5 (50%)	2 (20%)	6 (60%)	
Maintenance	**Easy**	10 (100%)	10 (100%)	10 (100%)	10 (100%)	--
	Tough	0	0	0	0	

Chi-square test; * indicates significant difference at p≤0.05

Table 6: Comparison of patient opinion criteria among four groups

There was no difference in denture satisfaction as reported by the patients in all the four methods. Compromised aesthetics was reported by the patients wearing dentures with aadhar barcode printed. Pairwise comparison of aesthetics criteria between Aadhar barcode and other types did not show any significant difference. There was no difference in the discomfort caused due to denture, speech and maintenance of denture reported by the patients in all the four methods.

Discussion

The result of this study shows that in both instances that are patient and dentist preferred other three methods of denture barcoding namely incorporation of Aadhar Card number, Pan Card number and Election card number over the method which involves incorporation of Aadhar Barcode. In the results, it is seen that with incorporation of Aadhar barcode compromises aesthetics as per patients and denture retention in dentist opinion as it occupies to much surface area. Further reduction in size of Aadhar barcode is not possible, as the current size of Aadhar Barcode itself has reduced the visibility, thus compromised the scanning and reduced the chance for information retrieval required for identification purposes.

Identification of individuals has always been a major issue due to lack of proper record management in various parts of the world. Thus, it becomes difficult to maintain records for a person [23]. Due to these various methods have come up in the field of Forensics that deals with identification of a person ranging from expensive to pocket friendly ones. Most of the methods available are widely used for dentulous patients. Very few methods are available for identification of a completely edentulous patient due to lack of teeth; residual ridge resorption etc, there is less of body remain needed for a positive identification. Residual Ridge Resorption is defined as the diminishing quantity & quality of residual ridge after teeth are removed. (G.P.T -8).[18] The resorption of the ridge starts as soon as the teeth are removed and continues rapidly. Since no tooth structure is remaining it becomes even more difficult to identify the concerned individual. This makes it further more important to label the dentures that can be done using micro-chips, QR codes or by own identity proof numbers that have a centralized system for record that takes into consideration starting from the person's name to their biometrics.

In United Kingdom, an incentive is offered by the National Health Service to the dentists who label the dentures of the patients, who are elderly and in nursing care facility. In United States, the social security number of the individual is marked on the denture, but such mandate is only present in its 21 states [26], whereas in Sweden the patient's unique personal ID is marked on a metal band and incorporated in the denture before processing. [27, 28, 29, 30]

Here, in India even though we have multiple identity proofs, yet we have failed to incorporate denture marking in our daily dental teaching and practices. In India, we need a method that is cost-effective and could be easily identified by all the people of the society, across the length and breadth of the country equally.

Aadhar card comprising both card number and bar code, Pan card and Election card details serves just the above-mentioned purpose.

Currently, there are two methods of denture barcoding in practice that are the surface marking methods and the inclusion methods. The earlier used methods are usually done by inclusion method where in the in Micro-chip is inserted in the denture that can be removed and opened in the laptop for viewing of the data which makes it a bit expensive and cumbersome. Here in this study we have used surface method to link dentures with Identity proof number which is different as it is more economical and can be done on a day-to-day basis even by a General dentist with no prior training.

The reason for not using cold cure as a material for fabrication of denture is due to its low strength [24]. The QR codes are inserted after the fabrication of denture with heat cure with self-cure so that it can be easily incorporated in the denture in day-to-day practice by a General Dentist and also to correct any post insertion problems if any.

The major reasons for not marking dentures are cost and lack of awareness. Hence, an appropriate framework within dental education is required. There is a need to offer patients an esthetically suitable denture marking system that is also inexpensive and permanent. Considering the social and practical value of denture marking, there is a need for marking dentures by members of the dental team involved in the provision of dentures to the public. The following recommendations to achieve this are offered:

Education at undergraduate level is urgently needed regarding the social and forensic value of marking dentures. The practice of denture marking in all teaching institutions should be initiated immediately. Further research should be carried out into improving and simplifying methods of labeling dentures. Dental associations should find more effective ways of promoting the practice of denture labeling within the dental profession and the community.

Conclusions

The patients were recalled after a month to enquire if they were facing any problems in respect to the denture or the QR codes inserted. The patients faced no such problems in respect to the denture. This study describes an easy and cost-effective technique with readily available armamentarium in any dental office or institution for denture identification. The label demonstrates no sign of deterioration withstands and is esthetic. It is biologically acceptable and fulfills all the forensic requirements of a suitable prosthesis. Denture ID linked to unique Aadhaar card system of labeling dentures. Government of India make mandatory of linking Aadhaar card in various schemes which include e.g. linking of Aadhaar card to liquid petroleum gas cylinder distribution system. Similarly, there is a need to implement this strategy by government also in the field of dental sciences in labeling prosthesis. Dental Council of India can suggest Government of India to make necessary legislations regarding compulsory denture labeling system in India.

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ORIGINAL RESEARCH

Comparative Evaluation of Different Surface Treatments on Soft Tissue Changes and Inflammatory Markers of Osseointegrated Implants: A Clinical Study

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Abstract

Purpose: The purpose of the present study was to evaluate the soft tissue changes and inflammatory markers with two different surface-treated implants.

Materials and methods: A total of 20 patients were randomly divided into two groups; group I—implants with sandblasted, large-grit, acid etched treatment (SLA) and group II—implants with SLA with superhydrophilic treatment (mSLA). Soft tissue changes [probing depth (PD), bleeding on probing (BOP)] and inflammatory marker [interleukin-6 (IL-6)] count were evaluated and compared after 16 and 24 weeks of implant placement. Paired *t*-test and unpaired *t*-test were done for intergroup and intragroup comparison.

Results: There was no effect of surface treatment on PD, BOP, and IL-1β load. There was a significant increase in PD ($p < 0.0001$) and inflammatory marker load ($p < 0.0001$) at 24 weeks when compared to 16 weeks in both implants, while BOP was not found to be significant after 24 weeks.

Conclusion: Surface treatment modification for superhydrophilicity does not influence PD and BOP as well as cytokine levels. Probing depth increased significantly after loading irrespective of implant type. Similarly, there was also a significant difference in inflammatory marker load after loading in both implant groups.. Surface treatment didn't influence soft tissue parameters and inflammatory marker load.

Keywords: Inflammatory marker, Implant surface treatment, Sandblasted, acid etched treatment implants, Soft tissue parameter, Superhydrophilic implants.

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Introduction

The success and longevity of different endosseous implant systems is influenced by various hypothesis of surface topography and prosthetic rehabilitation over a certain period of time.[1] The biocompatibility seems to be dependent on the micromorphological properties of dental implants.[1] Despite biocompatible form and shape, there have been continuous developments in implant texture in reference to surface topography, surface energy, and surface treatments.[2]

The surrounding biological environment plays a crucial role in the success of the treatment. The hard and soft tissues respond in a certain manner and undergo remodeling which is a clinical marker of implant success. Thus, it is pertinent to understand the physiologic changes that happen after an implant is positioned and later when loading is done. The difference in the surrounding environment of the implant and tooth makes the implant prosthesis more prone to inflammation and subsequent bone loss when exposed to microbial invasion due to plaque accumulation.[3,4]

Biomaterials in implants are modified on microscopic and macroscopic levels to enhance cell integration which includes plasma spraying, acid etching, blasting etc. The aim of numerous surface treatments is not only to reduce osseointegration time and provide early loading but also to reduce peri-mucositis and peri-implantitis.[5]

Acid etching and blasting with alumina particles cause roughening of the implant surface which enhances the fixation of the implant as compared to a smoother one.[6] Chemical composition and surface chemistry of the Implant is determining factor for hydrophilicity. Preliminary *in vitro* studies have stated that an increase in hydrophilicity may influence cell differentiation and growth factor production.[7–9] After acid etch treatment implant biomaterial is stored in calcium chloride in modified hydrophilic treatment (m-SLA) and storage in the solution prevents the adsorption of contaminants on the surface of the titanium implant and also increases surface energy.[7]

The outcome of biomaterial used in implants is determined by a series of events initiated by immune cells.[10] Initial response to biomaterial activates immune cells to release cytokines and chemokines. Macrophages are the first line of cells in the initial stages of inflammation by the release of cytokines (M1 or M2) and

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chemokines. M1 phenotype stimulates cell-mediated responses with the production of interleukin-1β (IL-1β), IL-6, IL-12, IL-23, tumor necrosis factor-α (TNF-α) etc. Anti-inflammatory chemokines and cytokines such as IL-10 are released by M2 phenotype.[11]

Biomarkers and enzymes in peri-implant sulcular fluid (PISF) play a vital role in early detection of per-implantitis which is found to be 1–47%.[12] Peri-implant microbial contaminations or infection elicits an immune response regulated by TNF-α, IL, transforming growth factor. Studies showed elevated levels of prostaglandin E2 (PGE2), IL-1β, platelet-derived growth factor (PDGF), alkaline phosphatase, and α2-macroglobulin in the PISF affected by peri-implantitis.[13–15]

The study has been conducted on crestal bone loss with reference to superhydrophilic surface treated implants[16] but the literature is not sufficient with human studies determining the relation of modified implant surface treatment and soft tissue response along with inflammatory markers and also the effect of loading on these parameters. In this context, the present study worked toward the comparison of soft tissue changes [probing depth (PD), bleeding on probing (BOP)] and IL-1β around endosseous implants with different surface treatments [Sandblasted, large-grit, acid etched treatment (SLA) and sandblasted, acid etched with superhydrophilic treatment (m-SLA)] measured at two different time intervals. Therefore, the null hypothesis for this study was that there was no significant difference in soft tissue changes and inflammatory markers with two different surface-treated implants.

Materials and Methods

Study Design

This was an analytical comparative study conducted in the Department of Prosthodontics, Crown & Bridge, ITS-CDSR from November 2018 to October 2020. Institutional Ethical Committee clearance was obtained before commencing this study (ITSCDSR/IIEC/2018 - 21/PROSTHO/02 on 24th October 2018). The prospective clinical study was conducted according to the principles outlined in the Helsinki Declaration. After a comprehensive medical and dental history of the patients, the intraoral examination was conducted to gauge the condition of the alveolar ridge and mucosa overlying it. Informed consent in the local language was obtained for the study.

Sample Size Estimation

Using G*Power vs 3.1., 80% power and 95% confidence interval, 5% marginal error, with a calculated effect size of 1.198. The minimum sample size was 10 per group.

Inclusion and Exclusion Criteria

Patients with a single edentulous region in the mandibular molar area with adequate mesiodistal (at least 7 mm) and buccolingual width (minimum 6 mm) measured by cone-beam computed tomography (CBCT) were included. Male patients aged between 20 and 60 years, having adequate interocclusal distance (8–12 mm) for implant placement with healed and well-rounded cortical bone and patients who do not require any additional surgical procedure were only included. The implant sites with primary stability of a minimum of 35 Ncm following surgical implant placement were included. Patients with a history of any systemic disease forewarning surgery were excluded. Patients having a history of chronic periodontitis and major risk factors such as uncontrolled diabetes, bisphosphonate therapy, and radiation therapy were also excluded.

Grouping of Samples and Protocol for Randomization

One implant per patient was placed and patients were randomly allocated into two groups. Sealed envelopes with numbering were used for the randomized distribution of patients in two groups of 10 each:

- Group I—implants with surface treated with SLA (Adin Touareg-S, Adin Implant System Ltd., Tel Aviv-Yafo, Israel).
- Group II—implants with surface treated with m-SLA (Cowell–INNO, Cowell Medi Implant System, Busan, Korea).

Surgical Procedure

Adequate dimensions were determined by CBCT prior to planning of implant insertion. Diagnostic impressions were made of both arches with impression material (Algitex, DPI) and a surgical guide was fabricated for accurate implant placement. The standard surgical protocol was followed for the placement of implants in the mandibular first molar region (4.2 mm in diameter and 10–11.5 mm in length). Strict asepsis was maintained during the surgery. A pilot drill followed by sequential osteotomy was done as instructed by the manufacturer for the insertion of both implants. In "group I" patients SLA and in "group II" patients, m-SLA implants were inserted. Implant insertion was done by the same operator.

Only those implants, that achieve primary stability (minimum 35 Ncm) assessed using a calibrated torque wrench were included in the study. Stage two surgery was performed after implant osseointegration for healing abutments (torque of 20 Ncm) for 7–10 days. For both groups, an implant-level impression was obtained and porcelain fused to metal crowns was fabricated and cemented using the manufacturer's guidelines with an implant-protected occlusion scheme.

Clinical Evaluation of Soft Tissues

Soft tissue was evaluated by measuring PD and BOP.[17] Probing was done on the implant site as well as a tooth from the adjacent tooth which served as a control.

The PD was measured as the distance from the mucosal (or gingival) margin to the bottom of the sulcus/pocket using a manual pressure-sensitive probe (CP-12; Hu-Friedy, Chicago, Illinois, United States) with a force of about 0.2 N at six aspects for each dental implant/tooth (mesiobuccal, midbuccal, distobuccal, mesiolingual, midlingual, and distolingual). PDs were recorded after 16 and 24 weeks after implant placement. BOP had been recorded as positive (BOP+) when bleeding of the peri-implant mucosa (or gingiva) had been detected at the implant (tooth) site after bleeding emerged within 30 seconds after probing (gingival sulcus bleeding index).[18] BOP was recorded along with PD at 16 and 24 weeks after implant placement (Fig. 1).

Evaluation of Inflammatory Markers using Enzyme-linked Immunosorbent Assay Kit

Gingival crevicular fluid (GCF) samples and peri-implant crevicular fluid (PICF) samples were collected by using a calibrated micropipette (sciences polypropylene micropipette tips 100–1000 µL, Lucknow, India). Crevicular fluid samples were obtained at 16 and 24 weeks after the implant placement (Fig. 2). GCF was taken as a control from the adjacent tooth for IL-1β.

After fluid isolation, a pipette was inserted into the gingival sulcus, just below the free gingival margin of the implant and a tooth adjacent to the implant location as a control. Samples were obtained from different locations within the gingival sulcus. Any samples with visible blood contamination with blood or saliva were discarded. All samples collected were immediately transferred to a –20°C freezer for storage (Elanpro, Gurugram, India).

Inflammatory marker was evaluated with the help of ELISA Kit (Diaclone, Medix biochemical, Besançon Cedex, France) (Fig. 3). Around 1 µL sample of PICF was diluted into 100 µL phosphate-buffered saline before readings were taken for IL-1β inflammatory marker.[18]

Fig. 1: Evaluation of PD and BOP around implants

Fig. 2: Collection of PICF with micropipette

Statistical Analysis

The data was entered in Microsoft Excel format and was analyzed using Statistical Package for the Social Sciences software (SPSS) (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, version 21.0. Armonk, New York: IBM Corp.). The continuous data was represented as mean ± standard deviation. The statistical technique applied was a paired *t*-test to evaluate the change from baseline to follow-up within the same group. Intergroup comparison was analyzed using an unpaired *t*-test to compare the mean of measurements. The *p*-value < 0.05 is considered as significant.

Results

The mean age of patients was 35.16 ± 4.25 years, with 12 males and eight females. There were no dropouts in the present study.

Probing Depth and BOP Evaluation

On comparison of PD around implants between both groups, no statistically significant difference between both groups at 16 and 24 weeks using an independent *t*-test as $p > 0.05$ (Table 1). On intragroup comparison within group I implants and group II implants, a significant increase was found in PD at 16 and 24 weeks by paired *t*-test ($p > 0.05$) (Tables 2 and 3).

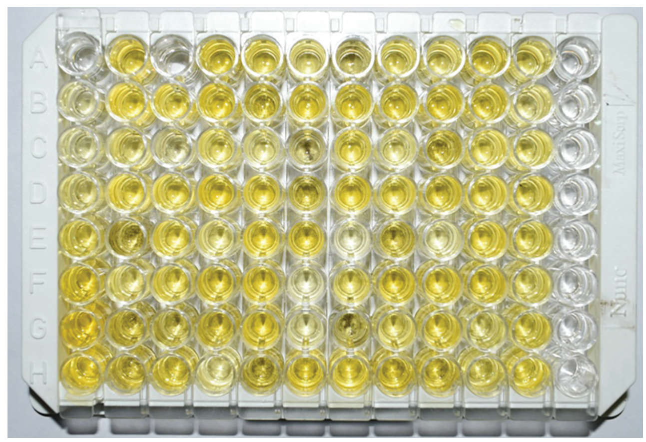

Fig. 3: Inflammatory marker IL-1β assessment using ELISA kit

Table 1: Intergroup comparison of PD (mm) around implants

			PD at 16 weeks			*PD at 24 weeks*		
Site			*Mean*	*Standar deviation*	*p-value*	*Mean difference*	*Standard deviation*	*p-value*
Buccal	Mesial	Group I	1.100	0.316	1.000	2.300	0.483	0.288
		Group II	1.100	0.316		2.100	0.316	
	Middle	Group I	1.300	0.483	0.196	2.500	0.527	0.054
		Group II	1.600	0.516		2.900	0.316	
	Distal	Group I	1.100	0.316	0.288	2.400	0.516	0.673
		Group II	1.300	0.483		2.500	0.527	
Lingual	Mesial	Group I	1.000	0.000	0.331	2.000	0.000	0.65
		Group II	1.100	0.316		2.300	0.483	
	Middle	Group I	1.300	0.483	0.660	2.200	0.421	0.177
		Group II	1.400	0.516		2.500	0.527	
	Distal	Group I	1.100	0.316	0.288	2.000	0.000	0.65
		Group II	1.300	0.483		2.300	0.483	

Independent *t*-test; level of significance set at $p < 0.05$

On comparison of BOP around the implant, two studied implant groups showed nonsignificant differences at different study sites and time intervals when compared using the independent *t*-test as $p < 0.05$ (Table 4). On intragroup comparison of BOP in groups I and II implants, around adjacent teeth for implants, there was no significant difference between 16 and 24 weeks (Tables 5 and 6).

Inflammatory Marker Evaluation

Inflammatory markers around implants and adjacent teeth in both groups of implants showed nonsignificant difference (Table 7) however, there was a significant rise in marker load after 24 weeks when compared to 16 weeks in both groups ($p < 0.05$) (Tables 8 and 9).

Discussion

The analytical clinical study was conducted on 20 patients rehabilitated with implants in the mandibular molar region. Group I constituted 10 patients who were provided with an implant that was sandblasted and acid-etched on the surface, while group II patients constituted of superhydrophilic implants that were sandblasted, acid-etched and subjected to neutralization solution and nano calcium phosphate (Nano/CaP) treatment. This treatment reduces the contact angle, increases osteoblast activity and enhances protein deposition to the surface. Also, it has been proved in a retrospective study that superhydrophilic implants exhibited a high survival rate and were not influenced by many factors.[19]

In the absence of previous clinical and radiographic data, bleeding/suppuration on probing and sulcular width >6 mm can be prognosticators of peri-implant health detriment,[20] and in the present study, the sulcular depth was <6 mm for both types of implants. It was also concluded in one of the studies that there are multiple variables specific to the implant site and implant positioning that may affect the BOP,[21] so to standardize the site-specific implants for the first mandibular molar was inserted by a single operator. In the present study null hypothesis was accepted as there was an insignificant difference in PD, BOP, and IL-1β load when compared between both implant groups. In the current study, there was a significant difference in PD after loading which was contrary to study conducted by Rahman et al.[22] The reason may be that in that study the PD was measured after 3 months of loading but in the present study it was evaluated just after loading.

Table 2: Intragroup comparison of PD (mm) in group I around implants after 16 weeks (before loading) and 24 weeks (after loading)

Site			*Mean*	*Standard deviation*	*Standard error mean*	*Mean difference*	*Standard deviation*	*p-value*
Buccal	Mesial	16 weeks	1.100	0.316	0.100	−1.200	0.632	<0.0001*
		24 weeks	2.300	0.483	0.152			
	Middle	16 weeks	1.300	0.483	0.152	−1.200	0.788	<0.0001*
		24 weeks	2.500	0.527	0.166			
	Distal	16 weeks	1.100	0.316	0.100	−1.300	0.483	<0.0001*
		24 weeks	2.400	0.516	0.163			
Lingual	Mesial	16 weeks	1.000	0.000	0.000	1.00	0.000	<0.0001*
		24 weeks	2.00	0.000	0.000			
	Middle	16 weeks	1.300	0.483	0.152	−0.900	0.737	<0.0001*
		24 weeks	2.200	0.421	0.133			
	Distal	16 weeks	1.100	0.316	0.100	−0.900	0.316	<0.0001*
		24 weeks	2.000	0.000	0.000			

*$p < 0.05$ is significant; paired *t*-test

Table 3: Intragroup comparison of PD in group II around implants after 16 weeks (before loading) and 24 weeks (after loading)

Site			*Mean*	*Standard deviation*	*Standard error mean*	*Mean difference*	*Standard deviation*	*p-value*
Buccal	Mesial	16 weeks	1.100	0.316	0.100	−1.000	0.471	<0.0001*
		24 weeks	2.100	0.316	0.100			
	Middle	16 weeks	1.600	0.516	0.163	−1.300	0.483	<0.0001*
		24 weeks	2.900	0.316	0.100			
	Distal	16 weeks	1.300	0.483	0.152	−1.200	0.788	<0.0001*
		24 weeks	2.500	0.527	0.166			
Lingual	Mesial	16 weeks	1.100	0.316	0.100	−1.400	0.516	<0.0001*
		24 weeks	2.50	0.527	0.167			
	Middle	16 weeks	1.400	0.516	0.163	−1.100	0.737	<0.0001*
		24 weeks	2.500	0.527	0.166			
	Distal	16 weeks	1.300	0.483	0.152	−1.00	0.66	<0.0001*
		24 weeks	2.300	0.483	0.152			

*$p < 0.05$ is significant; paired *t*-test

Table 4: Intergroup comparison of BOP around implants after 16 weeks (before loading) and 24 weeks (after loading)

			16 weeks			*24 weeks*		
Site			*Mean*	*Standard deviation*	*p-value*	*Mean difference*	*Standard deviation*	*p-value*
Buccal	Mesial	Group I	0.100	0.316	0.331	0.000	0.000[a]	–
		Group II	0.000	0.000		0.000	0.000[a]	
	Middle	Group I	0.400	0.516	0.398	0.400	0.516	0.673
		Group II	0.600	0.516		0.500	0.527	
	Distal	Group I	0.200	0.421	1.000	0.100	0.316	0.343
		Group II	0.200	0.421		0.000	0.000	
Lingual	Mesial	Group I	0.000	0.000	0.331	0.100	0.316	0.331
		Group II	0.100	0.316		0.000	0.000	
	Middle	Group I	0.500	0.527	0.388	0.500	0.527	0.673
		Group II	0.300	0.483		0.400	0.516	
	Distal	Group I	0.300	0.483	0.628	0.000	0.000	0.331
		Group II	0.100	0.316		0.100	0.316	

Independent *t*-test; level of significance set at $p < 0.05$

Table 5: Intragroup comparison of BOP in group I around implants after 16 weeks (before loading) and 24 weeks (after loading)

Site			*Mean*	*Standard deviation*	*Standard error mean*	*Mean difference*	*Standard deviation*	*p-value*
Buccal	Mesial	16 weeks	0.100	0.316	0.100	0.100	0.316	0.343
		24 weeks	0.000	0.000	0.000			
	Middle	16 weeks	0.400	0.516	0.163	–	–	–
		24 weeks	0.400	0.510	0.163			
	Distal	16 weeks	0.200	0.421	0.133	0.100	0.316	0.343
		24 weeks	0.100	0.316	0.100			
Lingual	Mesial	16 weeks	0.000	0.000	0.000	–0.100	0.316	0.343
		24 weeks	0.100	0.316	0.100			
	Middle	16 weeks	0.500	0.527	0.166	–	–	–
		24 weeks	0.500	0.527	0.166			
	Distal	16 weeks	0.300	0.483	0.152	0.300	0.483	0.081
		24 weeks	0.000	0.000	0.000			

Paired *t*-test; level of significance set at $p < 0.05$

Table 6: Intragroup comparison of BOP in group II around implants after 16 weeks (before loading) and 24 weeks (after loading)

Site			*Mean*	*Standard deviation*	*Standard error mean*	*Mean difference*	*Standard deviation*	*p-value*
Buccal	Mesial	16 weeks	0.000[b]	0.000	0.000	–	–	–
		24 weeks	0.000[b]	0.000	0.000			
	Middle	16 weeks	0.600	0.516	0.163	0.100	0.316	0.343
		24 weeks	0.500	0.527	0.166			
	Distal	16 weeks	0.200	0.421	0.133	0.200	0.421	0.168
		24 weeks	0.000	0.000	0.000			
Lingual	Mesial	16 weeks	0.100	0.316	0.100	0.100	0.316	0.343
		24 weeks	0.000	0.000	0.000			
	Middle	16 weeks	0.300	0.483	0.152	–0.100	0.316	0.343
		24 weeks	0.400	0.516	0.163			
	Distal	16 weeks	0.200	0.421	0.133	0.100	0.316	0.343
		24 weeks	0.100	0.316	0.100			

Paired *t*-test; level of significance set at $p < 0.05$

The BOP is a reliable indicator to identify inflammation circumambient to the implant, so in the current study, BOP is also evaluated along with PD to determine the peri-implant health status. Jepsen et al.[23] identified BOP as the measure to clinically apprise peri-implant health and peri-implant disease, while Lang et al.[24] and Heitz-Mayfield[25] described BOP being an immutable

Table 7: Intergroup comparison of IL-1β (pg/μL) after 16 weeks and 24 weeks

Duration	*Groups*	*Mean difference*	*Standard deviation*	*Standard error mean*	*p-value*
16 weeks (teeth)	Group I	50.35	6.333	1.909	0.894
	Group II	50.02	3.647	1.216	
16weeks (implant)	Group I	34.64	9.024	2.721	0.897
	Group II	33.78	6.878	2.293	
24 weeks (teeth)	Group I	50.45	2.757	0.831	0.732
	Group II	49.74	6.090	2.030	
24 weeks (implant)	Group I	85.04	6.789	2.047	0.867
	Group II	85.69	6.136	2.045	

Independent *t*-test; level of significance set at $p < 0.05$

Table 8: Intragroup comparison of IL-1β (pg/μL) for group I around implants and teeth after 16 weeks (before loading) and 24 weeks (after loading)

Duration		*Mean*	*Standard deviation*	*Standard error mean*	*Mean difference*	*Standard deviation*	*p-value*
Teeth	16 weeks	50.35	6.333	1.909	–0.109	5.294	0.947
	24 weeks	50.45	2.757	0.831			
Group I implants	16 weeks	34.64	9.024	2.721	–50.400	12.589	<0.0001*
	24 weeks	85.04	6.789	2.047			

*$p < 0.05$ is significant; paired t-test

Table 9: Intragroup comparison of IL-1β (pg/μL) for group II around implants and teeth after 16 weeks and 24 weeks

Duration		*Mean*	*Standard deviation*	*Standard error mean*	*Mean difference*	*Standard deviation*	*p-value*
Teeth	16 weeks	50.02	3.647	1.216	0.278	7.346	0.912
	24 weeks	49.74	6.090	2.030			
Group II implants	16 weeks	33.78	6.878	2.293	–51.911	7.128	<0.0001*
	24 weeks	85.69	6.136	2.045			

*$p < 0.05$ is significant; paired t-testt

diagnosticate of peri-implant mucositis and peri-implantitis. In a study by Bielemann et al.,[26] narrow-diameter implants with hydrophobic and modified surface-treated implants were compared for BOP and PD and found no significant difference between the two which was similar to our study. There was a significant increase found in PD at 24 weeks within each implant group when compared to 16 weeks, the reason may be due to occlusal load.[27]

In the present study, IL-1β was evaluated in PICF because a confluence of radiographic evidence and biomarkers may help in prognostication of implant success and peri-implantitis. Kao et al.[28] reported that PISF IL-1β levels were significantly higher around diseased implants than those around stable implants, thus providing scientific evidence that this cytokine is involved in catabolic activity in peri-implant bone destruction. Another advantage of analyzing PICF is its noninvasive nature and repeatability. It has also been concluded in a previous study that PICF is similar to gingival crevicular fluid (GCF) in depicting the periodontal status of an implant.[29]

Hotchkiss et al.[30] conducted a study and found that surface roughness and increased wettability have synergistic action on Anti-inflammatory activity. The results were contrary to the current study as there was an insignificant difference in both groups of implants. The reason may be that the aforementioned study was conducted on animals, not on human beings.

The finding of this study indicated that there was a rise in PICF IL-1β levels between the 16 and 24-week intervals which were highly significant. The presence of PICF IL-1β after 16 weeks may cause minimal peri-implant mucosal irritation as compared to 24 weeks at which the implant was prosthetically loaded and this justifies the greater load of marker at 24 weeks. This also signifies that even immediately after loading there was some form of inapparent inflammation around the implants which was detected by the biomarker.

Nevertheless, both the 16 and 24 weeks values of IL-1β in PISF were well within the range of healthy implants as seen by Ataoglu et al.[31] and Murata et al.[32] Hence, the findings suggest that IL-1β can be a useful concomitant diagnostic marker for gauging the peri-implant health status at an early stage.

Since the study was a pilot study conducted for only 20 patients and only 24 weeks of follow-up records were taken into consideration, future clinical trials with larger sample sizes and longer follow-ups may be planned to reach a conclusive decision.

Conclusion

Within the limitations of the study, it was concluded that surface treatment modification for superhydrophilicity does not influence PD and BOP as well as cytokine level. PD increased significantly after loading irrespective of implant type. Similarly, there was also a significant difference in inflammatory marker load after loading in both implant groups but there was an insignificant difference in inflammatory markers in different surface-treated implants.

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Research

A comparative evaluation of marginal fit and microleakage of computer-aided design/computer-aided manufacturing-milled zirconia and prefabricated posterior occlusal veneers: An *in vitro* study

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Abstract

Aims: The aim of this study was to compare the marginal fit of prefabricated occlusal veneers with computer-aided design/computer-aided manufacturing (CAD-CAM)-milled zirconia occlusal veneers in the posterior teeth.

Settings and Design: Forty extracted human maxillary premolars were divided into two groups of 20 each. Group 1 was prepared to receive prefabricated occlusal veneers, and Group 2 was prepared to receive CAD-CAM-milled zirconia occlusal veneers.

Materials and Methods: Prefabricated samples (Edelweiss) were selected for Group 1, whereas for Group 2, the tooth preparations were scanned, and occlusal veneers were fabricated using Exocad designing software and milling machine. After luting, both the groups were submerged in dye, sectioned, and evaluated for marginal fit and microleakage under a stereomicroscope using the microscope imaging software and its measurement tool.

Statistical Analysis Used: Data collected were subjected to statistical analysis using SPSS 27.0. Intragroup and intergroup comparison was done using the Mann–Whitney *U* test. The Chi-square test was applied to check the depth of penetration of dye based on percentages.

Results: The marginal gap of zirconia occlusal veneers fabricated with CAD-CAM is higher compared to that of prefabricated occlusal veneers. Similarly, the depth of penetration of dye is higher in CAD-CAM-milled zirconia occlusal veneers than prefabricated occlusal veneers.

Conclusion: The marginal fit of prefabricated occlusal veneer is better than the marginal fit of zirconia occlusal veneers fabricated with CAD-CAM. Similarly, it can also be concluded that the microleakage of prefabricated occlusal veneer is less compared to the CAD-CAM-milled zirconia occlusal veneers.

Keywords: Computer-aided design/computer-aided manufacturing, composite, marginal fit, microleakage, posterior occlusal veneer, prefabricated occlusal veneers, zirconia

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INTRODUCTION

Tooth wear is a multifactorial and complex problem that leads to localized or generalized loss of tooth structure. Local or general loss of tooth structure can be caused by several reasons. Erosion, abrasion, abfraction, and attrition are related to mechanical, chemical, and physiological factors or a combination of two or more factors. Occlusal tooth wear (attrition) is a long-term physiological defect or a very aggressive pathological lesion requiring consultation, monitoring, or intervention in severe cases. Restoring functional occlusal relationships and esthetics in a completely worn out dentition requires a full-mouth rehabilitation and increasing the vertical dimension of occlusion, which is a complex multiphase treatment.[1] In this case, a prosthesis with a full crown may be suitable, but, unfortunately, this procedure requires a more thorough preparation of the already affected dentition. Scientific studies have been conducted to solve this problem using a minimally invasive approach. Minimally invasive technique refers to the least possible tooth reduction to serve the purpose of treatment. G J Mount and RW Hume introduced minimally invasive dentistry; however, Rochette first described a minimal tooth preparation technique in anterior teeth. Resin composites are the most commonly used restorative material for minimally invasive preparation. Minimally invasive preparation is contraindicated in grossly decayed teeth and teeth with Pulp involvement. It is indicated in cases with occlusal wear or superficial decay and in cases where there is sufficient tooth structure present. It is time saving and less cumbersome. Restoration of worn teeth with occlusal veneers can be relatively noninvasive and requires little tooth reduction. The prefabricated occlusal veneers used in the study are manufactured by Edelweiss. Prefabricated occlusal veneers are laser-sintered nanohybrid composite shells which are luted to the tooth structure using nanohybrid flowable composite. These are readily available shells which need to be adjusted and can be directly luted to the tooth with minimal or no preparation of the tooth structure. The prefabricated occlusal veneers reduce the number of appointments hence reduce the overall treatment time. The prefabricated occlusal veneers are based on a size guide which is fabricated as small, medium, and large based on a study on variations of size and shape of teeth in population. There are not many studies available on the long-term usage of this material.

Marginal fit and microleakage is one of the important factors determining the success of a restoration. In addition, sufficient research studies are not available on the comparative evaluation of marginal fit and microleakage among the prefabricated posterior occlusal veneer and computer-aided design/computer-aided manufacturing (CAD-CAM)-milled zirconia occlusal veneers. Hence, this *in vitro* study was done to make a comparative assessment of marginal fit and microleakage between prefabricated occlusal veneers with zirconia occlusal veneers milled with CAD-CAM technology.

MATERIALS AND METHODS

Forty extracted human maxillary premolars (first and second) were collected and stored in the preserving media (normal saline). Samples were prepared by cutting the roots of the extracted teeth to fit them into the Typodont jaw set. Tooth preparations were done with an high speed hand-piece (API, Ashoosons, New Delhi) using tapered fissure bur (straight and round end) (SS White, New Jersey) (TF-12 173/016, TR-12 ISO 199/016 and ISO 856/012) to get a rounded shoulder margin [Figure 1]. Occlusal prep gauge (MIK Dental, Mumbai) based on the Feeler gauge concept was used to ensure standardization of tooth preparation by maintaining 1 mm reduction interproximally for minimal reduction. Ethical Committee approval number Ref. no.: IDST/IEC/2020-23/29 and dated on 18/01/2021.

These samples were randomly divided into two groups of 20.

- Group 1 – Twenty extracted prepared maxillary first and second premolar teeth for prefabricated nanohybrid laser-sintered composite occlusal veneer
- Group 2 – Twenty extracted prepared maxillary first and second premolar teeth for fabrication of CAD/CAM-milled zirconia occlusal veneers.

For the fabrication of Group 1 samples, the prefabricated occlusal veneers were selected using the size guide (S, M, and L based on the natural tooth morphology) and adjusted to the occlusal surface of the extracted tooth. For the fabrication of Group 2 samples, the prepared extracted premolar was placed in 15 positions and scanned in the sequence maxillary, mandibular, and bite using the intraoral scanner (3 Shape, Denmark) [Figure 2].

The scanned files were sent to the CAD software after converting into STL (stereolithography) format. CAD software (Exocad, Germany) was used for the designing of occlusal veneers. The CAD software datasets were converted into a milling sequence using CAM (VHF, Germany) and finally loaded into a 5-axis milling machine (VHF S1, Germany) to mill a part out of the zirconia blank (API Ashoosons, DELHI) using the subtractive manufacturing. The CAD-CAM-milled zirconia occlusal veneers in the presintered state were carefully retrieved from the zirconia blank. The excess powder on the milled occlusal veneers was cleaned with a brush. A layer of stain (A2 shade) was applied by dipping the occlusal veneer in the staining liquid. The excess stain was removed by drying with a tissue paper. The dried occlusal veneers are placed on the ceramic beads in the sintering unit (TAEBO1/M/ZIRKON-100, USA) at 1500°C for 12 h (overnight). Glazing liquid (Ivoclar Vivadent, USA) was applied on the occlusal veneers, and glazing was done in the glazing unit (VITA Zahnfabrik VACUMAT 40T, Germany) at an initial temperature of 500°C for 4 min gradually reaching the highest temperature of 940°C and finally maintaining the temperature at 600°C for 1 min.

Cementation

Group 1 – Cementation of the prefabricated occlusal veneers was done with veneer luting cement as it does not bond with other luting agents (nanohybrid composite, Edelweiss, Austria).

Group 2 – Cementation of CAD/CAM-milled zirconia occlusal veneers was done by dual cure resin-based luting cement since composite cannot be used to lute zirconia veneers (Prevest DenPro, USA).

Samples were then submerged in methylene blue solution for 24 h. The sectioning of these samples was done by the diamond cutting saw (18 mm) at the maximum width in the labiolingual direction. The tooth was stabilized in the Typodont.

Testing protocol

The sectioned samples were studied under the stereomicroscope (Model No. CD500A, trinocular zoom microscope) at ×45 magnification for the evaluation of marginal fit and microleakage [Figure 3]. The measurement tool is set at the designated calibration of micrometer and millimeter for microleakage and marginal fit, respectively. The set calibration was then used in the line form to determine the depth of penetration and gap in the image taken by the software.

1. Microleakage – It was evaluated by two methods:
   i. Using the microscope imaging software and its measurement tool
   ii. Calculating the penetration depth of dye using microscope imaging software.

The depth of penetration of dye was observed as follows

- 0 = Dye does not penetrate
- 1 = Dye penetration is limited to the outer half surface of the axial wall
- 2 = Dye penetration is limited to the inner half surface of the axial wall
- 3 = Penetration of the dye into the pulpal wall
- 4 = Penetration of the dye beyond the pulpal wall.

2. Marginal fit

The gap between the prosthesis and the tooth surface at the margin was measured to determine the marginal fit using

Figure 1: Armamentarium

Figure 2: Prepared maxillary premolar mounted on the Typodont jaw set

Figure 3: Sectioned samples

the microscope imaging software and its measurement tool [Figure 4].

RESULTS

This *in vitro* study was conducted in the department of prosthodontics and crown and bridge to evaluate the marginal fit and microleakage of prefabricated occlusal veneers with CAD-CAM-milled zirconia occlusal veneers. The marginal fit of samples was evaluated using a stereomicroscope using microscope imaging software. Microleakage of samples was evaluated using a stereomicroscope using microscope imaging software and depth of penetration of dye.

The data obtained were compiled and subjected to statistical analysis using the software, namely the Statistical Package for the Social Science (SPSS) 27.0 (IBM, Chicago, IL, USA). The measured mean value of marginal fit of Group 1 samples was 75.70 ± 10.38420 and for Group 2 was 121.64 ± 3.50074. The measured mean value for microleakage for Group 1 was 0.5497 ± 0.11089 and for Group 2 was 0.7572 ± 0.16036.

An intragroup comparison was done using the Mann–Whitney *U* test. With respect to Group 1, the mean microleakage was (i.e., 0.5497 ± 0.110) significantly lesser than the mean microleakage of Group 2 (0.7572 ± 0.160).

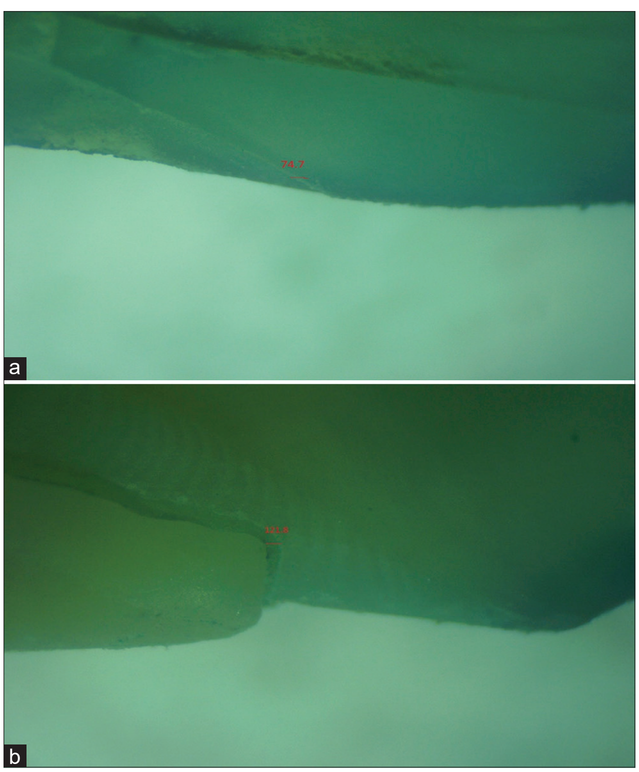


Figure 4: Pictomicrograph – (a) Prefabricated occlusal veneer. (b) Zirconia occlusal veneer

Nonparametric statistics suggests a z value of −3.774 with a highly significant *P* = 0.000. Similar to the above results, data analysis for marginal fit suggests a higher mean ± standard deviation of Group 2 than Group 1 with the value depicted as 121.64 ± 3.5 and 75.70 ± 10.38, respectively. Nonparametric statistics suggests a z value of −5.410 with a highly significant *P* = 0.00.

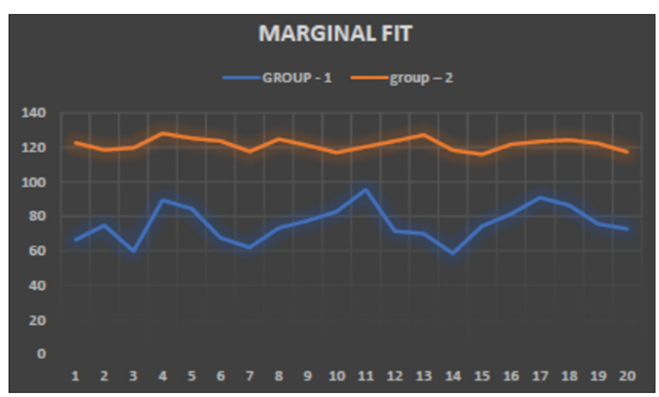
Among Group 1 samples, the depth of penetration of dye on a percentage basis indicated that three samples corresponded to the depth of penetration level 0, i.e., 15% of the total samples; five samples corresponded to level 1, i.e., 25% of total samples; four samples corresponded to level 2, i.e., 20%; five samples corresponded to level 3, i.e., 25%; and three samples corresponded to level 4, i.e., 15% [Graph 1].

Among Group 2 samples, the depth of penetration of dye on a percentage basis indicated that two samples corresponded to the depth of penetration level 0, i.e., 10% of all the samples; two samples corresponded to level 1, i.e., 10% of all samples; five samples corresponded to level 2, i.e., 25%; six samples corresponded to level 3, i.e., 30%; and five samples corresponded to level 4, i.e., 25% [Graph 2].

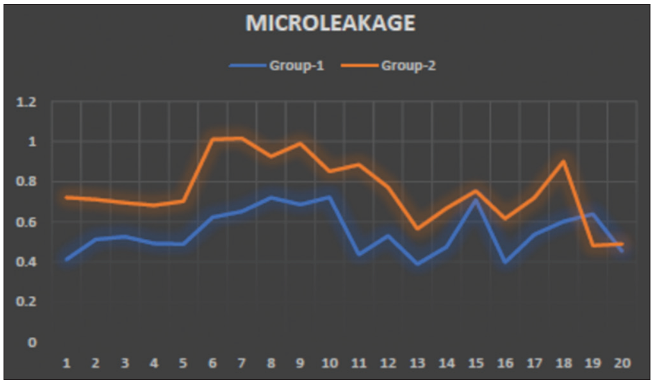
The Chi-square test was applied to check the penetration depth of dye based on percentages. It was found that the *P* value for intergroup comparison was 0.910 and 0.478 for Group 1 and Group 2, respectively [Graph 3]. Hence, the difference among these groups was not significant.

DISCUSSION

The nanohybrid composite prefabricated occlusal veneer is more hassle free. They are readily available and can be



Graph 1: Marginal fit quantitative comparison between Group 1 and Group 2



Graph 2: Microleakage quantitative comparison between Group 1 and Group 2

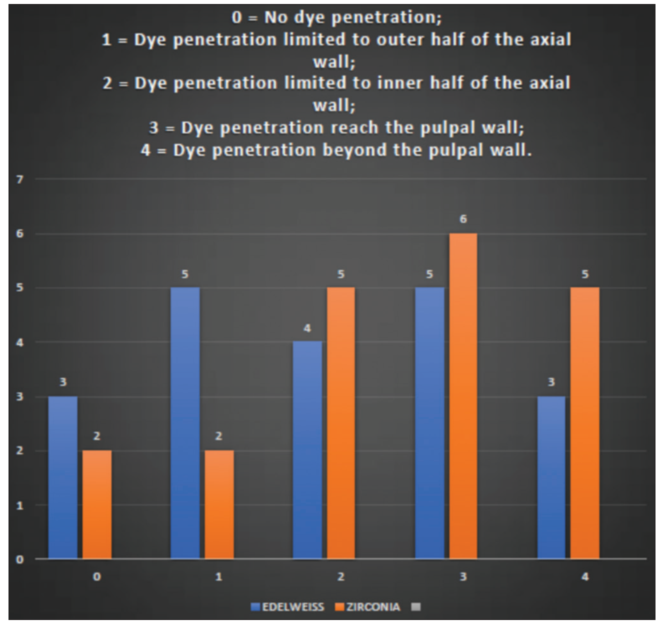
used with only minor adjustments of the shell and even without the requirement of tooth preparation. Unlike zirconia crown delivery, it does not even require multiple appointments.

The use of nanohybrid composite prefabricated occlusal veneer in the current study gives us affirming results based on Abdulrahman,[2] who stated that nanohybrid composites show a better marginal adaptation due to less polymerization shrinkage and hence show a lower level of microleakage. Hence, they are expected to have a better fit and longevity.

A mean marginal gap within 125 µm was observed in the current study. McLean and Fraunhofer[3] recommended a marginal gap and cement thickness of 125 µm for successful restorations after an estimate of 1000 crowns after 5 years of practice.

While designing the CAD-CAM-milled occlusal veneer, a 50 µm spacer thickness was used in this study. The same spacer thickness was recommended by Souza *et al.*[4] evaluated the marginal and internal discrepancies associated with the margin design of ceramic crowns manufactured using a CAD-CAM system and found that the consensus for an acceptable marginal fit difference was defined as a range of 50–150 µm. On the other hand, keeping the cement thickness as small as possible helps to improve the achievement of correct placement of the prosthetic component and enable the placement of an even layer of cement between values 25 and 50 µm on an average.

The present study showed a comparatively higher marginal gap in the zirconia occlusal veneers which could be present because the nonsintered zirconia blank was used, leading to shrinkage during sintering [Table 1]. As per Prasad and Al-Kheraif,[5] differences in marginal discrepancy values recorded in the KaVo Everest fully, partially



Graph 3: Depth of penetration of dye

Table 1: Marginal fit values of Group 1 and Group 2 samples

Marginal fit (µm)	
Group - 1	Group - 2
66.3	122.6
74.7	118.5
59.8	119.7
89.4	128.1
84.5	125.3
67.5	123.6
61.9	117.6
73.2	124.8
77.5	121.1
82.8	116.9
95.4	120.4
71.4	123.7
69.9	127.2
58.5	118.3
74.3	115.9
81.3	121.8
90.9	123.4
86.4	124.3
75.6	122.3
72.7	117.3

sintered and nonsintered blanks were not significant. Many manufacturers recommend milling of zirconia in presintered blanks, although sintering shrinkage can adversely affect the accuracy of fit, however, to date, there is limited evidence that milling fully sintered zirconia blanks provides superior marginal fit.[5] Moreover, replacement software features are available today to avoid such problems. According to the results of this study, the CAD virtual spacing was effective in providing adequate space for cement.

Although sample sectioning and stereomicroscope evaluation, as is done in our research, have been used for years to evaluate the marginal fit and microleakage for restorations, it should be noticed that these approaches are destructive methods that can be performed on a limited number of tooth sections and sectioning inevitably involves some loss of information; in addition, the cutting procedures are time-consuming and prevent further use of samples. Other techniques to evaluate marginal fit that are present in the literature include direct-view technique with a stereomicroscope or optical microscope, the three-dimensional laser scanner, the cross-sectioning technique, the weight technique, the impression replica technique, and computerized X-ray microtomography.

The results achieved in the present *in vitro* study were consistent with Jia *et al*.[6] who evaluated the microleakage using the dye penetration method. It was concluded, the use of composite veneers showed better results compared to cemented porcelain veneers. All the tested samples showed microleakage values within the clinically acceptable values.

The microleakage values in resin-based luting cement are comparatively more than that of the bonded resin samples [Table 2]. Similar results were quoted by Khudair and Alnajjar.[7] They stated it was possible because of the inability of the dual-cure, self-adhesive resin-based luting cement to remove the smear layer surrounding the surface of the enamel. This may also be due to the high viscosity of the self-adhesive cement after mixing it, which may prevent it from flowing and dispersing the acid monomers. All these factors can lead to an imperfect shape of the microscopic pores formed on the enamel surface, which limits the penetration of monomers into the hybrid layer and the formation of microscopic voids between the adhesive cement and the enamel surface where it is important. An inconspicuous gap also can cause outflow of liuid causing bond breakage and hence microleakage.

Table 2: Microleakage values based on measurement as well as depth of penetration of dye for Group 1 and Group 2 samples

Microleakage (mm)			
Group 1 Penetration depth of dye		Group 2 Penetration depth of dye	
Depth (mm)	Score	Depth (mm)	Score
0.412	0	0.721	2
0.511	2	0.711	2
0.525	2	0.695	1
0.492	1	0.682	1
0.489	1	0.702	2
0.622	3	1.010	4
0.651	3	1.015	4
0.719	4	0.925	3
0.686	3	0.989	3
0.722	4	0.851	3
0.437	1	0.884	3
0.530	2	0.771	2
0.389	0	0.564	2
0.475	1	0.667	3
0.709	4	0.753	4
0.397	0	0.615	3
0.536	2	0.719	4
0.601	3	0.900	4
0.638	3	0.481	0
0.453	1	0.490	0

The current study shows a better marginal fit in the prefabricated composite occlusal veneers in comparison with the CAD-CAM-milled zirconia occlusal veneers. This is probably because of the better adaptation of composite to the tooth structure as a result of the compaction technique. Furthermore, improper management of luting cement in case of zirconia occlusal veneers can also result in increased marginal inaccuracy. Occlusal veneer bonded to dentin with filling composite demonstrated superior marginal and internal adaptation than bonded to dentin with prepared cavity and bonded to dentin. Hybrid ceramic restoration exhibited superior marginal and internal adaptation than zirconia and lithium disilicate restoration.

After evaluating the marginal gap for both the groups using stereomicroscope and microscope imaging software in the present investigation, it was observed that the marginal gap was greater for Group 2, i.e. CAD-CAM-milled zirconia occlusal veneer than Group 1, i.e., prefabricated occlusal veneer. It was also observed that microleakage was higher in CAD-CAM-milled zirconia occlusal veneers as compared to the prefabricated occlusal veneer samples.

Due to the reduced sample size, the current study's conclusions are limited. The present study was conducted in a laboratory setup. Hence, the clinical outcome of the same might vary. Further investigations including a larger sample size and clinical study should be done in future to advocate the significance of the conclusion concerning the better marginal adaptability of prefabricated occlusal veneers.

CONCLUSION

Within the scope of this study, the following observations were made:

1. The overall average marginal gap of prefabricated occlusal veneers (75.70 μm) was found to be lesser than the average marginal gap of CAD-CAM-milled occlusal veneers (121.64 μm) [Table 3]
2. The microleakage results were also similar with prefabricated occlusal veneers showing a lesser

Table 3: Intragroup and intragroup comparison of microleakage and marginal gap

	n	Mean±SD		*P* value of intergroup comparison
		Group 1 - Edelweiss	Group 2 - Zirconia	
Microleakage	20	0.5497±0.11089	0.7572±0.16036	0.000
Marginal gap	20	75.70±10.38420	121.64±3.50074	0.00
P value of intragroup comparison		<0.001, significant	<0.001, significant	

SD: Standard deviation

microleakage (0.5497) than the CAD-CAM milled zirconia occlusal veneers (0.7572)

3. The overall mean marginal gap of prefabricated occlusal veneers and CAD-CAM-milled zirconia occlusal veneers falls under the clinically acceptable values.

Henceforth, it can be concluded that the marginal fit of prefabricated occlusal veneer is better than the marginal fit of zirconia occlusal veneers fabricated with CAD-CAM. Similarly, it can also be concluded that the microleakage of prefabricated occlusal veneer is less in comparison with the CAD-CAM-milled zirconia occlusal veneers.

Clinical significance

Since the marginal fit of both the groups the prefabricated occlusal veneers and CAD-CAM-milled zirconia veneers fall under clinically acceptable values, they can be successfully used as a material of choice for fabrication of minimally invasive tabletop prosthesis. The marginal fit of prefabricated occlusal veneer is better than the CAD-CAM-milled zirconia occlusal veneers. The longevity of any restoration is attributed to multiple factors, marginal gap may be one of them; hence, the longevity of prefabricated occlusal veneer is better than CAD-CAM-milled zirconia occlusal veneers.

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Conflicts of interest

There are no conflicts of interest.

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Comparison of the effect of zirconia and titanium abutments on peri-implant hard and soft tissues

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Abstract

Aim: The primary objective of this research was to assess and compare the impact of customized zirconia (Zr) and titanium (Ti) abutments, placed on early loaded dental implants, on both hard tissue (as measured crestal bone level) and soft tissue (as assessed by sulcular bleeding index [SBI], probing depth [PD], and Pink Esthetic Score [PES]), through clinical and radiographic evaluation.

Settings and Design: This research involved a sample of 15 patients who had partially dentulous mandibular arch. Within this group, a total of 30 implants were surgically placed. Specifically, each patient received two implants in the posterior region of the mandible, and the bone density in this area was classified as D2 type. In each patient, one implant was loaded with Zr abutment and the other was loaded with Ti abutment. The bone quality in the area of implant placement was Type D2. Two groups were created for this research. Each group consisted of 15 early loaded dental implants with customized Zr abutments and customized Ti abutments respectively.

Materials and Methods: Hard- and soft-tissue changes were evaluated in both the groups. Evaluation of crestal bone loss (CBL) with cone beam computed tomography and SBI, PD and PESs were evaluated by various indices at 2, 4, and 6 months postloading.

Statistical Analysis Used: After obtaining the readings, data were subjected to statistical analysis and comparison of quantitative data was done, paired *t*-test was used.

Results: The mean CBL in the Ti abutment is higher; the difference between the two groups was not statistically significant. SBI and PD for Zr were higher, but there was no statistically significant difference between the two groups. Zr had a higher PES than Ti abutment and the difference between the two groups was statistically significant. In the literature till date, the PES of Zr abutments were proven better for provisional restorations in implant prosthesis, but very few literatures support the same for the final implant restorations.

Conclusion: The study did not reveal a clear advantage of either Ti or Zr abutments over the other. Nevertheless, Zr abutments tended to produce a more favorable color response in the peri-implant mucosa and led to superior esthetic outcomes as measured by the PES.

Keywords: Customized zirconia abutment, hybrid abutment, titanium abutment

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INTRODUCTION

The field of dental implant has expanded significantly in the past few decades, bringing innovation with increasing the range of available treatments. One aspect of this advancement is specifically related to the prosthetic abutments. The prosthetic abutment attaches to the implant platform and serves as a connection point between the future superstructure or prosthesis and the fixture. In systematic reviews, titanium (Ti) has maintained a leading position as an abutment material. Due to their well-documented biocompatibility and mechanical characteristics, Grade 5 Ti alloys are typically used to create custom Ti abutments. However, the optical result may be harmed if the metallic color of Ti continues to shine through the mucosa. A dull gray shine through, even if placed sub gingivally, could make the soft tissue appear artificial.[1]

The development of tooth-colored ceramic and personalized implant abutments is a result of consumer demand for extremely esthetic restorations. From an esthetic standpoint, especially for patients with thin, mucosal tissues, and customized zirconia (Zr) implant abutments are advised. Zr is superior to Ti, having less plaque accumulation with similar soft-tissue response, probing depths (PDs), bleeding on probing, and marginal bone level.[2] Although, Ti abutments are still considered better mechanically and more reliable as compared to Zr when exposed to long term clinical function.[1]

Literature provides very limited evidence on comparative clinical evaluation of customized Zr and Ti abutments. Hence, this *in vivo* research aimed to compare and evaluate the hard- and soft-tissue response around early loaded dental implants with customized Zr and Ti abutments.

MATERIALS AND METHODS

The Institutional Ethical Committee gave its Clearance under number IDST/IEC/2020-23/28. The Clinical Trial Registry of India received the study registration. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp. Released 2012 was used to estimate the sample size. Fifteen partly edentulous individuals (male and female) between the ages of 30 and 50 years had 30 dental implants implanted. Two groups were created for the investigation. Fifteen early loaded dental implants in Group 1 had a customized Zr abutment, while 15 early loaded implants in Group 2 had a customized Ti abutment. An appointment for diagnosis marked the beginning of the trial regimen. According to the inclusion, exclusion, and laboratory investigation criteria, all 15 patients were chosen.

Inclusion criteria

- Age 30–50 years
- Partially edentulous sites
- Extraction socket that has healed
- No occlusal disharmony
- Sufficient height and quantity of bone for implant placement
- COVID-19 (reverse transcription polymerase chain reaction report) negative
- Having good dental and general wellness.

Exclusion criteria

- Immunocompromised state
- Chronic bone diseases
- Psychiatric disorders
- Uncontrolled diabetes
- Pregnant or lactating females.

A thorough clinical examination, radiographic assessment involving the cone beam computed tomography (CBCT) was done [Figure 1]. All treatment options were thoroughly discussed with the patients. The relative advantages and disadvantages of implant treatment were informed. The surgical procedure was adequately explained and thereafter, a written consent was taken from all the patients.

After making diagnostic impressions with alginate, Type 2 dental stone was used to pour the cast, bite registration was recorded and semi adjustable articulator was used to mount the cast. With the help of vacuum forming machine, thermoplastic material was applied to the cast, and stents were made to direct the surgical drills during surgery.

A presurgical prophylactic dose of 2 g Amoxicillin 1 h before the surgery was prescribed to the patient. The patient was instructed to do intraoral rinses with 0.12% chlorhexidine after the surgical site was prepped with 5% betadine paint.

Local anesthesia (2% Lignocaine with 1:100,000 adrenaline) was administered using disposable syringe and a mid-crestal incision was given in mandibular posterior region with no. 15 BP blade [Figure 2]. Two releasing incisions were placed on the mesial and distal aspect to raise a full thickness mucoperiosteal flap. Surgical guide was then placed in position, and the initial osteotomy was performed using pilot drill. The complete osteotomy was obtained after using all the required surgical drills in the progressively increasing diameter. The depth of the osteotomy site was measured with the help of implant depth gauge.

Then, using an implant driver and a torque wrench, implants were placed [Figure 3] at the site of the osteotomy with an insertion torque of 30–50 Ncm, according to the available bone density, healing abutments were attached and primary closure of the surgical site was achieved [Figure 4]. The healing abutments were then taken out and the closed tray impression copings were attached for making closed tray implant level impressions with the help of polyvinyl siloxane (putty and light body consistency) (Photosil DPI, India) impression material. At the end, healing abutments were reattached followed by postoperative instructions and medications were prescribed to the patient.

Final impression attached with lab analog was sent to the laboratory where the master casts were poured with Type IV Gypsum products and the scan bodies were attached to the cast followed by which the designing of the abutment was done according to the type of implants

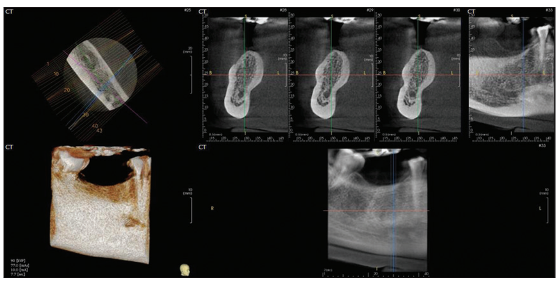


Figure 1: Preoperative cone beam computed tomography field of view

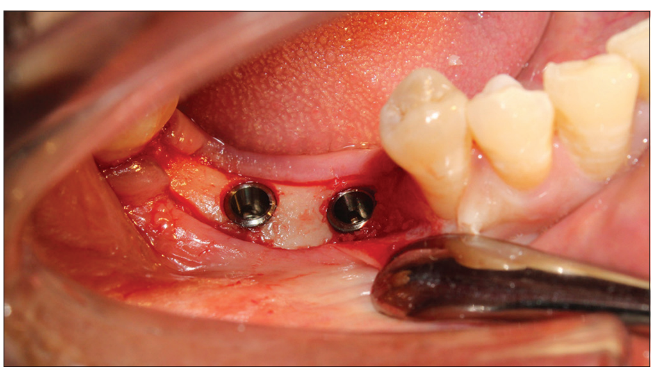


Figure 3: Implant placement done wrt 46, 47 region

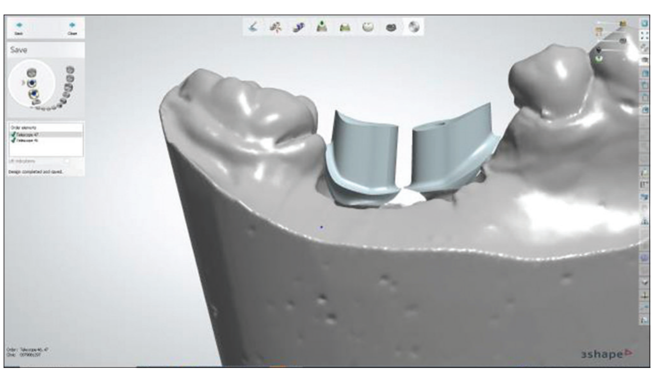


Figure 5: Designing of zirconia and titanium abutments wrt 46, 47

placed in the patient and milling of the abutments (Zr and Ti) were done with the help computer-aided-design/computer-aided-manufacturing software (3 Shape) [Figures 5 and 6]. The Porcelain Fused to Metal (DMLS) crowns were also fabricated in the laboratory.

In the next appointment, the sutures were removed and customized Zr and Ti abutments were attached to the implants and were loaded functionally within a week [Figures 7 and 8].

Figure 2: Mid crestal incision and flap raised wrt 46, 47 region

Figure 4: Healing abutment attached and suturing done

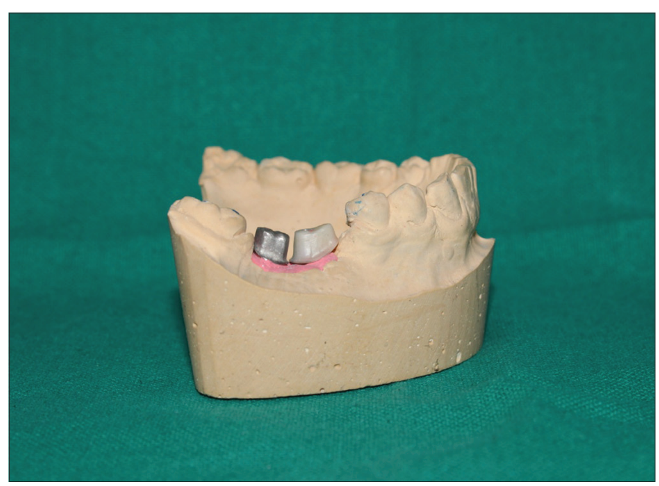


Figure 6: Zirconia and titanium abutments

At the 2nd, 4th, and 6th months after loading, standardized follow-up exams were planned to evaluate both hard- and soft-tissue changes [Figure 9].

Crestal bone loss was assessed with CBCT (Papaya 3D Plus, Genoray Korea Japan) postoperatively at 0, 2, 4, and 6 months to assess the hard-tissue changes for both the groups. At 2, 4, and 6 months postloading PD, bleeding index (BI), Pink Esthetic Score (PES), which includes the mesio-distal papilla, alveolar process deficiency, soft-tissue level, contour, color, and texture were all recorded to assess any change in both groups using the Hu-Friedy Colorvue plastic probe.

Figure 7: Zirconia and titanium abutment wrt 46, 47

Figure 8: Implant loading with porcelain fused to metal (DMLS) crowns wrt 46, 47

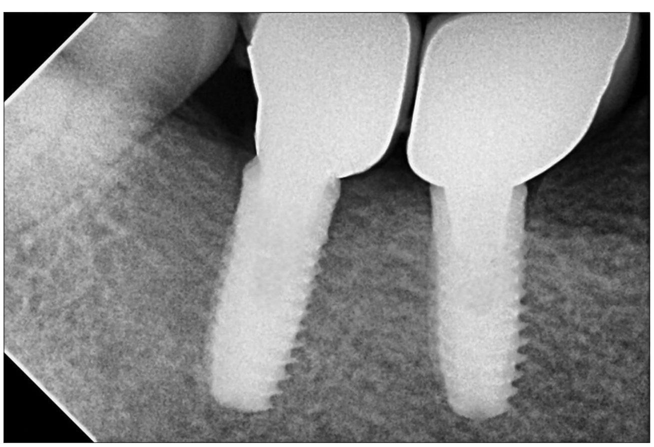


Figure 9: Postoperative IOPA X- ray wrt 46, 47

RESULTS

Data were collected and compiled methodically, converted from a pro forma with precoded fields to a computer, and a master table was created. The complete amount of data were thoughtfully distributed and displayed as separate tables and graphs.

Intergroup comparison of mean sulcular BI (SBI) at 2, 4, and 6 months was done using paired *t*-test. It was found that SBI for Group 1 is higher at recorded time intervals in comparison to Group 2. *P* value at 2 months was 0.650, at 4 months 0.825, and at 6 months 0.532, but the difference between the two groups was statistically not-significant [Table 1 and Graph 1].

Intergroup comparison of mean PD at 2, 4, and 6 months was done using paired *t*-test. It was found that PD for Group 1 is higher at recorded time intervals in comparison to Group 2. *P* value at 2 months was 0.906, at 4 months 0.748, and at 6 months 0.683, but the difference between the two groups was not statistically significant [Table 2 and Graph 2].

Intergroup comparison of mean PES at 2, 4, and 6 months was done using paired *t*-test. It was found that PES for Group 1 is higher at recorded time intervals in comparison to Group 2. *P* value at 2 months was 0.004, at 4 months

Table 1: Intergroup comparison of sulcular bleeding index

Groups	*n*	Mean	SD	*P*
At 2 months				
Group 1	15	0.7833	0.18581	0.650, NS
Group 2	15	0.7500	0.21129	
At 4 months				
Group 1	15	0.5333	0.18581	0.825, NS
Group 2	15	0.5167	0.22093	
At 6 months				
Group 1	15	0.2333	0.11443	0.532, NS
Group 2	15	0.2000	0.16903	

SBI: Sulcular bleeding index, NS: Not significant, SD: Standard deviation

Table 2: Intergroup comparison of probing depth

Group	*n*	Mean	SD	*P*
At 2 months				
Group 1	15	3.9500	0.33004	0.906, NS
Group 2	15	3.9333	0.42748	
At 4 months				
Group 1	15	3.4833	0.56273	0.748, NS
Group 2	15	3.4167	0.56432	
At 6 months				
Group 1	15	3.2500	0.60504	0.683, NS
Group 2	15	3.1667	0.49701	

PD: Probing depth, NS: Not significant, SD: Standard deviation

0.004, and at 6 months 0.008 and statistically significant difference was found in both the groups [Table 3 and Graph 3].

Intergroup comparison of mean crestal bone loss (CBL) at 2, 4, and 6 months was done using the paired *t*-test. It was found that mean CBL for Group 2 is higher at recorded time intervals in comparison to Group 1. *P* value at 2 months was 0.443, at 4 months 0.950, and at 6 months 0.170 and there was no significant difference in both the groups [Table 4 and Graph 4].

Obtained data showed bleeding on probing was higher for customized Zr abutment at recorded time intervals than customized Ti abutment, PD was less for customized Ti abutment compared to customized Zr abutment, PES was higher for customized Zr abutment at recorded time intervals and crestal bone loss was less for customized Zr abutment than customized Ti abutment.

DISCUSSION

The objective of this *in vivo* study was to examine and assess the hard- and soft-tissue response to early loaded dental implants with custom-made Zr and Ti abutments.

The CBCT was done to evaluate hard-tissue changes. The measuring tools used were provided within the Triana Software. Linear measurements were calculated using ruler tool to calculate distance on mesial and distal aspect to measure bone loss in coronal section and lingual and buccal aspect in sagittal section, respectively. Bone measurements calculated on 0, 2, 4, and 6 months postloading of implants were compared by using this tool to calculate bone loss at a given time. The soft-tissue changes were evaluated by using Hu-Friedy Colorvue plastic probe for the both groups.

According to the study's findings, Group 1 (customized Zr abutment) had higher mean SBI scores than Group 2 (customized Ti abutment) at the recorded time points of 2, 4, and 6 months; however, there was no significant difference in both the groups. Because of the young junctional epithelium around the dental implants, initial

Table 3: Intergroup comparison of Pink Esthetic Score

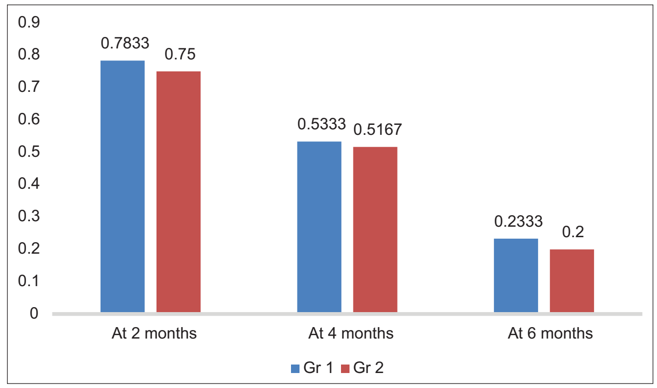
Group	*n*	Mean	SD	*P*
At 2 month				
Group 1	15	7.8667	1.12546	0.004 (significant)
Group 2	15	6.5333	1.18723	
At 4 months				
Group 1	15	9.8000	1.20712	0.004 (significant)
Group 2	15	8.4667	1.12546	
At 6 months				
Group 1	15	11.4000	0.91026	0.008 (significant)
Group 2	15	10.3333	1.11270	

PES: Pink Esthetic Score, SD: Standard deviation

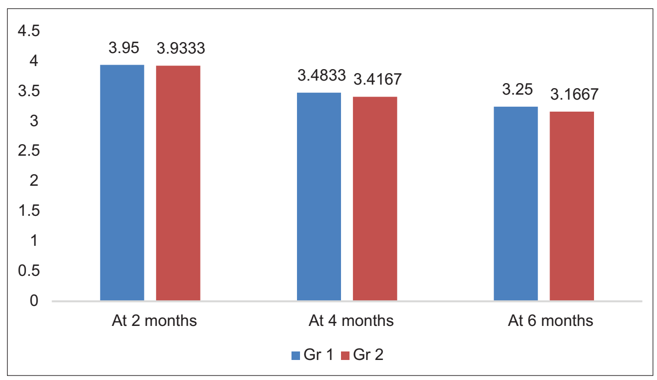
Table 4: Intergroup comparison of crestal bone loss

Group	*n*	Mean	SD	*P*
At 2 month				
Group 1	15	0.2340	0.16211	0.443, NS
Group 2	15	0.2823	0.17769	
At 4 months				
Group 1	15	0.4576	0.18525	0.950, NS
Group 2	15	0.4626	0.24331	
At 6 months				
Group 1	15	0.6829	0.20007	0.170, NS
Group 2	15	0.5706	0.23524	

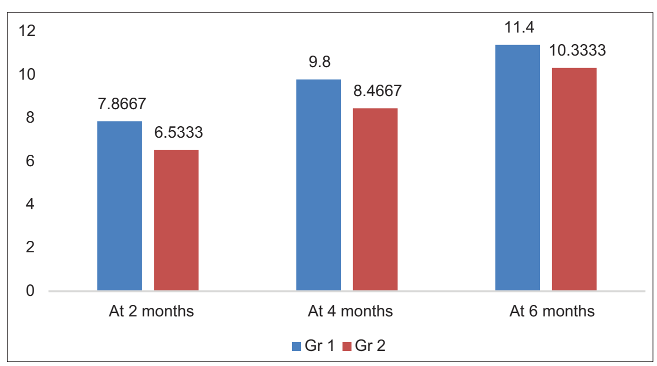
CBL: Crestal bone loss, SD: Standard deviation, NS: Not significant



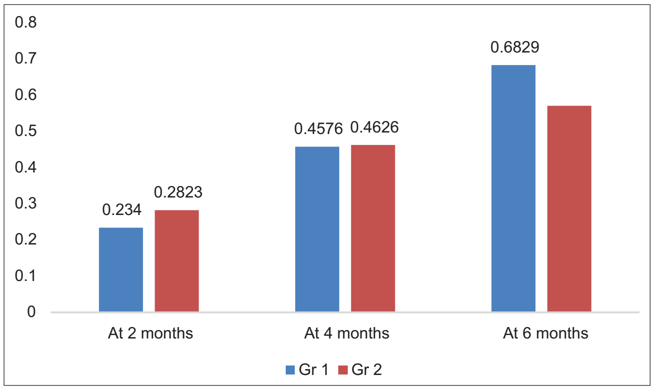
Graph 1: Intergroup comparison of sulcular bleeding index. SBI: Sulcular bleeding index



Graph 2: Intergroup comparison of probing depth



Graph 3: Intergroup comparison of Pink Esthetic Score. PES: Pink Esthetic Score



Graph 4: Intergroup comparison of crestal bone loss. CBL: Crestal bone loss

bleeding on probing was greater, although this gradually subsided over time.

The percentage reduction in the SBI decreased more quickly in Group 2 (Ti) than in Group I (Zr) from the 2nd to 8th months and from the 4th to 6th months, although the difference was not statistically significant.

Sailer *et al*. concluded that there was more bleeding on probing at the prosthesis supported by Zr abutment in comparison to Ti abutment.[3] However, Zembic *et al*.,[2] Lops *et al*.,[4] and Hosseini *et al*. (2013)[5] reported no significant difference in BOP around Zr and Ti abutments.

Payer *et al*. evaluated SBI around two-piece Zr implants with Ti abutments for 24 months and concluded that there was no statistical difference among both the groups.[6]

At the recorded time intervals of 2, 4, and 6 months, it was discovered that Group 2 (Ti) had lower mean scores for PD, but this difference between the two groups was once again not statistically significant. This may possibly be related to the initially immature junctional epithelium around the dental implants, which improve gradually overtime.

The percentage reduction in PD also showed a faster reduction from 2nd to 4th months and from 4th to 6th months in Group 2 (Ti) compared to Group 1 (Zr), but the difference was not statistically significant.

Sailer *et al*. and Carrillo de Albornoz *et al*. showed mean PD for Zr abutment (3.5 mm) was more than mean PD for Ti abutment (3.3 mm) at 1 year follow-up, but difference was not statistically significant between two groups.[3,7]

In contrast Lops *et al*. reported that mean PD for Zr abutment was less than mean PD for Ti abutment, but difference was not statistically significant between two groups.[4]

While considering the mean scores for PES, it was found that scores were considerably higher for Group 1 (Zr) at recorded time interval (2, 4, and 6 months) and there was a significant difference in both the groups.

The percentage increase in PES also showed a faster increase from 2nd to 4th months and from 4th to 6th months in Group 1 (Zr) compared to Group 2 (Ti) and the difference was statistically significant.

Payer *et al*. recorded PES to evaluate Zr and Ti abutments. The mean score for Zr abutments were higher after 24 months, showing a significant difference between the two.[6]

Zembic *et al*. - Papilla Index, Hosseini *et al*. (2013) - Copenhagen Index Score, and Carrillo de Albornoz *et al*. - Implant Crown Aesthetic Index reported that no significant difference was found between the two.[2,5,7]

Mean CBL was less for customized Zr abutment at recorded time intervals, but only for initial two follow-ups which were 2nd and 4th months. For the 3rd follow-up which was at 6th month, lesser CBL was found for customized Ti abutment than customized Zr abutment, but the difference between the two groups was nonsignificant.

Zembic *et al*., Lops *et al*., Hosseini *et al*. (2013), Payer *et al*., and Carrillo de Albornoz *et al*. reported on interproximal CBL. Studies that were included reported no significant differences in CBL among both the abutments.[2,4-7]

From observations, it can be deduced that the PD, bleeding on probing and CBL around implants were comparable with no statistical significant difference.

Significant difference was found in the PES among both the groups confirming the hypothesis that the Zr abutments can improve the esthetics around the dental implants compared to Ti abutment.

Furthermore, it was observed that the survival rate of early loaded implant was around 97% at 6 months. Occlusal loading 4–21 days after implant surgery is defined as "early loading."

Pigozzo *et al*. stated that the overall survival rates were 97.5% for early loading at 1 year and 97.6% at 3 years.[8] Ganeles *et al*. stated that implant survival rate is around 97% for early loading protocol at 12 months.[9] Several studies supported early loading and stated that it is a good treatment alternative more esthetic and less time taking procedure.[10]

Limitation of this study was the short follow-up period and sample size was small. Further investigations including a large sample size and a long follow-up period to enhance the significance of the conclusion concerning the use and predictability of the Zr abutment.

CONCLUSION

Following conclusions were made based on the limitations of this study:

1. SBI was higher for customized Zr abutment at recorded time intervals than customized Ti abutment, but there was no significant difference between both the groups
2. PD was less for customized Ti abutment at recorded time intervals than customized Zr abutment, but there was no statistically significant difference between both the groups
3. PES was considerably higher for customized Zr abutment at recorded time interval than customized Ti abutment with statistically significant difference among both the groups. It showed potential to improve the esthetics with Zr abutments and the overall quality of the soft tissue was also improved around implants
4. Crestal bone loss was less for customized Zr abutment, but only for initial two follow-ups which were 2^{nd} and 4^{th} months. At the 6^{th} month, CBL was less for customized Ti abutment than customized Zr abutment, but the difference was statistically nonsignificant among both the groups.

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There are no conflicts of interest.

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Review Article

Piezosurgery in periodontology

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A B S T R A C T

Piezosurgery is a relatively new method derived from the Greek term "piezein" which means "to press tight or to squeeze". Tomaso Vercellotti an italian physician invented it. He teamed up with Mectron Medical Technology, a medical device company was founded by Italian engineers Fernando Bianchetti and Domenico Vercellotti. It is a technique conceived to overcome the limitations of traditional bone cutting instruments in order achieve the most effective treatment with minimal amount of morbidity. It is used for bone removal and bone recontouring procedure on the principle of ultrasonic vibration. Piezoelectric effect generates an electrical charge when subjected to mechanical stress.

1. Introduction

Over the past years dentistry has underwent lots of advancement in day to day life. Various diagnostic imagining technique such as Ultrasonography, Cone Beam Computed Tomography, LASERS, Implants, Microsurgery and Nanotechnology had made the dentistry front runners in the medical field. Traditionally, osseous surgery has been performed with hand instruments (chisel, osteotome or mallet) or various motorized equipment that can be powered by air pressure or electrical energy. Manual hand cutting instruments take much longer time to yield desired results and often difficult to apply in many osseous surgical procedures. Motorized devices have rotary, reciprocal or oscillatory movements that have certain disadvantages such as: necrosis occurs due to overheating of bone tissue; loss of perceptivity to a gentle touch due to pressure on the handpiece; cutting depth is difficult to determine; iatrogenic impairment in undesirable areas due to a failure in the accurate adjustment of the speed of a rotating head or saw; and the risk of soft tissue injury to important anatomical structures such as the inferior alveolar nerve or the maxillary sinus.[1]

2. Objectives

To overcome the limitation of traditional instruments, researchers have surpassed advanced therapeutic devices that function on the idea of ultrasonic microvibrations to cut bone precisely in harmony with the surrounding tissue.[2]

Rationale of the study is to delinate the piezosurgery invention, its indication and contraindication, armamentarium, application of piezosurgery in periodontology and its limitation.

3. Piezosurgery

Piezosurgery is a method used for bone removal and bone recontouring that uses the principle of ultrasonic vibration. The word "piezo" derived from the Greek word piezein which means "to press tight or to squeeze."[3] The Piezoelectric effect is the property of certain materials to

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produce an electrical charge in response to an applied mechanical stress. It was innovated in 1988 by Professor Tomaso Vercellotti and was developed by Mectron Medical Technology.[4] He proposed the idea of using sharpened instruments fitted on ultrasonic device for ablation to perform peri radicular osteotomy to extract an ankylosed tooth. Vercellotti et al. (2000) have revised this method for nerve and soft tissue protecting surgery that has overcame the limitations of traditional instruments in oral bone surgery. Mectron (2000) developed the first generation piezosurgery device.[5,6]

4. Historical Background

Piezoelectrical device was first discovered in 1880 by Jacques and Pierre Curie. They found that applying pressure to different crystals, ceramics, and bone produces electricity. In 1881, Gabriel Lippmann found the converse piezoelectric effect.[7] In 1927, Wood and Loomis explained the physical and biological impacts of high frequency soundwaves.[8] Pohlman used ultrasound on human tissues to treat myalgias and neuropathic pain in 1950.[9,10]In the same year, Maintz demonstrated a beneficial effect on bone regeneration and healing.[11]In 1952, Blamuth introduced an ultrasonic device which was used in dentistry for cavity preparation.[12] Catuna was the first person to use ultrasound in the field of dentistry specifically for preparing dental cavities. This resulted in the introduction of high-speed rotary instruments. In 1955, Zinner introduced the first ultrasonic scalers in periodontal procedures. Richman MJ was the first to disclose the surgical use of an ultrasonic chisel without slurry to remove bone and resect roots in apicoectomies in 1957.[13] Mcfall TA et al in 1961 evaluate distinction of healing by comparing of rotating instruments and oscillating scalpel blades and found a slow healing with no severe complications by use of these scalpel blades.[14]Horton JE et al in 1980 ultrasonic devices improves bone regeneration.[15]

In 1997, Vercellotti was the first who introduced the use of an ultrasonic device for ablation fitted with a sharpened insert, such as a scalpel blade, to perform periradicular osteotomy to extract an ankylosed root of a maxillary canine. Piezosurgery an ultrasound device in 1998 was introduced in medical field by Vercellotti for different procedures such as for hard tissue surgery. In 1999, Tomaso Vercellotti invented Piezoelectric bone surgery in collaboration with Mectron Spa and published about this topic in year 2000.[16]

In 2000, Vercellotti et al. renewed the approach for nerve and soft tissue protecting surgery to overcome the limitations of traditional instruments in oral bone surgery. It was first reported for pre-prosthetic surgery, alveolar crest expansion, and sinus grafting. Mectron developed first generation piezosurgery device in 2000. Vercellotti et al developed a suitable device for routine work in oral surgery that replaced conventional osteotomy instruments in 2001. The first sinus lift and bone block grafting surgeries employing piezosurgery was performed in 2001 and 2002. In 2003, Vercellotti used piezosurgery in animal studies to compare its traumatic impact with that of traditional orthopaedic surgery and reported that it allows for more accurate cuts and a clearer view of the operative field.

In 2004, Mectron introduced Second generation of piezosurgery device. Ultrasonic osteotomy was utilised to relocate the inferior alveolar nerve (IAN) by Bovi in 2005.

The same year first implant site preparation was performed by using piezosurgical device. In the same year, the US Food and Drug Administration extended the use of ultrasonics in dentistry to encompass bone surgeries.[17] In 2006, first ultrasound osteotomy in hand surgery was performed by Hoigne et al.[18] Third generation piezosurgery device was introduced in 2009, and a clean, precise technique of harvesting bone grafts from mandibular ramus was given by Happe A.

5. The Piezosurgical Armamentarium

Piezoelectric devices consists of:

5.1. Main body

Display screen, electronic touchpad, peristaltic pump, stand for handle, and stand for irrigation fluid bag are the constituents of the main body. For selecting the operating mode, particular programme, and coolant flow, the interactive touchpad comprises four keys. Every command is displayed on the screen.[18]

The main unit has three different power levels:[19]

1. Low Mode: It is utilised for orthodontic treatment and apico-endo-canal cleaning procedures
2. High Mode: It is used to clean and smooth the radicular surfaces
3. Boosted Mode: Is used in bone surgeries, osteotomy and osteoplasty procedures.

5.2. Peristaltic pump

Peristaltic pump contains an irrigation solution that flows at an adjustable rate of 0–60 ml/min to cool the cutting area and remove debris. The solution is refrigerated at 4°C to provide a cooling effect, and the volume of liquid can be adjusted with the + and - buttons.

5.3. Hand piece

Piezosurgical device consist of two hand pieces. The handpiece is firmly connected to the cord, which may be sterilised together.[20]

5.4. Handle

The cutting action is based on ultrasonic waves that travelling via piezoelectric ceramic within. These ceramic plates are created by an external generator and alter in volume to produce ultrasonic vibrations. They are channelled into the amplifier, which transmits them to the handle pointed end. A specific key is used to clamp the insert for this function.In this manner, the optimum efficiency for cutting and insert duration is accomplished.[21]

5.5. Foot pedal

Handpiece is controlled by an adjustable pedal on the base.

5.6. Base unit

The power is supplied by the base unit which also have the holder for handpiece and irrigation fluids. The device has display that allows the operator to select between the BONE cutting mode and ROOT operating modes. Using a specific selection for the type or density of the bone, the BONE cutting mode is utilised to cut bone. For endodontic and periodontal root treatments, the ROOT mode is utilised to shape, clean and smooth the root surfaces.

5.6.1. Bone mode

Bone mode are characterized as extremely high ultrasonic power compared to root mode.[22] Its performance is monitored by several advanced software and hardware controls. Due to excessive frequency modulation, mechanical ultrasonic vibration are unique for cutting different kinds of bone.

The selection recommended are:[23]

1. Quality 1: Cutting cortical bone or high density cancellous bone.
2. Quality 3: Cutting low density cancellous bone.

5.6.2. Root mode

The vibrations generated by selecting root mode have an average ultrasonic power without frequency over modulation.[22]

Root operating mode consists of two different programs:[23]

1. Endo program: A limited level of power provided by applying a reduced electrical tension to the transducer, which generates insert oscillation by a few microns. These mechanical micro-vibrations are ideal for irrigating the apical part of the root canal in endodontic surgery.
2. Perio program: An intermediate power level between the endo program and the bone program. The ultrasonic wave is continuosly transmitted through the transducer in a continuous sinusoidal manner, characterized by a frequency equal to the resonance frequency of the insert used.

A special program is designed with a slightly lower standard power than the bone programs has the same frequency over modulation. A special program is dedicated to a limited series of particularly thin and delicate surgical insertstips. These are only recommended for surgeons experienced in piezosurgery and who want an extremely thin and efficient incision.

5.6.3. Inserts tips

The Mectron Medical Technology has developed the design and function of all insert tips used in Piezoelectric bone surgery. Taking into account morphological-functional and clinical factors, the inserts tips have been defined and organized according to a dual classification system.

Various insert tips are classified as:

5.7. According to insert tip coating:[20]

1. Titanium Nitride coated tips are effective in osteoplasty procedure and for harvesting of bone chips as they provide maximum cutting efficiency, resist corrosion and last longer.
2. Diamond coated tips are used for osteotomy of thin bone and/or proximity to anatomic structures.

   They are classified as follows:

   (a) Sharp Insert tips are designed for maximum cutting efficiency and are used for osteoplasty procedures and to harvest bone chips.
   (b) Smooth Insert tips have diamond coated surfaces that enables precise and controlled work on the bone structures. They are used in osteotomy procedures to prepare difficult and delicate structures such as preparation of the sinus window and/or nerve access.
   (c) Blunt Insert tips are used for preparing soft tissues, e.g., elevation Schneider's membrane and/or, lateralization of the inferior alveolar nerve. In periodontics, these tips are used for root planing.

5.8. According to insert tip color

1. Gold Insert tips are utilised specifically for bone surgery. The gold color of the insert tips is obtained from the titanium nitride which improves the hardness of the surface for longer working life.[24]
2. Steel Insert tips are used specifically for treating soft tissue and/or delicate tooth structures (roots of teeth).[25]

5.9. Clinical classification

Clinical classification comprises insert tips (sharp, smooth, blunt) based on surgical techniques such as osteotomy,

osteoplasty, extraction.[26]

1. Osteotomy OT - OT1, OT2, OT3, OT4, OT5, OT6, OT7, OT7S4, OT7S3, OT8R/L
2. Osteoplasty OP - OP1, OP2, OP3, OP4, OP5, OP6, OP7
3. Extraction EX - EX1, EX2, EX3
4. Implant site preparation IM - IM1(OP5 -IM2A-IM2P OT4-IM3A-IM3P
5. Periodontal Surgery PS - PS2-OP5-OP3-OP3A- Pp1
6. Endodontic Surgery EN - OP3-PS2-EN1-EN2-OP7
7. Sinus Lift- OP3-OT1-OP5 - EL1-EL2-EL3
8. Ridge Expansion- OT7-OT7S4-OP5- IM1 -IM2-OT4 -Im3
9. Bone Grafting- OT7, OT7S4, OP1, OP5
10. Orthodontic Microsurgery- OT7S4-OT7S3

5.9.1. Indications

1. Implantology:[26]
   (a) Implant site development (socket preparation)
   (b) Splintting and expansion of the alveolar ridge
   (c) Alveolar crest recontouring
   (d) Mental nerve repositioning
   (e) Distraction osteogenesis with subsequent implant placement
   (f) Retrieval of blade implants
   (g) Placement of implants
   (h) Harvesting block grafts
2. Maxillary sinus bone grafting surgery:[26]
   (a) Creating lateral bone window
   (b) Sinus mucosa atraumatic dissection
   (c) Elevation of internal sinus floor elevation
3. Periodontal treatment procedures:[26]
   (a) Supragingival and subgingival scaling
   (b) Irrigation of periodontal pockets
   (c) Crown lengthening
   (d) Soft tissue debribement
   (e) Resective and regenerative surgerical procedure
4. Others:[27]
   (a) Retrograde root canal preparation
   (b) Apicectomy
   (c) Cystectomy
   (d) Extraction
   (e) Tooth extraction with osteogenic distraction Ankylosed tooth
   (f) Extraction
   (g) Orthodontic surgery
   (h) Removal of cyst

5.10. Contraindications[28]

No absolute contraindications

1. Patients or the clinician with electrical implants such as pacemakers.
2. Certain systemic diseases such as cardiovascular diseases, diabetes and bone disease or in patients undergoing radiotherapy, all of which can hinder the dental implant surgery.
3. Alterations that may or may not be related to systemic diseases, bone structure and vascularization.
4. Behaviours such as smoking and excessive drinking.

6. Application of Piezosurgery in Periodontology

6.1. Scaling and root planing

The piezosurgery device is used to remove supragingival and subgingival calculus as well as stains from teeth. It has been discovered that employing cavitation alone without the touch of the vibrating tip is insufficient for removing the calculus; direct contact between the vibrating tip and the calculus is required. The piezosurgery ultrasonic scaler, set to function On/Mode Periodontics (ROOT), with the insert PS1 and PP1, is used for deposit removal on all tooth surfaces for 15 seconds at a medium power of two. Parallel movements were used, with working strokes perpendicular to the tooth axis.[29]

Busslinger et al.[30] conducted a study to compare magnetostrictive and piezoelectric devices and found a substantial difference in time required. The SEM pictures after instrumentation were utilised to compare the four groups. SEM examination of tooth surface roughness revealed that the C100 group had a smoother surface than the C200 group and that the P100 group had a smoother surface than the P200 group, although the difference was not significant. The difference between the C200 and P200 groups was statistically significant. According to Santos et al[31] there were no changes in the results of magnetostrictive and piezoelectric devices uder SEM.

6.2. Curettage

When compared to manual tools, a piezosurgery device is employed for debridement of the epithelial lining of the pocket wall, resulting in microcauterization and removal of root calculus by employing thin tapered tips with an adjusted power setting.[32]

6.3. Clinical crown lengthening

Raising a full-thickness flap, conducting an ostectomy with manual instruments, osteoplasty with a bur for crest bone architecture recontouring, periradicular bone removal, root planing, and ultimately restoring the flap in an apical position are all part of the conventional surgical approach. The crown lengthening procedure done with piezosurgery for successful bone reduction while maintaining root surface integrity.[33,34]

A controlled clinical split mouth study was conducted by Dayoub ST et al[35] to evaluate the clinical results of a minimally invasive flapless method versus an open-flap approach in aesthetic crown lengthening for the treatment of gingival smile up to three months following piezoelectric bone surgery. The study demonstrated that utilising piezosurgery in bone resection is successful with both surgical techniques and resulted in a considerable increase in clinical crown length as compared to baseline. They concluded that the minimally invasive flapless approach and piezosurgery provide alternatives to traditional procedures of aesthetic crown lengthening.

6.4. Resective surgery

In comparision to other instruments, the piezosurgery device is beneficial in periodontal surgery. After the primary flap is raised during resective surgery the device makes it simpler to accompany with the secondary flap and remove the inflammatory granulation tissue. This process results in minor bleeding but by applying the proper ultrasonic vibration, bleeding is prevented.

6.5. Periodontally accelerated orthodontics

Small vertical bone incisions between the teeth were done as part of the periodontally accelerated orthodontics procedure that allows more expedient orthodontic movement. With acceptable levels of pain and discomfort, the corticotomy procedure conducted with a piezosurgical equipment reduce the treatment duration by 60 to 70%. For selective alveolar corticotomies using the Peizosurgical device, surgical control was reported to be simpler than with traditional surgical burs.[36]

6.6. Block harvesting technique

Traditional rotary cutting instruments for bone block harvesting reduce the width of the cortical bone by at least 1 mm circumferentially and are unable to cut the internal cancellous bone effectively. Piezosurgery provides high accuracy and operational sensitivity, as well as simple distinction between cortical and cancellous bone while removing blocks of monocortical cancellous bone.[37]

6.7. Autogenous bone grafting

Due to absence of osteocytes and prevalence of non-vital bone, utilising manual or motor-driven devices for bone surgery may not be suited for grafting. The Piezosurgery inserts tips that are used for bone harvesting process creates a vibration with a width of 60 to 210 in an oscillation controlled module. In contrast to rotary burs or reciprocating saws, the utilisation of ultrasonic vibration creates controlled osteotomies by micrometric bone slices.

6.8. Osteoplasty and bone grafting

Piezosurgical device enables gentle scrubbing of the bone surface in order to obtain appropriate amount of graft material and can be used for gafting infrabony defects.

The function of the bony chips that are obtained vary with size

1. Small size chips aids in early remodelling
2. Larger size chips particles provide mechanical support and act as scaffold for bone growth.

7. Limitations

1. Difficulty to perform the deeper osteotomies.
2. Requires longer time for bone cutting or preparing osteotomy site than traditional cutting instruments.
3. Have longer and different learning curve.
4. Technique sensitive.

8. Conclusion

When compared to traditional rotational devices, ultrasound application to hard tissue is considered a slow procedure. Because it necessitats specialised surgical abilities associated with a certain learning curve. When compared to conventional procedures and soft tissues, piezosurgery is an advanced and conservative approach. Because, device precisely cuts bone, significant nerve damage may be avoided, and minimally invasive operations are conceivable. Using the fine tip enables curved cutting and provides an opportunity for new osteotomy technique. Predictability, Less Postoperative Pain, And Increased Patients Compliance are three P's of piezosurgery.

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10. Conflict of Interest

None.

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A Review

Cone Beam Computed Tomography & Its Application In Periodontics

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Abstract

The presence of periodontal diseases is diagnosed on the basis of evaluation of clinical signs and symptoms followed by radiographs. Radiographs provide diagnostic information about the quality localization of the bone defect and the pattern of the bone resorption, changes in the bony trabeculae, condition of the lamina dura, length and shape of the root, furcation defects, subgingival calculus, and additional pathology. Two dimensional periapical and panoramic radiographs are routinely used for diagnosing periodontal bone levels.The amount of information obtained from conventional film and digitally-captured periapical radiographs is limited by the fact that the three-dimensional anatomy of the area being radiographed is compressed into a two-dimensional image. As a result of superimposition, periapical radiographs reveal limited aspects of the three-dimensional anatomy. Three dimensional imaging (3D) evolved to meet the demands of advanced technologies in delivering the treatment and at the same time responsible for the evolution of new treatment strategies. Cone beam computed tomography (CBCT) generates 3D volumetric images and is also commonly used in dentistry. All CBCT units provide axial, coronal and sagittal multi-planar reconstructed images without magnification. CBCT displays 3D images that are necessary for the diagnosis of intra bony defects, furcation involvements and buccal/lingual bone destructions. CBCT applications provide obvious benefits in periodontics, however; it should be used only in correct indications considering the necessity and the potential hazards of the examination.

Keywords: cone beam computed tomography (CBCT); 3D radiography; periodontal defects; periodontal diagnosis; furcation; intrabony defects

Introduction

The periodontium is a functional unit of the tooth that consists of the gingiva, periodontal ligament, cementum, and alveolar bone. Radiographically, the periodontal ligament space appears as a dark line surrounding the root and an increased radio density of alveolar bone is visible adjacent to the periodontal ligament space, referred to as the lamina dura which is an extension of cortical bone into the alveolus.[1]

Periodontal diseases can be broadly classified as gingival diseases (gingivitis) and periodontitis. The bone destruction in periodontal disease occurs when the inflammation extends from the marginal gingiva into supporting periodontal tissues.

Although periodontitis is always preceded by gingivitis, gingivitis does not always progress to periodontitis.[2] The periodontium is first evaluated clinically followed by radiographic study.

Dental radiographs are a valuable non-invasive tool used as an adjunct to clinical examination for assessment of the periodontal conditions of the teeth.[3] Radiographs provide diagnostic information about the quality localization of the bone defect and the pattern of the bone resorption, changes in the bony trabeculae, condition of the lamina dura, length and shape of the

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root and the crown root ratio, plaque retention factors, caries, furcation defects, subgingival calculus, and additional pathology.[4]

Broadly, imaging techniques used in dentistry can be categorized as: intraoral and extraoral, analogue and digital, ionizing and non-ionizing imaging and two-dimensional (2-D) and three-dimensional (3-D) imaging. Traditional analog imaging modalities are two dimensional systems that use image receptors like radiographic films or intensifying screens. These include periapical views, panoramic, occlusal and cephalometric radiography.[5]

The interpretation of an image can be altered by the anatomy of both the teeth and surrounding structures. The amount of information obtained from conventional film and digitally-captured periapical radiographs is limited by the fact that the three-dimensional anatomy of the area being radiographed is compressed into a two-dimensional image. As a result of superimposition, periapical radiographs reveal limited aspects of the three-dimensional anatomy.[6] Three dimensional imaging (3D) evolved to meet the demands of advanced technologies in delivering the treatment and at the same time responsible for the evolution of new treatment strategies. G.N. Houns field, in 1972 introduced computerized transverse axial scanning which lead to introduction of Computed Tomography (CT). The high radiation dose, cost, availability, poor resolution and difficulty in interpretation have resulted in limited use of CT imaging in dentistry. These problems may be overcome using small volume cone-beam computed tomography (CBCT) imaging techniques.[7]

CBCT is also known as CBVT (Cone Beam Volumetric Tomography), CBVI (Cone Beam Volumetric Imaging) dental 3D CT, dental CT and DVT (Digital Volume Tomography) has touched every aspect of medical and dental profession. In periodontology as well as implantology, CBCT scanning has become a valuable imaging technique, for the diagnosis of intrabony defects, furcation involvements, and buccal/lingual bone destructions.

Principles of CBCT

The principal feature of CBCT is that multiple planar projections are acquired by rotational scan to produce a volumetric data set from which interrelation images can be generated.[8] Cone-beam scanners use a two-dimensional digital array providing an area detect or rather than a linear detect or as conventional CT does. This is combined with a three-dimensional X-ray beam with circular collimation so that the result ant beam is in the shape of a cone, hence the name "cone-beam". Because the exposure incorporates the entire region of interest (ROI), only one rotational scan of the gantry is necessary to acquire enough data for image reconstruction.[9]

Steps in Cone Beam Computed Tomography Image Production

Image production by CBCT involves four steps[10]:

A. Image Acquisition
B. Image detection
C. Image reconstruction
D. Image display

A. Image Acquisition

The cone-beam technique involves a rotational scan exceeding 180 degrees of an x-ray source and a reciprocating are a detect or moving synchronously around the patient's head. During the rotation, many exposures are made at fixed intervals, providing single projection images known as —basis", —frame" or "raw" images similar to lateral cephalometric radiographic images, each slightly off set from one another. The complete series of basis images is referred to as the projection data. Software programs incorporating sophisticated algorithms including back-filtered projection are applied to the projection data to generate a 3D volumetric data set that will provide primary reconstruction images in three orthogonal planes (axial, sagittal, and coronal).[11]

There are four components to image acquisition in CBCT:

1. Acquisition mechanics: Full/ partial rotation scan
2. X-ray generation: continuous/ pulsed
3. Field of view
4. Scan factor

1. Acquisition Mechanics:

The CBCT technique involves a single scan from an X-ray source which can be a partial or full rotational scan, exposing a reciprocating area detector that moves synchronously around the patient's head.

2. X-ray generation

Although CBCT is technically simple in that, only a single scan of the patient is made to acquire a data set, a number of clinically important parameters should be considered in x-ray generation.

Patient Positioning:

CBCT can be performed with the patient in three possible positions: Supine, Standing and Sitting.

X-ray generator

During the scan rotation, each projection image is made by sequential single image capture of the remnant x-ray beam by the detector.

3. Field of view

Ideally, the FOV should be adjusted in height and width which mainly depends on the size and shape of the detector, projection of the X-ray beam, and collimation of the X-ray beam. CBCT systems can be grouped according to the available FOV or selected scan volume height as follows:

1. **Localized region:** Approximately 5 cm or less (e.g., dento alveolar and TMJ)
2. **Single arch:** 5–7 cm (e.g., maxilla or mandible)
3. **Interarh:** 7–10 cm (e.g., mandible and superiorly to**c** include the inferior concha)
4. **Maxillofacial:** 10–15 cm (e.g., mandible and extending to nasion)
5. **Craniofacial:** >15 cm (e.g., from the lower border of the mandible to the vertex of the head).

4. Scan Factors

The speed with which individual images are acquired is called the frame rate and is measured in frames, projected images, per second. The maximum frame rate of the detector and rotational speed determines the number of projections that may be acquired. The number of projection images comprising a single scan may be fixed or variable. With a higher frame rate, more information is available to reconstruct the image; therefore, primary reconstruction time is increased. Higher frame rates are usually accomplished with a longer scan time and hence higher patient dose.[9,10,11]

A. Image Detection:

Current CBCT units can be divided into two groups on the basis of detector type:

- An image intensifier tube/ charge couple device combination (IIT/CCD)or
- Flat-panel imager.

B. Image Reconstruction

The reconstruction process consists of two stages:

Acquisition stage

Raw images from CBCT detectors exhibit spatial variations of dark image offset and pixel gain due to varying physical properties of the photodiodes and the switching elements in the flat panel detector and also due to variations in the X-ray sensitivity of the scintillator layer. These raw images need systematic offset and gain calibration and a correction of defect pixels which is done by “detector preprocessing.”

Reconstruction stage

After the correction of the images, the images are transformed into sinogram which is done by reconstruction filter algorithm, the modified Feldkamp algorithm, that converts the image into a complete 2D CT slice. All the slices are finally recombined into a single volume for visualization.[11]

C. Image Display

The volumetric data set comprises of collection of all available voxels and projected on the screen as secondary reconstructed images in three orthogonal planes - axial, sagittal, and coronal.

Advantages of CBCT

CBCT technology in clinical practice has important advantages such as minimization of the radiation dose, image accuracy, rapids can time, fewer image artefacts, chair-side image display, and real-time analysis.

Disadvantages of CBCT

Although there has been enormous interest in CBCT, this technology has limitations related to the cone-beam projection geometry, detect or sensitivity and contrast resolution that produce images that lack the clarity and utility of conventional images. The patient must be motion less during the scanning to achieve a good image; other wise the image may display streaking.[12]

Diagnostic Application In Periodontics

The clinical applications of three-dimensional craniofacial imaging are one of the most exciting and revolutionary topics in dentistry.[13] (Figure1)

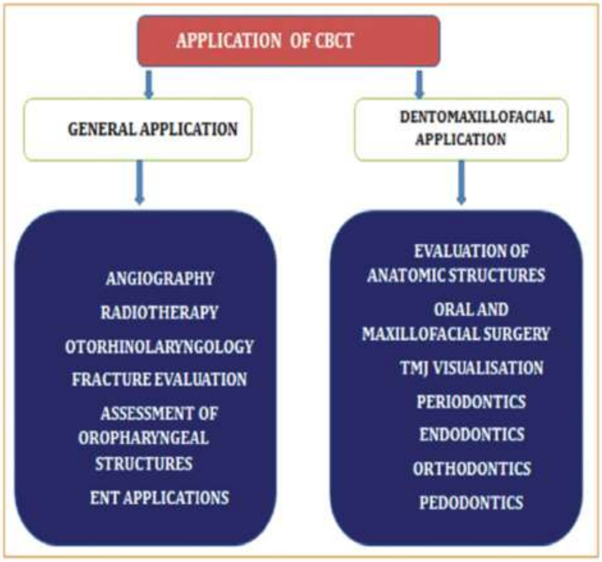

Figure 1: Application of CBCT

Role in Periodontics

Identification of periodontal landmarks

Periodontal Ligament Space

Radiographically lamina dura appears as a thin radiopaque line around the length of root. The space present between lamina dura and adjacent tooth is termed as PDL space. Any break in the continuity of lamina dura and a wedge shape radiolucenly at the mesial or distal aspect of the PDL space indicates periodontitis. Ozmeric et al did a study and compared CBCT with conventional radiography in terms of their ability to produce images of periodontal ligament space on a phantom model with artificially created periodontal ligament of various thicknesses and had found that the Periapical radiographs were superior to CBCT for the measurement of periodontal ligament space. But conflicting results were reported by the authors of another in vitro study that found CBCT to be better than conventional radiography in visualizing the periodontal ligament space. A phantom demonstrating variable periodontal ligament spaces was radiographed using CBCT and intraoral radiographs. This study found that CBCT provided better visualization of simulated periodontal ligament space in this phantom.[14]

Alveolar Bone Defect

The extent of periodontal marginal bone loss is necessary to determine the periodontal destruction. CBCT images provide better information on periodontal bone levels in 3D view than conventional radiography. CBCT is considered a superior technique in detecting the buccal and lingual defects and the interproximal lesions.Radiographs are mainly used to diagnose the amount and shape of alveolar bone destruction that affects treatment planning in periodontal therapy.[14,15]Two Dimensional radiographs can be insufficient for the detection of intrabony alveolar defects due to the obstruction of spongious bone changes by cortical plate. Thus, three-dimensional imaging is required for mapping of alveolar defects. Vandenberghe et al studied thirty periodontal bone defects of 2 adult human skulls using intraoral digital radiography and CBCT and concluded that the intraoral radiography was significantly better for contrast, bone quality, and delineation of lamina dura, but CBCT was superior for assessing crater defects and furcation involvements.[16]In Misch and colleagues study they demonstrated that CBCT was as accurate as direct measurements using a periodontal probe and as reliable as radiographs for interproximal areas.[17]Stavropoulos and Wenzel evaluated the accuracy of CBCT scanning with intraoral periapical radiography for the detection of periapical bone defects. CBCT was found to have better sensitivity compared to intraoral radiography.[18]

Furcation Involvement

Radicular bone assessment is anessential step in furcation involvement treatment planning procedures such as apically repositioned flaps with or without tunnel preparation, root amputation, hemi-/trisection or root separation. Conventional two dimensional radiographs can be deceptive in evaluating periodontal tissue support and inter radicular bone due to superposition of anatomical structures. However, 3D images provide detailed information about areas of multi rooted teeth. Intrasurgical furcation involvement measurements were compared by using CBCT images and it was reported that CBCT images demonstrated a high accuracy in assessing the loss of periodontal tissue and classifying the degree of furcation involvement in maxillary molars. In another study author had compared CBCT to intraoral radiography and concluded that the detection of crater and furcation involvements had failed in 29% and 44% for the intraoral radiograph, respectively, as compared to 100% detectability for both defects with CBCT.[19]

Regenerative periodontal therapy and bone grafts

Bone grafting is commonly used for maxillary sinus lifting and treatment of intra bony defects but evaluation of osseous defect regeneration with conventional radiography can be limited due to superimpositions. Furthermore, histological evaluation of a sample of the graft is not a preferred method due to its quite invasive procedure. CBCT was found to be significantly more accurate than digital intraoral radiographs when direct surgical measurements served as the gold standard for the evaluation of intra-bony defects' regenerative treatment outcomes. CBCT can replace surgical re-entry by providing 3D images and measurements that are almost equivalent to direct surgical measurements.[19,20] Dimensions of alveolar process should be examined in detail prior to dental implant placement to avoid various complications and evaluation of CBCT images has a major importance in preoperative planning and postoperative localization of dental implant.[21]

Role In Implant Site Assessment:

Implant placement requires technique which is capable of obtaining highly accurate alveolar and implant site measurement to assist with treatment planning and avoid damage to adjacent vital structure during surgery. Earlier alveolar and implant site measurement was done either using 2-D radiographs and in some instance using conventional CT (Figure 2). When compared, CBCT is preferable option for implant dentistry, providing greater accuracy in measuring with utilization of lower radiation dose.

Uses[22]

1. To assess the quantity and quality of bone in edentulous ridges.
2. To assess the relation of planned implants to neighboring structures.
3. To assess the success of implant osseointegration.
4. To provide information on correct placement of implants.
5. Before ridge augmentation in anodontia
6. Before bone reconstruction and sinus lifting
7. During planning and in designing a surgical guidance template.

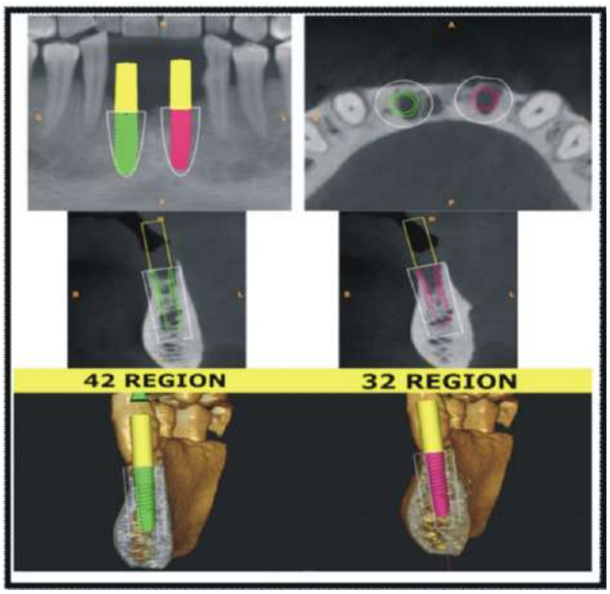

Figure 2: Implant site assessment

Role of CBCT in detecting anterior looping during implant placement:

Apostolakis D and Brown JE (2012) stated that the final part of the inferior alveolar nerve sometimes passes below the lower border and the anterior wall of the mental foramen.[23] After giving off the smaller mandibular incisive branch, the main branch curves back to enter the foramen and emerge to the soft tissues, as the mental nerve. The section of the nerve in front of the mental foramen and just before its ramification to the incisive nerve can be defined as the anterior loop of the inferior alveolar nerve. Selective surgery in the area of the anterior mandible such as implant installation in the interforaminal region or symphysis bone harvesting, may violate the anterior loop resulting in neurosensory disturbances in the area of the lower lip and chin. To avoid such a sequel a 5-mm safe distance to the most distal fixture from the anterior loop and a 5-mm distance from the mental foramen for chin bone harvesting have been proposed.[23,24]

Tolstunov identified and described four alveolar jaw regions—functional implant zones (Figure 3)[21] with unique characteristics of anatomy, blood supply, pattern of bone resorption, bone quality and quantity, need for bone grafting and other supplemental surgical procedures, and a location related implant success rate.

Four functional implant zones identified by Tolstunov[21,22,23]:

i. Functional Implant Zone 1 (Traumatic zone)consists of alveolar ridge of premaxilla and eight anterior teeth: 4 incisors, 2 canines, and 2 first premolars. Any bone loss in the anterior maxillary area is vital due to the esthetic implications on dental implant supported restorations. Loss of teeth in this area is mostly due to trauma and if the teeth are not replaced immediately following trauma, the bone loss continues, leading to difficulty in dental implant placement in a prosthetically favorable position.

ii. Functional Implant Zone 2(Sinus zone): bilateral maxillary posterior zone extends from the maxillary second premolar to the pterygoid plates and is located at the base of the maxillary sinuses.

iii. Functional Implant Zone 3 (Inter-foraminal zone): comprised of the area of the mandibular alveolar ridge between mental foramen and first premolar on each side. This zone is also associated with a thin alveolar ridge. There is abundant evidence in the literature reporting severe bleeding with the formation of expanding sublingual hematomas due to the perforation of the lingual cortex.

iv. Functional Implant Zone 4:- This zone of the alveolar process of the mandible behind the mental foramen on each side and extends from the second premolar to retromolar pad. The distance of the alveolar bone height from the inferior alveolar canal is evaluated when dental implants are considered in the posterior mandible. Careful assessment of the height must be made to avoid injury to the inferior alveolar canal. If there is a violation of the inferior alveolar nerve (IAN), depending on the degree of nerve injury, alteration in sensation, from mild paresthesia to complete anesthesia, is reported.

Figure 3: Functional implant zones identified by Tolstunov

Conclusion

Cone beam computed tomography is a diagnostic imaging technology that is changing the way dental practitioners view the oral and maxillofacial complex as well as the teeth and the surrounding tissues. CBCT has been specifically designed to produce undistorted three dimensional images similar to computed tomography (CT), but at a lower equipment cost, simpler image acquisition, and lower patient radiation dose. However the two-dimensional diagnostic imaging has served dentistry well and will continue to do so for the foreseeable future. Intraoral and panoramic radiographs are the basic imaging techniques used in dentistry and are quite often the only imaging techniques required for the detection of dental pathology.

For periodontal disease, CBCT promises to be superior to 2Dimaging for the visualization of bone topography and lesion architecture but no more accurate than 2D for bone height. This factor should be tempered with awareness that restoration in the dentition may obscure views of the alveolar crest. No doubt, future improvements in CBCT technology will result in systems with even more favorable diagnostic yields and lower doses.

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Review Article

Changing trends in implant designs: A review

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A B S T R A C T

Implantology is an ever-evolving scientific field that undergoes continuous refinement and innovation. Dedicated research and development efforts are focused on consistently improving the success rates of implants through innovative redesign and advancements. The introduction of advanced technologies has revolutionized the evaluation of patients in three dimensions, enabling clinicians to utilize precise and predictable approaches for diagnosis, planning, and treatment. This multidisciplinary patient-centric framework has opened new avenues for providing tailored and effective healthcare solutions. Therefore, it is of utmost importance for clinicians to conduct a comprehensive analysis of each patient's condition, ensuring meticulous selection of the suitable implant design and material, and making informed decisions regarding the most appropriate technique to be employed.

1. Introduction

Dental implants are widely recognized as one of the most promising and effective solutions for replacing missing teeth. With long-term success rates surpassing 90%, they have proven to be highly effective in restoring oral function and aesthetics in both partially and fully edentulous patients.[1] Thanks to the current availability of advanced diagnostic tools that assist in treatment planning, along with the ongoing research leading to improved implant designs, materials, and techniques, a wide range of challenging clinical situations can now be effectively managed with a high level of predictability and success.[2] Implant design features are vital factors that have a significant impact on the initial stability of implants and their ability to endure loading throughout the osseointegration process and beyond. These design elements play a fundamental role in ensuring the long-term stability and durability of dental implants. Furthermore, dental implants are engineered with specific textures and shapes that can promote cellular activity and facilitate direct bone apposition, facilitating successful integration with the surrounding tissues.[3]

Dental implant design has undergone significant advancements in recent years. In the past, primitive dental implants such as blade, staple, and periosteal types were used, but they had inherent biomechanical limitations, leading to high failure rates.[4] Recent advancements have brought about significant improvements in the morphology, structure, and design of dental implants, aimed at enhancing their biomechanical properties, stability, and long-term success. These developments reflect the ongoing commitment to innovation and the continuous pursuit of excellence in the field of dental implantology.

Implant design encompasses the comprehensive three-dimensional structure of the implant, including its various elements and characteristics. It encompasses factors such as form, shape, configuration, as well as the surface macrostructure and macro irregularities, all of which

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contribute to the overall attributes of the implant's three-dimensional structure.

2. Implant Shape

Implant shape directly influences the surface area available for stress transfer, playing a critical role in determining the implant's initial stability. The predominating macro structure for root-form endosseous implants is the screw shape, which consists of parallel-sided screw and the tapered screw.[2] Smooth-sided cylindrical implants offer a convenient advantage when it comes to surgical placement.[4] A tapered implant with smooth sides enables the transfer of a comprehensive load to the interface between the bone and the implant, the extent of which depends on the taper's degree. Implants with threaded design and circular cross sections facilitate easy surgical placement and enable enhanced optimization of the functional surface area to effectively transmit compressive loads to the bone-to-implant interface.[2]

3. Implant Geometry

The primary criterion for developing the treatment plan is still the size of the implant, including its diameter and length, primarily determined by the amount of available alveolar bone. For a given implant length, increasing the implant diameter will increase the implant surface area that is available for force transfer to the bone.[5] Provided there is sufficient bone volume, a larger diameter implant is better able to resist occlusal forces, particularly in the molar region. When designing the treatment plan, it is important to consider the drawbacks associated with bone augmentation, which used to be considered the "gold standard" in severe atrophy cases. These drawbacks include morbidity at the donor site, elevated risks of complications, extended time and increased costs, as well as potential resorption of the bone graft. Additionally, the advancing capabilities of smaller-sized implants should be considered when formulating the treatment approach.[6]

Several new concepts may provide other options for implantation, aiming to reduce treatment duration, minimize complication rates, and simplify the overall treatment procedure, such as:

4. One-piece Implant

In a one-piece implant the endosseous and abutment portions form a single unit. By eliminating the abutment interface, the one-piece implant enhances the strength and stability of the prosthesis. It is a suitable option for patients or surgical sites with insufficient bone to adequately support a prosthesis. In spite of these advantages, one-piece dental implants do have a limitation in terms of flexibility compared to two-piece implants. Their single-unit construction restricts the ability to make precise adjustments once placed.

The design of one-piece implants allows for uninterrupted healing of the soft tissues surrounding the implant and avoids any disruption to the soft tissue seal when placing the final prosthetic restoration.[7]

5. Mini-Implants

Compared to standard dental implants, mini-implants are characterized by their reduced diameter, typically less than 3 mm, and shorter length. Despite their smaller size, they are typically made from the same biocompatible materials as standard implants. These implants are particularly useful when achieving acceptable and satisfactory function with conventional prostheses is challenging. Clinical situations like flabby ridges, atrophic ridges, or inadequate residual bone where denture retention is less, are likely to do well with mini-implants.[8]

6. Short Implants

Placing conventional implants can be challenging in cases of atrophic alveolar ridges due to various anatomical restrictions. These include the presence of the maxillary sinus, nasal floor, nasopalatine canal, and inferior alveolar canal. These structures can limit the available bone volume and affect the feasibility of conventional implant placement. To address these and other vertical bone deficits, additional surgical procedures are often employed to facilitate the placement of standard implants. These may include guided bone regeneration, block bone grafting, maxillary sinus lift, distraction osteogenesis, and nerve repositioning. These techniques aim to augment the available bone volume, create a favorable environment for implant placement, and overcome the challenges presented by the anatomical restrictions.

Short implants are often regarded as a simpler and more effective solution for rehabilitating the atrophic alveolar ridge. By minimizing the likelihood of complications, patient discomfort, procedure costs, and overall treatment time, they offer several advantages. In this context, however, it is worth mentioning that the categorization of a dental implant as "short" is subjective, and there are no universally defined criteria for determining the specific length that qualifies as a short dental implant. Recently, less than 8 mm- long short implants have been offered by implant companies.[9]

7. Tilted and Zygomatic implants

The utilization of a tilted or angulated implant in the posterior maxilla has been suggested as a potential alternative to sinus augmentation procedures. In the All-on-4 concept (a theory that uses four implants to restore total edentulism) for completely edentulous maxilla patients trans-sinus tilted implants are employed.

Zygomatic implants present an alternative to sinus augmentation procedures. They are lengthy implants travelling through the sinus or laterally into the sinus and are almost identical to trans-sinus tilting implants.[10]

8. Pterygoid implants

Pterygoid implants were introduced as another method of increasing the amount of bone that can be used for placement of implants in posterior maxillary region. The typical implant size for this method is between 15 and 20 mm. The implant enters the maxilla in the first or second molar region, following an oblique mesio-cranial direction. From there, the implant trajectory proceeds posteriorly toward the pyramidal process. Thereafter, it ascends between wings of the pterygoid processes and continues its course in the sphenoid bone to find anchorage in pterygoido scaphoid fossa.

The presence of dense cortical bone provides excellent engagement and stability for the pterygoid implants. That and an opportunity to obviate the requirement for maxillary sinus augmentation and other grafting procedures are two benefits of employing these implants.[11]

9. Tuberosity implants

Tuberosity implants are designed to be placed at the most distal aspect of the maxillary alveolar process, specifically targeting the tuberosity region. They are positioned to potentially engage the pyramidal process of the maxilla. Because of the dense bone present in this region, the difference in bony support for a pterygoid implant and a tuberosity implant can be significant.[11]

10. Utilizing three-dimensional printing for customized implants

The initial adoption of three-dimensional printing (3DP) for custom implants took place in the domains of rapid tooling and rapid prototyping. Digital scanning was combined with a CAD/CAM design and using 3DP, dental labs produced dental prostheses and patient models in significantly less time and with a precision that was unmatched by most traditional procedures. The combination of cone beam computed tomography (CBCT) and CAD/CAM was proposed to generate a surgical guide for precise implant placement.[12]

11. Transitional Implant

Their length varies from 7 to 14 mm, and diameter is between 1.8 and 2.8 mm. Transitional implants are manufactured using pure titanium and consist of a single-body design with a treated surface. They play an important role by absorbing the masticatory stress during the healing phase. This stress absorption helps promote a stress-free environment for the maturation of bone around the submerged implants, allowing them to heal smoothly and without complications.

Some commercially available Transitional Implant System include the Immediate Provisional Implant System–IPI by Nobel Biocare; Modular Transitional Implant System -MTI by Dentatus; and TRN/ TRI Implants by Hi Tec implants.[13]

12. Ligaplant

This technology involves the integration of periodontal ligament (PDL) cells with implant biomaterial. Research is currently being done to make this implant honourable. In Ligaplant, the PDL cells serve as a soft, vascular tissue that distributes forces, absorbs shocks, and provides proprioception for the tooth within its socket.[14]

13. Design Variables in Surface Area Optimization Thread Geometry

The market today offers a variety of implant systems with different implant thread configurations (Figure 1). The number of threads, width of the thread, depth of the thread, face angle of the thread and its pitch are among the various geometric combinations that affect final bone-implant contact (BIC) and distribution of load. A greater number of threads and increased thread depth provides greater available surface area for load distribution.[15]

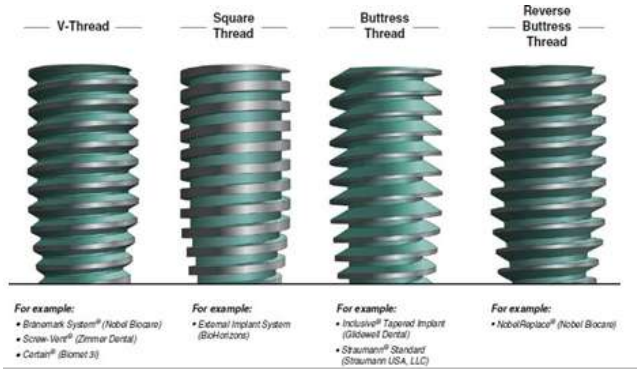

Fig. 1: Thread shapes of dental implants (V-thread, square, buttress, and reverse buttress).
Source: Grant Bullis .Functional Basis for Dental Implant Design. In: Misch,s Contemporary Implant Dentistry .4th ed. St Louis, USA: Mosby.;2021. p.48-68.

Implant threads are crucial for achieving primary stability, particularly in areas where bone quality is not good and for dissipating stresses at the bone-implant interface. This aids in minimizing the risk of complications and supports successful healing and integration of the implant with the bone.

The implant apical region should be tapered to assist insertion into the osteotomy and initial engagement of

threads of the implant. It should be either rounded or flattened to reduce the probability of perforating membranes during placement. It will have flat regions or grooves circumferentially arranged on the implant body to stabilize the implant against rotation after healing and to aid in insertion.[16]

14. Implant Crest Module and Abutment (Figures 2 and 3)

Current knowledge of prosthetic connections suggests that an internal prosthetic connection offers the best functionality. Of the internal prosthetic connection types in use today, the conical prosthetic connection have the best feature set, also conical prosthetic connections provide a stable abutment connection, lower peak bone stresses when positioned level to the marginal bone, and have a high resistance to axial loads. The Morse taper implant abutment connection features a tapered projection on the abutment that fits into a tapered recess in the implant. This creates a friction fit and cold welding to prevent rotation, providing stability during function. Taper angles vary, such as 8° in ITI Straumann or Ankylos, or 11° in Astra. The Bicon implant system has rounded channels with a 1.5 degree taper. When the cross section of the implant permits, platform shifting should be used to redistribute the stress away from the bone-implant interface. Platform shifting or using abutments with a diameter less than the implant collar is thought to be advantageous to maintain marginal bone levels while providing a biomechanical advantage in osseointegrated implants as it redirects the concentration of stress, taking it away from the cervical region of bone-implant interface; with an inverse relationship between the amount of implant-abutment diameter mismatch and cortical bone stress concentration.

Angled abutments, UCLA Abutment, Ceramic abutments, CERADAPT Abutment, and Multi- Unit abutment are recent advancements in implant abutments.[17]

Fig. 2: a): CAD/ CAM custom abutments. Left to right, posterior milled titanium abutment, anterior milled titanium abutment, and hybrid milled zirconia bonded to titanium abutment base. **b):** Multiunit abutments with screws.

Fig. 3: a): Stock/standardized healing abutments **b):** Custom healing abutment with ideal contours.
Source: Park NI, and Kerr M. Terminology in Implant Dentistry. In: Misch,s Contemporary Implant Dentistry .4th ed. St Louis, USA: Mosby.;2021.p.20-4

15. Implant Materials

Dental implants have been tested using various materials, including metals, alloys, ceramics, polymers, glasses, and carbon. Biocompatibility, bio functionality, availability, and the ability to Osseo integrate are specific characteristics needed for their manufacturing.

Materials for dental implants and the prosthetic components they support must adhere to several strict requirements. For dental implants, titanium alloys continue to have the finest mechanical and biocompatibility qualities, and their usage is recommended. Currently, commercially pure titanium, titanium alloys, and zirconia (zirconium dioxide, ZrO2), ceramic implants are the representative biomaterials in wide use for dental implant applications. Additional other advanced material are Zirconia Toughened Alumina (ZTA) and Alumina Toughened Zirconia (AZT), Poly-Ether-Ether-Ketone (PEEK), Powder Injection Molding (PIM), Tantalum Implants, Porous Tantalum Trabecular Metal (PTTM), LASER- LOK Technology.[18]

16. Surface Modification of Implants

Research has shown that microrough surfaces had higher degrees of bone-to-implant contact or BIC. These modifications can be divided into subtractive and additive processes, depending on whether material is removed or deposited on the implant surface in the development of the surface.[19] Plasma arc is an additive process that involves depositing a bioactive hydroxyapatite (HA) material onto the implant surface. Polishing, machining, and acid etching are subtractive procedures used for implant surface treatment. These treatments can be classified into various methods, including mechanical, chemical, electrochemical, electropolishing, vacuum, thermal, and laser techniques (Figure 4). Various modifications have been implemented to enhance the biological surface of dental implants, aiming to achieve optimal bone-to-implant contact.[20]

Surface treatments involving calcium deposition have shown increasing bioactivity over time, with the highest deposition observed in the sandblasted, acid-etched, and thermally oxidized group. This is in lieu of greater surface roughness that promotes cell adhesion, proliferation, and differentiation.[20]

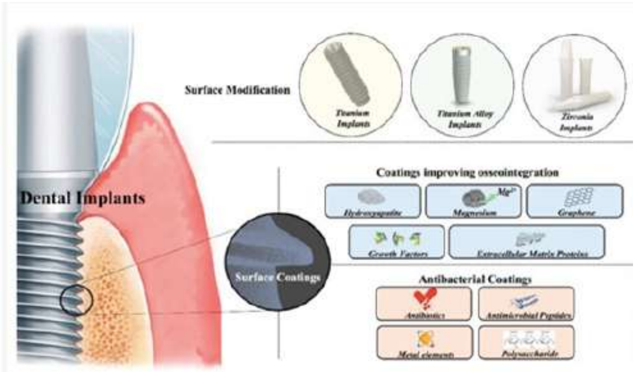

Fig. 4: Schematic illustration depicting surface modification and coatings of dental implants Source: Dong H, Liu H, Zhou N, Li Q, Yang G, Chen L, MouY. Surface Modified techniques & Emerging Functional Coating of Dental Implants. Coatings 2020, 10(11),1012:3-25

Recent studies have explored bioactive surface modifications of dental implants using inorganic materials (e.g., HA, calcium phosphate), growth factors, peptides, and extracellular matrix components. These approaches aim to enhance implant osseointegration and improve biological responses.[20] Research has shown the potential of utilizing stem cell-mediated bone regeneration for the treatment of peri-implant defects. However, stem cell implant technology is still in its early stages and is not currently a viable option for replacing missing teeth. Ongoing research hopes to enhance these techniques and develop more cost-effective procedures involving stem cells.[21]

17. Current Technologies for Implant Design and Placement Analysis

The success of dental implantation depends on accurate imaging. Cone Beam Computed Tomography (CBCT) utilising three-dimensional images is one of the newest technologies in dentistry imaging. This technology offers a continuous flow of data that allows dental surgeons to reconstruct images as needed, while minimizing radiation exposure for patients.[22,23]

18. Current developments in computed tomography technology include

1. (a) *Cone beam Computed Tomography:* This technology utilises a cone shaped beam of radiations. The image is reconstructed with special software. Comprehensive information like a Computed Tomography is obtained, albeit with 1/8th of radiation exposure and at minimal cost.
   (b) *Microtomograph:* This device helps in obtaining serial sections of the interface between implant and bone.
   (c) *Multislice helical CT:* This device has the advantage of providing high quality images when compared to Computed Tomography. It is referred as Dentascan Imaging.
   (d) *Interactive Computed Tomography:* This device develops image files that can be transferred from Radiologist to dentist's computer, who can work upon the case with precision and ease. Both the dentist and the radiologist work together and simulate placement of cylinders of arbitrary sizes in images, replicating root form implants, allowing for virtual surgical planning and an "Electronic Surgery".
   (e) *Magnetic resonance imaging (MRI):* This 3D non-invasive imaging method uses an electronic image acquisition process where image is produced digitally.

Better stability is made possible by the shape and configuration of implants, which is essential for the osseo-integration process. Refinement of drilling machines has led to better control over drilling speed and associated torque, which reduces risk of overheating the surrounding bone.[24] Improved control of water irrigation and the incorporation of internal implant irrigation systems also play a crucial role in minimizing the elevation of bone temperature during implant procedures. Additionally, the use of custom-made surgical splints, guided by CT data, assists in accurately defining the implant location and angulation, ensuring precise and optimal placement.[25]

Dental professionals and specifically prosthodontists have greater concern of the occlusal load on given prosthesis. Achieving precise dental implant alignment and connecting implants in a triangular configuration is crucial for the successful placement of fixed bridges in some cases. This configuration enhances stability and helps to resist lateral displacement forces.[26]

19. Peri implant surgery

It is common for tooth loss to be accompanied by the simultaneous resorption of the alveolar bone. As adequate implant width and length are crucial for long-term success of any implant, cases with insufficient remaining bone often pose a problem. The volume of the bone can be increased by varied techniques. For slight depressions, a simple onlay bone graft can be used while an inlay bone

graft can be employed where a sandwich osteotomy is required. Maxillary sinus floor augmentation can be used to increase bone volume in the upper jaw. Distraction osteogenesis is also a state-of-the-art procedure used for augmenting areas of bone. Now a days, osteo-inductive and osteo-conductive substances can help accelerate the healing process. Vestibuloplasty and palatal graft transplant are getting popular in cases where ablative surgery or tissue atrophy decreases the amount of available soft tissue. Free gingival graft transplant is a simpler procedure that produces less overall patient morbidity. Thus, the issues linked to either the soft tissue or bone deficit around the implant can likely be treated by combining several peri- implant operations.[27,28]

20. Image Guided Implantology

Image-guided implant surgery has experienced remarkable advancements in recent years. It involves two main types that utilize dedicated software for precise implant planning to define implant angulation and position, while avoiding contact with the maxillary sinus or with the inferior alveolar nerve. While one procedure consists of real-time navigational implant surgery, the other inserts implants using a surgical splint created using stereo lithography.[29]

Computer-designed surgical splints significantly expedite the implant placement process. However, any errors in planning or splint fabrication cannot be easily corrected during surgery. In such cases, surgeons may need to forgo the use of the splint altogether, potentially leading to incorrect implant placement.[30]

21. Conclusion

The future of dental implantology holds immense potential through continuous innovation and progress. Areas such as biomaterials, implant design, surface modification, and functionalization are critical for improving patient care and enhancing treatment outcomes. Advancements at every stage, including diagnosis, treatment planning, surgery, grafting, and implant designs, are essential for achieving successful long-term results in restoring missing dentition. By focusing on these areas of improvement, we can strive towards better patient outcomes and advancements in dental implant technology.

22. Source of Funding

None.

23. Conflict of Interest

None.

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Review Article

Current Concepts in Alveolar Ridge Augmentation

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Abstract

Ridge augmentation is a predictable procedure that can correct the defects caused by bone loss in areas with missing teeth. More importantly, this procedure allows the chance to return the natural contours of the soft tissues that existed before the loss of the tooth. It is done in patients with insufficient bone height and width by using various bone substitute materials and bone graft procedures where the successful placement of dental implants is difficult with regards to maintaining an ideal pathway and avoiding important anatomical structures. This review article will be carried out to describe the various techniques of ridge augmentation.

Keywords: Ridge Augmentation; Deficient Ridge; Hard and Soft Tissue Ridge Augmentation

Introduction

Periodontium is an important structure that provides support to the tooth necessary to maintain its function and is affected by any changes that the tooth may undergo, including eruption and extraction [1]. It consists of four principal components which includes gingiva, periodontal ligament, cementum and alveolar bone. Healing process occurring post extraction follows uneventful changes in the alveolar bone causing structural and dimensional changes in the overlying soft tissue [2]. These changes can occur in horizontal and vertical dimensions or both and may hamper with the functional and aesthetic success of prosthetic replacements including implants [3].

The predictability and technical difficulty of surgically reconstructing the ridge can be guided by classifications of ridge defects which are helpful to appreciate treatment modality chosen. According to Glossary of Prosthodontic Terms (GPT) 2009, Ridge augmentation is defined as a procedure designed to enlarge or increase the size, extent or quality of a deformed residual ridge [4]. Ridge augmentation is intended to augment the alveolar ridge volume beyond the existing skeletal envelop on the edentulous site of a deficient alveolar ridge with the variety of materials and techniques to optimize the ridge profile, to re-establish inter maxillary ridge correlation, confirm esthetic outcomes, achieve the biomechanical requisite of the prosthesis and to confirm osseointegration and persistence of Implant. The purpose of soft tissue preservation and bone formation is to provide stability and support for the future dental prosthesis. The sufficient horizontal as well as vertical bone dimensions are a prerequisite to warranty the success of implants.

Techniques For Ridge Augmentation

Ridge augmentation procedures are divided into vertical or horizontal ridge augmentation, which are performed simultaneously and are broadly classified into surgical procedures which undertakes hard tissue procedures, soft tissue procedures and both. Particulate or block autogenous bone grafts with ridge splitting or ridge expansion combined with Guided Bone Regeneration (GBR) are widely used in horizontal ridge augmentations. The outcomes and success rates are more predictable and higher when compared to vertical ridge augmentation. The reconstruction amount has an average 3 to 4 mm target in horizontal ridge

augmentations [5]. Historically, onlay grafts are performed as GBR with particulate or block type autogenous bone grafts in vertical augmentation which involves reconstruction of one wall defects.

1. Socket Preservation

Socket grafting is a preventive procedure for socket preservation at the time of extraction, which does not inhibit the resorption but limits it [6]. The minimal amount of resorption happens after socket grafting but in a predictable manner and the magnitude of volume loss is less in the grafted socket versus the naive socket. The rationale is that it should be performed in aesthetic areas in case of buccal bone thickness ≤2 mm or when there is a proximity to anatomic structures, i.e., maxillary sinus or mandibular canal [7].

2. Hard Tissue Augmentation Procedures

a. Guided Bone Regeneration

The application of GBR was described in 1988 by Dahlin, et al., in an experimental study on animals to see the results of healing of bone defects in which the defect on one side of the jaw was covered with a porous Polytetrafluoroethylene (PTFE) membrane and the other side served as the control, without a membrane covering [8]. The results showed that there was increase in bone regeneration on the membrane side as compared to the control after 3, 6 and 9 weeks of healing. GBR, also known as guided bone regeneration, is an evidence based predictable approach for separating the bone graft material (usually particulate) from neighboring soft tissues to allow unimpeded bone formation. The graft material is covered by securing a membrane to stabilize the material, parting it from adjacent connective tissues and limiting resorption. The volume stability of the graft in defect is the main factor on which the choice of membrane depends. Osseous regeneration by GBR depends on the migration of pluripotent and osteogenic cells (e.g. osteoblasts derived from the periosteum and/or adjacent bone and/or bone marrow) to the bone defect site and exclusion of cells impeding bone formation (e.g. epithelial cells and fibroblasts) [8-11]. There are few principles which need to be met to ensure successful GBR: Cell exclusion in which the barrier membrane is used to prevent gingival fibroblasts and/or epithelial cells from gaining access to the wound site and forming fibrous connective tissue; Space maintenance (Tenting) in which the membrane is carefully fitted and applied in such a manner that a space is created beneath the membrane which completely isolates the defect to be regenerated from the overlying soft tissue and also the membrane should be trimmed so that it extends 2 to 3 mm beyond the margins of the defect in all directions. The corners of the membrane should also be rounded to prevent inadvertent flap perforation; Scaffolding is one of the principles of GBR in which tented space initially becomes occupied by a fibrin clot, which serves as a scaffold for the in-growth of progenitor cells; Stabilization in which the membrane must protect the clot from being disturbed by movement of the overlying flap during healing and then fixed into position with sutures, mini bone screws or bone tacks. The edges of the membrane are simply tucked beneath the margins of the flaps at the time of closure, providing stabilization; Framework is necessary in cases of dehiscences or fenestrations where the membrane must be supported to prevent collapse [12]. Bone regeneration follows a specific sequence of events after GBR procedures. After the bone graft, the graft material/barrier created space is filled with the blood clot within the first 24 hours, which releases growth factors (e.g., platelet derived growth factor) and cytokines (e.g., IL-8) to attract neutrophils and macrophages. The clot is absorbed and replaced with granulation tissue which is rich in newly formed blood vessels. Through these blood vessels, nutrients and mesenchymal stem cells capable of osteogenic differentiation are transported and contribute to osteoid formation [13,14].

b. Onlay Grafting

Onlay grafting is indicated in cases of inadequate palatal vault morphology which is caused by excessive bone resorption. It can either be block onlay grafting or particulate onlay grafting. The latter can further be categorized as subperiosteal tunnel grafting or direct particulate onlay grafting

i. Block Onlay Grafting

Indication

It is done for horizontal or vertical deficiency or combined horizontal and vertical deficiency.

Technique

This is one of the most commonly employed technique. The block graft can be autogenous graft harvested from neighbouring intraoral donor sites, distant extraoral donor sites or commercially available xenografts or alloplastic grafts [15]. The recipient bed is prepared by drilling multiple holes after raising the mucoperiosteal flap till the underlying spongiosa is reached (Fig. 1).

Depending on the type of defect, the graft is contoured to adapt in proximity to the recipient site as veneer, block or inverted J Block graft which is placed for the vertical defects while veneer graft is used in the case of horizontal defects. For combined defects, the graft is modified to the shape of the inverted letter J [16-18]. Defects augmented using autogenous onlay grafts provide a labial cortex of bone capable of resisting occlusal loads, especially in the anterior dentition [19].

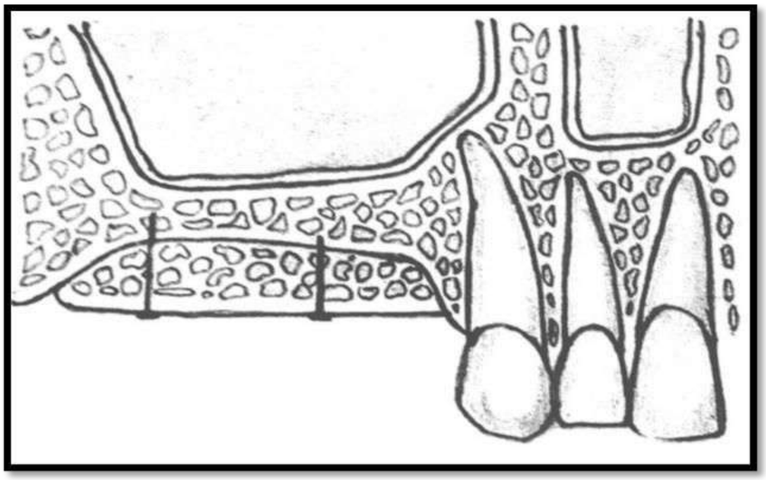

Figure 1: Block Onlay graft (Source: Goyal M, Mittal N, Gupta GK, Singhal M. Ridge augmentation in implant dentistry. J Int Clin Dent Res Organ 2015;7:94-112).

ii. Direct Particulate Onlay Grafting

Indication

It is performed to correct horizontal deficiencies in the anterior maxilla and for saddle depressions, i.e., vertical deficiency. Three-walled and four-walled defect morphology recipient sites with an apical stop are considered to be best amenable to direct particulate onlay grafting.

Technique

It is performed as a staged or simultaneous procedure (Fig. 2). To visualize the defect, the planned recipient area is exposed by raising a mucoperiosteal flap. The releasing incisions should be placed to ensure direct visualization of the defect and tension-free closure. The particulate graft is condensed over the defect after drilling holes in the recipient bed to ensure osseointegration. Demineralized grafts are preferred over mineralized grafts for defects with poorly contained boundaries, (i.e., maxillary sinus) due to their slower resorption [12]. The coverage with membranes is often recommended but can be omitted for small defects with sufficient neighbouring walls to provide volume stability [20,21]. The malleability and workability of particulate graft can be enhanced with tissue adhesives, i.e., fibrin sealants or protein-based regenerative gels.

Figure 2: Particulate graft (Source: Goyal M, Mittal N, Gupta GK, Singhal M. Ridge augmentation in implant dentistry. J Int Clin Dent Res Organ 2015;7:94-112).

iii. Subperiosteal Tunnel Grafting

Indication

It is indicated for small to moderate buccal plate defects. The morphology of such defects is characterized by wider buccal base with narrow crestal width (≤4 mm) and intact lingual wall with optimum vertical dimensions [22].

Technique

Access incision is placed distant (often mesially) from the recipient site after administration of local anesthesia, Subperiosteal tunnelling from the incision to graft site is performed with the help of a periosteal elevator. The demineralized particulate bone graft is placed in this subperiosteal tunnel with the help of modified 1 ml carrier syringe. To conform to the recipient bed in the desired form, the graft may need digital manipulation. The mesial incision is closed in a tension-free manner to ensure uneventful healing with minimal risks of dehiscence and graft exposure.

c. Interpositional Bone Graft (Sandwich Grafting)

Indication

It is indicated for vertical ridge defects with alveolar dimensions of 4-5 mm by placing two different layers of bone grafts and then cover them with a barrier membrane, creating a structure like the cross-section of the bone [22].

Technique

The facial aspect of the planned area of augmentation is exposed by giving a vestibular incision in nonkeratinized mucosa. Vertical corticotomies and osteotomies are performed using micro reciprocating and sees to the preservation of ≈2 mm of bone around the roots of neighbouring teeth followed by horizontal corticotomy and osteotomy to mobilize the segment.

There should be a minimum clearance of ≈3-5 mm from vital structures such as the maxillary sinus or mandibular canal. It is critical to perform only as much advancement as permitted by the soft tissue envelope to achieve tension-free closure. After careful transportation preserving soft tissue attachments, the bone graft block is sandwiched between the transported segment and basal bone with the advantages of reducing the need for compliance and less infection [23]. The graft fixation is achieved with miniplates. Periosteal releasing incisions are placed to aid tension free closure.

d. Ridge Split Procedure (RSP) (Fig. 3)

Indication

It was introduced in 1970s by Dr. Hilt Tatum to expand the existing residual ridge of the atrophic maxilla and mandible for implant insertion and augmentation has been referred to as ridge splitting, bone spreading, ridge expansion or the osteotome technique [24]. It is also known as Book Bone Flap. It is a technique-sensitive procedure that may be performed with many different instruments, ranging from chisel and mallet to scalpel blades, spatula, osteotomes, piezoelectric surgical systems, lasers and ultra-fine fissure burs. Osteotomes are the most popular used for ridge expansion ones amongst the various instruments and chisel and (hand) mallet are traditionally used devices [25,26].

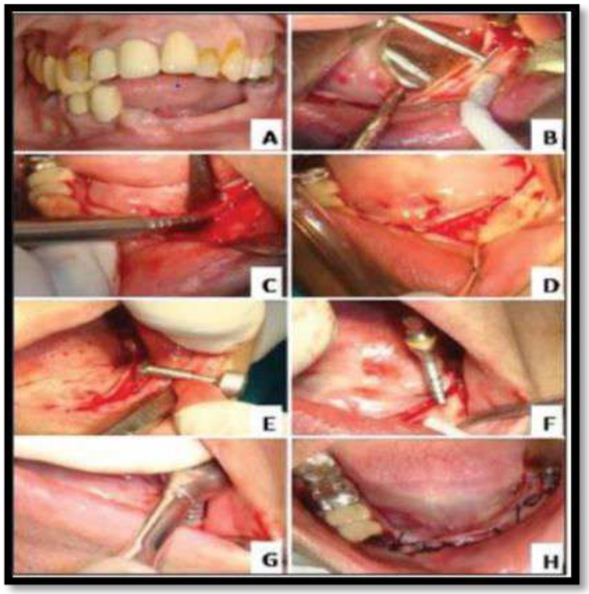

Figure 3: Ridge split. (A) thin alveolar ridge; (B) ridge split using MCT disk (3-mm radius); (C)expansion using rigid osteotome; (D)flexible chillet; (E) MCT ridge splitter; (F) bone expanders; (G) implant placement; (H)closure (Source: Goyal M, Mittal N, Gupta GK, Singhal M. Ridge augmentation in implant dentistry. J Int Clin Dent Res Organ 2015;7:94-112).

Technique I: Maxillary Single-Stage Alveolar RSP

This procedure usually consists of a single-stage, though occasionally a two-stage technique can be performed with the delayed placement of implant. 3 mm of alveolar width and 7 mm of alveolar length (between teeth) should be present for a single-tooth edentulous ridge to undergo RSP. The buccal-palatal dimension can be decreased and a full thickness incision of the appropriate length is performed in the edentulous area at the crest of the ridge. It is recommended to use a papilla-preservation approach. The developed flap is a limited crestal (not buccal) full-thickness flap just large enough to see the top of the alveolar crest with no formation or wide reflection of the buccal flap should occur.

Technique II: Mandibular Two-Stage Alveolar RSP

In the mandible, the procedure usually has 2 stages: stage 1 consists of corticotomy and stage 2 consists of splitting and grafting, which is performed 3-5 weeks later.

Stage 1: Corticotomy

The goal of corticotomy is to section through the exposed buccal cortex around the periphery of the buccal bony plate, which is to be laterally repositioned at the stage-2 surgery.

Stage 2: Splitting and Grafting

This procedure is done in a manner similar to a single stage of the maxillary ridge split, using a limited-reflection flap. A crestal incision just wide enough to see the crestal corticotomy is performed (closed approach). The operator should feel for the crestal groove created at the stage-1 surgery with the scalpel blade. The blade should be held firmly in this groove and run the full extension of this bony groove. Papilla-sparing curved incisions should be created toward the buccal and lingual side at the mesial and distal extensions of the groove. Tissue should be reflected to the lingual side as needed, but the tissue on the buccal side should only be elevated at the points where the buccal curved incisions are carried onto the adjacent bone. The spatula osteotome is tapped to depth with the osteotome of the next thickness and a controlled lateral force should begin to be used to mobilize the buccal plate. Thus, a buccal mucoosteo-periosteal flap with its own buccal soft-tissue blood supply is created and can be manipulated (widened). An overall ridge expansion up to 8-10 mm is usually adequate and grafting is performed. Primary closure of the wound is not needed nor is it usually possible. A 4 to 6 month waiting period is suggested before an implant treatment. The most common regions of the jaws that undergo RSP are the anterior and posterior maxilla and the posterior mandible [27].

RSP Using Piezosurgery

A papillary sparing crestal incision is performed on the atrophic ridge under local or general anaesthesia followed by two vertical releasing incisions beyond the mucogingival line. A full thickness mucoperiosteal flap is raised and when the bone surface is exposed, the planned osteotomies are outlined using tip number one at low power, in order to avoid oscillation of the tip and obtain a cut depth 1 mm [28]. Care must be taken to keep the lingual/palatal periosteum attached to the bony surface. The first osteotomy is carried out at the centre of the occlusal aspect of the ridge by tracing it, extending the incision in anteroposterior direction for the planned length. Subsequently, the vertical osteotomies are performed on the proximal and distal ends of the crestal incision. In surgical procedure, the vertical osteotomies are convergent and oblique, going from the outer surface of the vestibular cortex to the cancellous bone. The distance between the two vertical osteotomies is greater on the outer side than on the inner side of the vestibular cortical plate. The osteotomy lines should be traced using the tips progressively in order of size, varying the power level of the characteristics of the incision change too [29]. The tips are used in progression from number one to number five to deepen the osteotomies. As the groove on the bone surface becomes retentive, the tips can be used at high power resulting in more aggressive and faster cutting. The tips are calibrated to achieve the exact depth of cut desired but, if the cortical width exceeds 5 mm, a normal tip or chisels can be used to complete the osteotomy. Once the desired depth of the crestal and vertical osteotomies are achieved, the caudal ends of the vertical osteotomies are connected by a horizontal incision and the incision is a partial thickness osteotomy. The greenstick fracture is made using chisels. A cortical bone graft of appropriate size and shape is harvested from the ipsilateral mandibular ramus by means of the aforementioned tips and chisels. Bone chips are collected from the same donor site. The cortical graft is gently hammered between the vestibular and lingual cortex, acting as a bone wedge until the desired separation of the two cortices is reached. It is then stabilized using titanium osteosynthesis screws. In order to obtain supracrestal regeneration, the bone graft between the vestibular and lingual/palatal cortices can be fixed at a higher level in order to let it protrude from the occlusal aspect of the two bone plates. Finally, the grafted site is covered by a resorbable collagen membrane. The mucoperiosteal flap is repositioned and sutured.

e. Distraction Osteogenesis

Indication

It was developed by Gavriel Ilizarov in 1989 to treat skeletal deformities which works on principle of "tension-stress" with slowly incorporated tensile stress promoting histogenesis [30]. Bone traction generates tension and promotes osteogenesis, which occurs parallel to the distraction site and can be in vertical and/or a horizontal direction.

Technique

This technique allows significant augmentation of both hard and soft tissues in areas with extensive tissue loss in a staged manner [31-34]. A transport segment is mobilized in a similar manner as for interpositional bone grafting, preserving attachment to the crestal and lingual tissues.30 The distractor is fixed to transport basal bone segments with approximately 1-2 mm gap between the two segments. This is left in situ for a latency period of 5-7 days to allow the formation of soft tissue callus between the two segments and then activation is started at the rate of 0.5-2 mm/day for periodic distraction. After completion of the desired amount of distraction, the distraction device is removed and quality of the bone is explored. The newly formed bone is hourglass shaped and placement of additional grafts may be required for proper implant placement at this time. The implant placement is performed after a period of 4-6 months. It undergoes a more active remodeling process because of the better vascularization when compared to a block graft and minor complications could be averted using an appropriate technique [35,36].

f. Orthodontic Extrusion

In this method, forces are applied to the periodontally hopeless teeth, which brings the alveolar bone along with it. Elongation of the tooth in its alveolus causes shifting of gingival and Periodontal Ligament (PDL) fibres. The slow orthodontic extrusion technique is used to obtain a good amount of hard and soft tissue before dental implant placement. This technique avoids the surgical steps of the bone regeneration technique and is more simply managed by the clinicians. However, this technique requires more time to see the final results compared with surgical Guided Bone Regeneration (GBR). It is a non-traumatic technique whereas GBR is usually associated with pain and swelling in the immediate post op period [37,38].

g. Sinus Lift Procedure

It was proposed by Tatum for implant placement when there is insufficient bone between the maxillary alveolus and sinus [24]. The two procedures of sinus lift available are lateral window technique (lateral or direct sinus lift) and crestal approach (crestal or indirect sinus lift) [39-44].

Crestal Approach (Indirect Sinus Lift)

Indication

It is indicated when the Residual Alveolar Bone (RAB) is less than 6-8 mm.

Technique

After local anaesthesia is given, a pilot drill is used, followed by drills in increasing diameters and the osteotomy site is prepared. Care is taken to ensure that the drill length is maintained at 2 mm away from the floor of the sinus. As drills of higher diameter are introduced, it is observed that the sinus floor gets fractured and the sinus is slowly elevated to avoid injury to the Schneiderian membrane, by using a surgical mallet/osteotome with controlled force. Autogenous graft material is inserted within the socket, if required.

Lateral Window Technique (Direct Sinus Lift)

Indication

It is indicated when the residual alveolar bone is 5 mm or less.

Technique

A full-thickness flap is raised giving a crestal incision and a vertical releasing incision. The bone is exposed and sometimes a bluish hue is seen on the bony surface, which is indicative of the sinus. Then a window is made either using bur or piezosurgical instruments to delineate the sinus. After the window is prepared, it is slowly disengaged to expose the sinus. Care is taken to avoid perforation of the Schniederian membrane that lines the sinus. The sinus is then slowly elevated using the appropriate sinus lift instruments. If the window created has not been totally disengaged, it could be placed below the relocated sinus to form its floor. The empty void created between the elevated sinus and the basal bone is filled with either autologous or allogeneic graft material and a membrane is stabilized over it.

3. Soft Tissue Augmentation Procedures

a. Onlay Graft Procedures

Indication

It was first described by Seibert in 1983 for correcting horizontal deficiencies in the anterior maxillary arch and for saddle depressions, i.e. vertical deficiency [45,46].

Technique

A recipient bed is prepared with two parallel split-thickness incisions in the lamina propria of the edentulous area and the epithelium is removed in order to expose the underlying connective tissue. A free gingival graft is then harvested from the palate and secured on the recipient vascular bed with interrupted and compressive sutures, with the amount of augmentation depending on the thickness of the applied graft. There is no shrinkage of the tissue grafted, but a varying amount of volume is lost during the healing phase for which, it is frequently necessary to repeat the surgical procedure at 2 to 3 month intervals in order to reach the desired ridge height [45-48].

b. Roll Flap Technique:

Indication

It was introduced by Abrams in 1980 to correct small or moderate soft tissue defects associated with buccolingual defects of ridge [49].

Technique

It involves a connective tissue pedicle flap that originates from the de epithelialization of the palatal tissue close to the edentulous area in which two parallel incisions are made from the occlusal edentulous area towards the palate and connected with a horizontal incision. A split-thickness palatal flap is then elevated and a pouch is prepared in the defect area with a split dissection of the supra periosteal connective tissue. The palatal flap is 'rolled' into the pouch area and then sutured [50].

Modified Roll Technique

Indication

This technique is a modification of the roll technique which was introduced by Scharf and Tarnow for class I deformities wherein the epithelium over the connective tissue is not scraped but preserved to cover the donor site [51].

Technique

An incision is made using a Bard-Parker blade from the crest to the palatal area to include a sufficient length of the tissue to be rolled to the desired area on the buccal aspect. A similar incision is made on the other side to include sufficient width of the graft and the two vertical incisions are connected by a horizontal incision. A partial-thickness trap door-type flap is reflected. The pedicle is rolled on the buccal aspect and stabilized using a horizontal mattress suture.

c. Interpositional (Inlay) Graft Procedures

Indication

It was described in 1979 by Meltzer which involves the placement of graft without scraping the epithelium from the connective tissue to treat buccolingual and apicocoronal ridge defects [52].

Technique

A pouch is prepared in the defect area and a free graft derived from the palatal or maxillary tuberosity is harvested which is partially de-epithelialized and the exposed connective tissue is inserted in the pouch area like a wedge (inlay graft). Thus, the epithelialized part of the graft remained outside the pouch and sutured at the level of the epithelial surface of the surrounding tissues [45,46,52-54].

d. Combination Onlay-Inlay Grafts

Indication

It was introduced by Seibert and Louis in 1996 to treat buccolingual and apicocoronal ridge defects [55].

Technique

It is done to obtain simultaneous tissue augmentation in the horizontal and vertical dimensions. The donor site is prepared with a full-thickness coronal dissection and a partial thickness apical dissection. The graft is thus composed of two parts: the coronal part, which is epithelialized and the apical part, which is formed of connective tissue only. On the defect area, the crestal surface is de-epithelialized with a beveled incision and the apical surface is prepared with a partial-thickness dissection with two vertical-releasing incisions extended apically, without involving the adjacent papillae to create a pouch area. The onlay section (epithelialized area) of the graft is sutured on the crestal surface of the defect, while the inlay section (connective tissue) is inserted and secured in the vestibular pouch area.

e. Pouch Procedures

Indication

It was put forward by Burton Langer and Lawrence Calagna to treat ridge deformities in which a connective tissue graft was procured from the palatal area or maxillary tuberosity to increase the thickness of the soft tissue on the buccal surface of ridge [56,57].

Technique

A pouch is prepared with a split dissection of the supra periosteal connective tissue and the connective tissue graft is sutured to

the periosteum and then the flap is sutured in its original position and covers the connective tissue graft completely.

Discussion

The onlay technique is done mostly with an autogenous bone graft. Before the year 2000, most implants were immediately placed together with the bone grafts. The implants were used to secure the graft. The capacity and volume of the bone grafts are variable between the studies. These differences could be explained by different follow-up periods, timing of implants placement, different sites and different bone grafting material. Over all the resorption rate is higher in the first year, but stabilizes after it [18].

Alveolar distraction is only indicated for the mandible because of the pneumatization of the sinus in the maxilla. A disadvantage is the early resorption of the distracted bone. It undergoes a more active remodeling process because of the better vascularization when compared to a block graft as reported by Hodges NE [35].

The ridge split technique has been used in horizontal deficiency requiring 2-5 mm of augmentation. It is a minimally invasive technique indicated for alveolar ridges with adequate height, which enables immediate implant placement and eliminates morbidity and overall treatment time. The classical approach of the technique involves splitting the alveolar ridge into 2 parts with use of ostetomes and chisels. Tatum developed specific instruments including tapered channel formers and D-shaped osteotomes to expand the resorbed residual ridges of both the upper and lower jaws having a ridge width of <3 mm [24-26].

Ridge Expansion is indicated in patients with ridge width <6 mm. A full-thickness flap is raised to expose the bone. Scipioni, et al., reported a 98% 5-year implant survival rate when utilizing ridge expansion with simultaneous implant placement [58]. The split-crest technique had previously been compared to lateral ridge augmentation with autogenous bone block graft disclosing no significant differences in implant survival between the two treatment modalities, although the gain in alveolar ridge width was significantly higher with lateral ridge augmentation with autogenous bone block graft [59].

Liu J, et al., stated that guided bone regeneration is a surgical procedure that uses barrier membranes with or without particulate bone grafts or/and bone substitutes [60]. Wang HL, et al., stated that four principles need to be met to ensure successful GBR [13]. Sandwich grafting is done with vertical ridge deficiency with preexisting minimal vertical alveolar dimensions of 4-5 mm and without any soft tissue deficit. Choi BH, et al., concluded that sandwich osteotomy combined with interpositional allografts technique was safe although it leads to some resorption of the superior and anterior parts of the alveolar fragment [23].

Interpositional graft procedures were described by Meltzer which involves the placement of graft without scraping the epithelium from the connective tissue to treat buccolingual and apicocoronal ridge defects [52]. Tatum proposed a technique, "sinus lift procedure", for implant placement when there is insufficient bone between the maxillary alveolus and sinus [24]. Alveolar height <10 mm is often an indication for sinus lift surgery via the crestal (indirect) approach, while alveolar height <5 mm via is an indication for the lateral (direct) approach.

In orthodontic extrusion, forces are applied to the periodontally hopeless teeth, which will bring the alveolar bone along with it. Salama and Salama have documented clinical cases employing forced eruption on hopeless teeth to augment bony tissues in implant sites and also proposed a classification for extraction socket according to their morphology and placement of the implant into the socket [37]. PDL cells play a crucial role at a molecular level, thereby aiding in optimal results after implant placement [38].

The Roll technique introduced by Abrams was employed to correct small or moderate soft tissue defects associated with buccolingual defects of ridge [49]. Padhye, et al., compared the Subepithelial Connective Tissue Graft (SCTG) and buccally displaced flap [61]. The results showed that there was an increase in the width and thickness of keratinized mucosa in the buccally displaced flap group than the SCTG group, with reduced surgical sites, less postoperative pain and good blood supply. Pouch procedures were put forward by Burton Langer and Lawrence Calagna to treat ridge deformities in which a connective tissue graft was used which was procured from the palatal area or maxillary tuberosity to increase the thickness of the soft tissue on the buccal surface of ridge [56,57].

Conclusion

Reconstructive surgical procedures aimed at restoration of the alveolar ridge to its former dimensions are increasingly prescribed, particularly in the anterior region where esthetic issues are concerned. Nevertheless, there is a lack of clinical studies in the literature investigating this concern and therefore evidence- based conclusions cannot be drawn. Furthermore, because of the high esthetic impact it is advised that patient-centered outcomes be incorporated in clinical trials.

Conflict of Interests

The authors have no conflict of interest to declare.

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(57) Abstract :
Recent days have seen a steep rise in oral and dental diseases among people living especially in low- and middle- income countries, where the access to oral and dental health diagnosis and treatment are limited. According to World Health Organization Oral Health Status Report, nearly 3.5 billion people are affected by oral and dental health diseases worldwide on 2022. Dental Plaques may lead to various other diseases such as periodontitis, gingivitis and caries. Hence, devising a system and method for plaque detection is very important to ensure oral health of children. Proposed is a System and Method for Plaque Detection on Primary Teeth in Children using Machine Learning. Intraoral camera captures the photo of primary teeth image and the same is subject to data preprocessing to remove any unnecessary noise signals. Convolutional Neural Networks consists of alternative convolution and pooling layers for plaque detection on primary teeth. Initial weights of the neural networks are obtained using transfer learning methods. Developed Machine Learning model detects plaque using Backpropagation Learning.

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(57) Abstract :
One of the most common non-commutable types of chronic inflammatory disease is Periodontitis. It is the sixth most common disease affecting nearly 750 million population worldwide every year. It is very important to treat such Intrabony Osseous Defects, as if left untreated, it may lead to increased risk of disease progression sometimes leading to loss of teeth. Research studies suggest that piezoelectric surgical instruments with accurate precision would provide correct prediction of periodontal osseous defects. Any immediate reduction in periodontal dental angulation could be detected by bone swaging. Proposed is a System and Method to Detect the Depth of Intrabony Osseous Defect using Machine Learning. Input Cone Beamed Computed Tomography (CBCT) which provides inter-relational images in three orthogonal planes namely axial, sagittal and coronal and also customized planes are subject to Image Pre-Processing. Images are converted to Gray Scale and Binarization of images is carried out using Social Edge Detection to increase the object recognition rate. Target object recognition is trained using Convolutional Neural Networks. Multiclass Classifier and Bounding Box Regressor employed for each convolutional and pooling layers for accurate detection of depth of intrabony osseous defects.

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Review Article

Piezosurgery in periodontology

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ABSTRACT

Piezosurgery is a relatively new method derived from the Greek term “piezein” which means “to press tight or to squeeze”. Tomaso Vercellotti an italian physician invented it. He teamed up with Mectron Medical Technology, a medical device company was founded by Italian engineers Fernando Bianchetti and Domenico Vercellotti. It is a technique conceived to overcome the limitations of traditional bone cutting instruments in order achieve the most effective treatment with minimal amount of morbidity. It is used for bone removal and bone recontouring procedure on the principle of ultrasonic vibration. Piezoelectric effect generates an electrical charge when subjected to mechanical stress.

1. Introduction

Over the past years dentistry has underwent lots of advancement in day to day life. Various diagnostic imagining technique such as Ultrasonography, Cone Beam Computed Tomography, LASERS, Implants, Microsurgery and Nanotechnology had made the dentistry front runners in the medical field. Traditionally, osseous surgery has been performed with hand instruments (chisel, osteotome or mallet) or various motorized equipment that can be powered by air pressure or electrical energy. Manual hand cutting instruments take much longer time to yield desired results and often difficult to apply in many osseous surgical procedures. Motorized devices have rotary, reciprocal or oscillatory movements that have certain disadvantages such as: necrosis occurs due to overheating of bone tissue; loss of perceptivity to a gentle touch due to pressure on the handpiece; cutting depth is difficult to determine; iatrogenic impairment in undesirable areas due to a failure in the accurate adjustment of the speed of a rotating head or saw; and the risk of soft tissue injury to important anatomical structures such as the inferior alveolar nerve or the maxillary sinus.[1]

2. Objectives

To overcome the limitation of traditional instruments, researchers have surpassed advanced therapeutic devices that function on the idea of ultrasonic microvibrations to cut bone precisely in harmony with the surrounding tissue.[2]

Rationale of the study is to delinate the piezosurgery invention, its indication and contraindication, armamentarium, application of piezosurgery in periodontology and its limitation.

3. Piezosurgery

Piezosurgery is a method used for bone removal and bone recontouring that uses the principle of ultrasonic vibration. The word “piezo” derived from the Greek word piezein which means “to press tight or to squeeze.”[3] The Piezoelectric effect is the property of certain materials to

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produce an electrical charge in response to an applied mechanical stress. It was innovated in 1988 by Professor Tomaso Vercellotti and was developed by Mectron Medical Technology.[4] He proposed the idea of using sharpened instruments fitted on ultrasonic device for ablation to perform peri radicular osteotomy to extract an ankylosed tooth. Vercellotti et al. (2000) have revised this method for nerve and soft tissue protecting surgery that has overcame the limitations of traditional instruments in oral bone surgery. Mectron (2000) developed the first generation piezosurgery device.[5,6]

4. Historical Background

Piezoelectrical device was first discovered in 1880 by Jacques and Pierre Curie. They found that applying pressure to different crystals, ceramics, and bone produces electricity. In 1881, Gabriel Lippmann found the converse piezoelectric effect.[7] In 1927, Wood and Loomis explained the physical and biological impacts of high frequency soundwaves.[8] Pohlman used ultrasound on human tissues to treat myalgias and neuropathic pain in 1950.[9,10]In the same year, Maintz demonstrated a beneficial effect on bone regeneration and healing.[11]In 1952, Blamuth introduced an ultrasonic device which was used in dentistry for cavity preparation.[12] Catuna was the first person to use ultrasound in the field of dentistry specifically for preparing dental cavities. This resulted in the introduction of high-speed rotary instruments. In 1955, Zinner introduced the first ultrasonic scalers in periodontal procedures. Richman MJ was the first to disclose the surgical use of an ultrasonic chisel without slurry to remove bone and resect roots in apicoectomies in 1957.[13] Mcfall TA et al in 1961 evaluate distinction of healing by comparing of rotating instruments and oscillating scalpel blades and found a slow healing with no severe complications by use of these scalpel blades.[14]Horton JE et al in 1980 ultrasonic devices improves bone regeneration.[15]

In 1997, Vercellotti was the first who introduced the use of an ultrasonic device for ablation fitted with a sharpened insert, such as a scalpel blade, to perform periradicular osteotomy to extract an ankylosed root of a maxillary canine. Piezosurgery an ultrasound device in 1998 was introduced in medical field by Vercellotti for different procedures such as for hard tissue surgery. In 1999, Tomaso Vercellotti invented Piezoelectric bone surgery in collaboration with Mectron Spa and published about this topic in year 2000.[16]

In 2000, Vercellotti et al. renewed the approach for nerve and soft tissue protecting surgery to overcome the limitations of traditional instruments in oral bone surgery. It was first reported for pre-prosthetic surgery, alveolar crest expansion, and sinus grafting. Mectron developed first generation piezosurgery device in 2000. Vercellotti et al developed a suitable device for routine work in oral surgery that replaced conventional osteotomy instruments in 2001. The first sinus lift and bone block grafting surgeries employing piezosurgery was performed in 2001 and 2002. In 2003, Vercellotti used piezosurgery in animal studies to compare its traumatic impact with that of traditional orthopaedic surgery and reported that it allows for more accurate cuts and a clearer view of the operative field.

In 2004, Mectron introduced Second generation of piezosurgery device. Ultrasonic osteotomy was utilised to relocate the inferior alveolar nerve (IAN) by Bovi in 2005.

The same year first implant site preparation was performed by using piezosurgical device. In the same year, the US Food and Drug Administration extended the use of ultrasonics in dentistry to encompass bone surgeries.[17] In 2006, first ultrasound osteotomy in hand surgery was performed by Hoigne et al.[18] Third generation piezosurgery device was introduced in 2009, and a clean, precise technique of harvesting bone grafts from mandibular ramus was given by Happe A.

5. The Piezosurgical Armamentarium

Piezoelectric devices consists of:

5.1. *Main body*

Display screen, electronic touchpad, peristaltic pump, stand for handle, and stand for irrigation fluid bag are the constituents of the main body. For selecting the operating mode, particular programme, and coolant flow, the interactive touchpad comprises four keys. Every command is displayed on the screen.[18]

The main unit has three different power levels:[19]

1. Low Mode: It is utilised for orthodontic treatment and apico-endo-canal cleaning procedures
2. High Mode: It is used to clean and smooth the radicular surfaces
3. Boosted Mode: Is used in bone surgeries, osteotomy and osteoplasty procedures.

5.2. *Peristaltic pump*

Peristaltic pump contains an irrigation solution that flows at an adjustable rate of 0–60 ml/min to cool the cutting area and remove debris. The solution is refrigerated at 4°C to provide a cooling effect, and the volume of liquid can be adjusted with the + and - buttons.

5.3. *Hand piece*

Piezosurgical device consist of two hand pieces. The handpiece is firmly connected to the cord, which may be sterilised together.[20]

5.4. Handle

The cutting action is based on ultrasonic waves that travelling via piezoelectric ceramic within. These ceramic plates are created by an external generator and alter in volume to produce ultrasonic vibrations. They are channelled into the amplifier, which transmits them to the handle pointed end. A specific key is used to clamp the insert for this function.In this manner, the optimum efficiency for cutting and insert duration is accomplished.[21]

5.5. Foot pedal

Handpiece is controlled by an adjustable pedal on the base.

5.6. Base unit

The power is supplied by the base unit which also have the holder for handpiece and irrigation fluids. The device has display that allows the operator to select between the BONE cutting mode and ROOT operating modes. Using a specific selection for the type or density of the bone, the BONE cutting mode is utilised to cut bone. For endodontic and periodontal root treatments, the ROOT mode is utilised to shape, clean and smooth the root surfaces.

5.6.1. Bone mode

Bone mode are characterized as extremely high ultrasonic power compared to root mode.[22] Its performance is monitored by several advanced software and hardware controls. Due to excessive frequency modulation, mechanical ultrasonic vibration are unique for cutting different kinds of bone.

The selection recommended are:[23]

1. Quality 1: Cutting cortical bone or high density cancellous bone.
2. Quality 3: Cutting low density cancellous bone.

5.6.2. Root mode

The vibrations generated by selecting root mode have an average ultrasonic power without frequency over modulation.[22]

Root operating mode consists of two different programs:[23]

1. Endo program: A limited level of power provided by applying a reduced electrical tension to the transducer, which generates insert oscillation by a few microns. These mechanical micro-vibrations are ideal for irrigating the apical part of the root canal in endodontic surgery.
2. Perio program: An intermediate power level between the endo program and the bone program. The ultrasonic wave is continuosly transmitted through the transducer in a continuous sinusoidal manner, characterized by a frequency equal to the resonance frequency of the insert used.

A special program is designed with a slightly lower standard power than the bone programs has the same frequency over modulation. A special program is dedicated to a limited series of particularly thin and delicate surgical insertstips. These are only recommended for surgeons experienced in piezosurgery and who want an extremely thin and efficient incision.

5.6.3. Inserts tips

The Mectron Medical Technology has developed the design and function of all insert tips used in Piezoelectric bone surgery. Taking into account morphological-functional and clinical factors, the inserts tips have been defined and organized according to a dual classification system.

Various insert tips are classified as:

5.7. According to insert tip coating:[20]

1. Titanium Nitride coated tips are effective in osteoplasty procedure and for harvesting of bone chips as they provide maximum cutting efficiency, resist corrosion and last longer.
2. Diamond coated tips are used for osteotomy of thin bone and/or proximity to anatomic structures.

   They are classified as follows:

   (a) Sharp Insert tips are designed for maximum cutting efficiency and are used for osteoplasty procedures and to harvest bone chips.
   (b) Smooth Insert tips have diamond coated surfaces that enables precise and controlled work on the bone structures. They are used in osteotomy procedures to prepare difficult and delicate structures such as preparation of the sinus window and/or nerve access.
   (c) Blunt Insert tips are used for preparing soft tissues, e.g., elevation Schneider's membrane and/or, lateralization of the inferior alveolar nerve. In periodontics, these tips are used for root planing.

5.8. According to insert tip color

1. Gold Insert tips are utilised specifically for bone surgery. The gold color of the insert tips is obtained from the titanium nitride which improves the hardness of the surface for longer working life.[24]
2. Steel Insert tips are used specifically for treating soft tissue and/or delicate tooth structures (roots of teeth).[25]

5.9. Clinical classification

Clinical classification comprises insert tips (sharp, smooth, blunt) based on surgical techniques such as osteotomy,

osteoplasty, extraction.[26]

1. Osteotomy OT - OT1, OT2, OT3, OT4, OT5, OT6, OT7, OT7S4, OT7S3, OT8R/L
2. Osteoplasty OP - OP1, OP2, OP3, OP4, OP5, OP6, OP7
3. Extraction EX - EX1, EX2, EX3
4. Implant site preparation IM - IM1(OP5 -IM2A-IM2P OT4-IM3A-IM3P
5. Periodontal Surgery PS - PS2-OP5-OP3-OP3A- Pp1
6. Endodontic Surgery EN - OP3-PS2-EN1-EN2-OP7
7. Sinus Lift- OP3-OT1-OP5 - EL1-EL2-EL3
8. Ridge Expansion- OT7-OT7S4-OP5- IM1 -IM2-OT4 -Im3
9. Bone Grafting- OT7, OT7S4, OP1, OP5
10. Orthodontic Microsurgery- OT7S4-OT7S3

5.9.1. *Indications*

1. Implantology:[26]
   (a) Implant site development (socket preparation)
   (b) Splintting and expansion of the alveolar ridge
   (c) Alveolar crest recontouring
   (d) Mental nerve repositioning
   (e) Distraction osteogenesis with subsequent implant placement
   (f) Retrieval of blade implants
   (g) Placement of implants
   (h) Harvesting block grafts
2. Maxillary sinus bone grafting surgery:[26]
   (a) Creating lateral bone window
   (b) Sinus mucosa atraumatic dissection
   (c) Elevation of internal sinus floor elevation
3. Periodontal treatment procedures:[26]
   (a) Supragingival and subgingival scaling
   (b) Irrigation of periodontal pockets
   (c) Crown lengthening
   (d) Soft tissue debribement
   (e) Resective and regenerative surgerical procedure
4. Others:[27]
   (a) Retrograde root canal preparation
   (b) Apicectomy
   (c) Cystectomy
   (d) Extraction
   (e) Tooth extraction with osteogenic distraction Ankylosed tooth
   (f) Extraction
   (g) Orthodontic surgery
   (h) Removal of cyst

5.10. *Contraindications*[28]

No absolute contraindications

1. Patients or the clinician with electrical implants such as pacemakers.
2. Certain systemic diseases such as cardiovascular diseases, diabetes and bone disease or in patients undergoing radiotherapy, all of which can hinder the dental implant surgery.
3. Alterations that may or may not be related to systemic diseases, bone structure and vascularization.
4. Behaviours such as smoking and excessive drinking.

6. Application of Piezosurgery in Periodontology

6.1. *Scaling and root planing*

The piezosurgery device is used to remove supragingival and subgingival calculus as well as stains from teeth. It has been discovered that employing cavitation alone without the touch of the vibrating tip is insufficient for removing the calculus; direct contact between the vibrating tip and the calculus is required. The piezosurgery ultrasonic scaler, set to function On/Mode Periodontics (ROOT), with the insert PS1 and PP1, is used for deposit removal on all tooth surfaces for 15 seconds at a medium power of two. Parallel movements were used, with working strokes perpendicular to the tooth axis.[29]

Busslinger et al.[30] conducted a study to compare magnetostrictive and piezoelectric devices and found a substantial difference in time required. The SEM pictures after instrumentation were utilised to compare the four groups. SEM examination of tooth surface roughness revealed that the C100 group had a smoother surface than the C200 group and that the P100 group had a smoother surface than the P200 group, although the difference was not significant. The difference between the C200 and P200 groups was statistically significant. According to Santos et al[31] there were no changes in the results of magnetostrictive and piezoelectric devices uder SEM.

6.2. *Curettage*

When compared to manual tools, a piezosurgery device is employed for debridement of the epithelial lining of the pocket wall, resulting in microcauterization and removal of root calculus by employing thin tapered tips with an adjusted power setting.[32]

6.3. *Clinical crown lengthening*

Raising a full-thickness flap, conducting an ostectomy with manual instruments, osteoplasty with a bur for crest bone architecture recontouring, periradicular bone removal, root planing, and ultimately restoring the flap in an apical position are all part of the conventional surgical approach. The crown lengthening procedure done with piezosurgery for successful bone reduction while maintaining root surface integrity.[33,34]

A controlled clinical split mouth study was conducted by Dayoub ST et al[35] to evaluate the clinical results of a minimally invasive flapless method versus an open-flap approach in aesthetic crown lengthening for the treatment of gingival smile up to three months following piezoelectric bone surgery. The study demonstrated that utilising piezosurgery in bone resection is successful with both surgical techniques and resulted in a considerable increase in clinical crown length as compared to baseline. They concluded that the minimally invasive flapless approach and piezosurgery provide alternatives to traditional procedures of aesthetic crown lengthening.

6.4. Resective surgery

In comparision to other instruments, the piezosurgery device is beneficial in periodontal surgery. After the primary flap is raised during resective surgery the device makes it simpler to accompany with the secondary flap and remove the inflammatory granulation tissue. This process results in minor bleeding but by applying the proper ultrasonic vibration, bleeding is prevented.

6.5. Periodontally accelerated orthodontics

Small vertical bone incisions between the teeth were done as part of the periodontally accelerated orthodontics procedure that allows more expedient orthodontic movement. With acceptable levels of pain and discomfort, the corticotomy procedure conducted with a piezosurgical equipment reduce the treatment duration by 60 to 70%. For selective alveolar corticotomies using the Peizosurgical device, surgical control was reported to be simpler than with traditional surgical burs.[36]

6.6. Block harvesting technique

Traditional rotary cutting instruments for bone block harvesting reduce the width of the cortical bone by at least 1 mm circumferentially and are unable to cut the internal cancellous bone effectively. Piezosurgery provides high accuracy and operational sensitivity, as well as simple distinction between cortical and cancellous bone while removing blocks of monocortical cancellous bone.[37]

6.7. Autogenous bone grafting

Due to absence of osteocytes and prevalence of non-vital bone, utilising manual or motor-driven devices for bone surgery may not be suited for grafting. The Piezosurgery inserts tips that are used for bone harvesting process creates a vibration with a width of 60 to 210 in an oscillation controlled module. In contrast to rotary burs or reciprocating saws, the utilisation of ultrasonic vibration creates controlled osteotomies by micrometric bone slices.

6.8. Osteoplasty and bone grafting

Piezosurgical device enables gentle scrubbing of the bone surface in order to obtain appropriate amount of graft material and can be used for gafting infrabony defects.

The function of the bony chips that are obtained vary with size

1. Small size chips aids in early remodelling
2. Larger size chips particles provide mechanical support and act as scaffold for bone growth.

7. Limitations

1. Difficulty to perform the deeper osteotomies.
2. Requires longer time for bone cutting or preparing osteotomy site than traditional cutting instruments.
3. Have longer and different learning curve.
4. Technique sensitive.

8. Conclusion

When compared to traditional rotational devices, ultrasound application to hard tissue is considered a slow procedure. Because it necessitats specialised surgical abilities associated with a certain learning curve. When compared to conventional procedures and soft tissues, piezosurgery is an advanced and conservative approach. Because, device precisely cuts bone, significant nerve damage may be avoided, and minimally invasive operations are conceivable. Using the fine tip enables curved cutting and provides an opportunity for new osteotomy technique. Predictability, Less Postoperative Pain, And Increased Patients Compliance are three P's of piezosurgery.

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None.

10. Conflict of Interest

None.

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A Review

Cone Beam Computed Tomography & Its Application In Periodontics

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Abstract

The presence of periodontal diseases is diagnosed on the basis of evaluation of clinical signs and symptoms followed by radiographs. Radiographs provide diagnostic information about the quality localization of the bone defect and the pattern of the bone resorption, changes in the bony trabeculae, condition of the lamina dura, length and shape of the root, furcation defects, subgingival calculus, and additional pathology. Two dimensional periapical and panoramic radiographs are routinely used for diagnosing periodontal bone levels.The amount of information obtained from conventional film and digitally-captured periapical radiographs is limited by the fact that the three-dimensional anatomy of the area being radiographed is compressed into a two-dimensional image. As a result of superimposition, periapical radiographs reveal limited aspects of the three-dimensional anatomy. Three dimensional imaging (3D) evolved to meet the demands of advanced technologies in delivering the treatment and at the same time responsible for the evolution of new treatment strategies. Cone beam computed tomography (CBCT) generates 3D volumetric images and is also commonly used in dentistry. All CBCT units provide axial, coronal and sagittal multi-planar reconstructed images without magnification. CBCT displays 3D images that are necessary for the diagnosis of intra bony defects, furcation involvements and buccal/lingual bone destructions. CBCT applications provide obvious benefits in periodontics, however; it should be used only in correct indications considering the necessity and the potential hazards of the examination.

Keywords: cone beam computed tomography (CBCT); 3D radiography; periodontal defects; periodontal diagnosis; furcation; intrabony defects

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Introduction

The periodontium is a functional unit of the tooth that consists of the gingiva, periodontal ligament, cementum, and alveolar bone. Radiographically, the periodontal ligament space appears as a dark line surrounding the root and an increased radio density of alveolar bone is visible adjacent to the periodontal ligament space, referred to as the lamina dura which is an extension of cortical bone into the alveolus.[1]

Periodontal diseases can be broadly classified as gingival diseases (gingivitis) and periodontitis. The bone destruction in periodontal disease occurs when the inflammation extends from the marginal gingiva into supporting periodontal tissues.

Although periodontitis is always preceded by gingivitis, gingivitis does not always progress to periodontitis.[2] The periodontium is first evaluated clinically followed by radiographic study.

Dental radiographs are a valuable non-invasive tool used as an adjunct to clinical examination for assessment of the periodontal conditions of the teeth.[3] Radiographs provide diagnostic information about the quality localization of the bone defect and the pattern of the bone resorption, changes in the bony trabeculae, condition of the lamina dura, length and shape of the

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root and the crown root ratio, plaque retention factors, caries, furcation defects, subgingival calculus, and additional pathology.[4]

Broadly, imaging techniques used in dentistry can be categorized as: intraoral and extraoral, analogue and digital, ionizing and non-ionizing imaging and two-dimensional (2-D) and three-dimensional (3-D) imaging. Traditional analog imaging modalities are two dimensional systems that use image receptors like radiographic films or intensifying screens. These include periapical views, panoramic, occlusal and cephalometric radiography.[5]

The interpretation of an image can be altered by the anatomy of both the teeth and surrounding structures. The amount of information obtained from conventional film and digitally-captured periapical radiographs is limited by the fact that the three-dimensional anatomy of the area being radiographed is compressed into a two-dimensional image. As a result of superimposition, periapical radiographs reveal limited aspects of the three-dimensional anatomy.[6] Three dimensional imaging (3D) evolved to meet the demands of advanced technologies in delivering the treatment and at the same time responsible for the evolution of new treatment strategies. G.N. Houns field, in 1972 introduced computerized transverse axial scanning which lead to introduction of Computed Tomography (CT). The high radiation dose, cost, availability, poor resolution and difficulty in interpretation have resulted in limited use of CT imaging in dentistry. These problems may be overcome using small volume cone-beam computed tomography (CBCT) imaging techniques.[7]

CBCT is also known as CBVT (Cone Beam Volumetric Tomography), CBVI (Cone Beam Volumetric Imaging) dental 3D CT, dental CT and DVT (Digital Volume Tomography) has touched every aspect of medical and dental profession. In periodontology as well as implantology, CBCT scanning has become a valuable imaging technique, for the diagnosis of intrabony defects, furcation involvements, and buccal/lingual bone destructions.

Principles of CBCT

The principal feature of CBCT is that multiple planar projections are acquired by rotational scan to produce a volumetric data set from which interrelation images can be generated.[8] Cone-beam scanners use a two-dimensional digital array providing an area detect or rather than a linear detect or as conventional CT does. This is combined with a three-dimensional X-ray beam with circular collimation so that the result ant beam is in the shape of a cone, hence the name "cone-beam". Because the exposure incorporates the entire region of interest (ROI), only one rotational scan of the gantry is necessary to acquire enough data for image reconstruction.[9]

Steps in Cone Beam Computed Tomography Image Production

Image production by CBCT involves four steps[10]:

A. Image Acquisition
B. Image detection
C. Image reconstruction
D. Image display

A. Image Acquisition

The cone-beam technique involves a rotational scan exceeding 180 degrees of an x-ray source and a reciprocating are a detect or moving synchronously around the patient's head. During the rotation, many exposures are made at fixed intervals, providing single projection images known as —basis", —frame" or "raw" images similar to lateral cephalometric radiographic images, each slightly off set from one another. The complete series of basis images is referred to as the projection data. Software programs incorporating sophisticated algorithms including back-filtered projection are applied to the projection data to generate a 3D volumetric data set that will provide primary reconstruction images in three orthogonal planes (axial, sagittal, and coronal).[11]

There are four components to image acquisition in CBCT:

1. Acquisition mechanics: Full/ partial rotation scan
2. X-ray generation: continuous/ pulsed
3. Field of view
4. Scan factor

1. Acquisition Mechanics:

The CBCT technique involves a single scan from an X-ray source which can be a partial or full rotational scan, exposing a reciprocating area detector that moves synchronously around the patient's head.

2. X-ray generation

Although CBCT is technically simple in that, only a single scan of the patient is made to acquire a data set, a number of clinically important parameters should be considered in x-ray generation.

Patient Positioning:

CBCT can be performed with the patient in three possible positions: Supine, Standing and Sitting.

X-ray generator

During the scan rotation, each projection image is made by sequential single image capture of the remnant x-ray beam by the detector.

3. Field of view

Ideally, the FOV should be adjusted in height and width which mainly depends on the size and shape of the detector, projection of the X-ray beam, and collimation of the X-ray beam. CBCT systems can be grouped according to the available FOV or selected scan volume height as follows:

1. **Localized region:** Approximately 5 cm or less (e.g., dento alveolar and TMJ)
2. **Single arch:** 5–7 cm (e.g., maxilla or mandible)
3. **Interarh:** 7–10 cm (e.g., mandible and superiorly to**c** include the inferior concha)
4. **Maxillofacial:** 10–15 cm (e.g., mandible and extending to nasion)
5. **Craniofacial:** >15 cm (e.g., from the lower border of the mandible to the vertex of the head).

4. Scan Factors

The speed with which individual images are acquired is called the frame rate and is measured in frames, projected images, per second. The maximum frame rate of the detector and rotational speed determines the number of projections that may be acquired. The number of projection images comprising a single scan may be fixed or variable. With a higher frame rate, more information is available to reconstruct the image; therefore, primary reconstruction time is increased. Higher frame rates are usually accomplished with a longer scan time and hence higher patient dose.[9,10,11]

A. Image Detection:

Current CBCT units can be divided into two groups on the basis of detector type:

- An image intensifier tube/ charge couple device combination (IIT/CCD)or
- Flat-panel imager.

B. Image Reconstruction

The reconstruction process consists of two stages:

Acquisition stage

Raw images from CBCT detectors exhibit spatial variations of dark image offset and pixel gain due to varying physical properties of the photodiodes and the switching elements in the flat panel detector and also due to variations in the X-ray sensitivity of the scintillator layer. These raw images need systematic offset and gain calibration and a correction of defect pixels which is done by "detector preprocessing."

Reconstruction stage

After the correction of the images, the images are transformed into sinogram which is done by reconstruction filter algorithm, the modified Feldkamp algorithm, that converts the image into a complete 2D CT slice. All the slices are finally recombined into a single volume for visualization.[11]

C. Image Display

The volumetric data set comprises of collection of all available voxels and projected on the screen as secondary reconstructed images in three orthogonal planes - axial, sagittal, and coronal.

Advantages of CBCT

CBCT technology in clinical practice has important advantages such as minimization of the radiation dose, image accuracy, rapids can time, fewer image artefacts, chair-side image display, and real-time analysis.

Disadvantages of CBCT

Although there has been enormous interest in CBCT, this technology has limitations related to the cone-beam projection geometry, detect or sensitivity and contrast resolution that produce images that lack the clarity and utility of conventional images. The patient must be motion less during the scanning to achieve a good image; other wise the image may display streaking.[12]

Diagnostic Application In Periodontics

The clinical applications of three-dimensional craniofacial imaging are one of the most exciting and revolutionary topics in dentistry.[13] (Figure1)

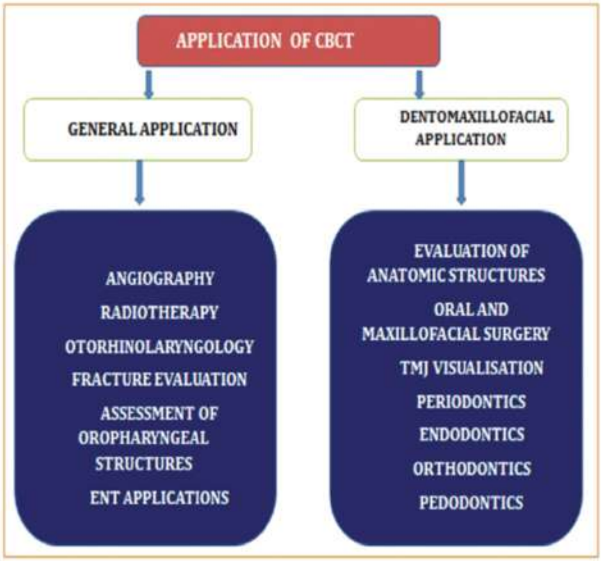

Figure 1: Application of CBCT

Role in Periodontics

Identification of periodontal landmarks

Periodontal Ligament Space

Radiographically lamina dura appears as a thin radiopaque line around the length of root. The space present between lamina dura and adjacent tooth is termed as PDL space. Any break in the continuity of lamina dura and a wedge shape radiolucenly at the mesial or distal aspect of the PDL space indicates periodontitis. Ozmeric et al did a study and compared CBCT with conventional radiography in terms of their ability to produce images of periodontal ligament space on a phantom model with artificially created periodontal ligament of various thicknesses and had found that the Periapical radiographs were superior to CBCT for the measurement of periodontal ligament space. But conflicting results were reported by the authors of another in vitro study that found CBCT to be better than conventional radiography in visualizing the periodontal ligament space. A phantom demonstrating variable periodontal ligament spaces was radiographed using CBCT and intraoral radiographs. This study found that CBCT provided better visualization of simulated periodontal ligament space in this phantom.[14]

Alveolar Bone Defect

The extent of periodontal marginal bone loss is necessary to determine the periodontal destruction. CBCT images provide better information on periodontal bone levels in 3D view than conventional radiography. CBCT is considered a superior technique in detecting the buccal and lingual defects and the interproximal lesions.Radiographs are mainly used to diagnose the amount and shape of alveolar bone destruction that affects treatment planning in periodontal therapy.[14,15]Two Dimensional radiographs can be insufficient for the detection of intrabony alveolar defects due to the obstruction of spongious bone changes by cortical plate. Thus, three-dimensional imaging is required for mapping of alveolar defects. Vandenberghe et al studied thirty periodontal bone defects of 2 adult human skulls using intraoral digital radiography and CBCT and concluded that the intraoral radiography was significantly better for contrast, bone quality, and delineation of lamina dura, but CBCT was superior for assessing crater defects and furcation involvements.[16]In Misch and colleagues study they demonstrated that CBCT was as accurate as direct measurements using a periodontal probe and as reliable as radiographs for interproximal areas.[17]Stavropoulos and Wenzel evaluated the accuracy of CBCT scanning with intraoral periapical radiography for the detection of periapical bone defects. CBCT was found to have better sensitivity compared to intraoral radiography.[18]

Furcation Involvement

Radicular bone assessment is anessential step in furcation involvement treatment planning procedures such as apically repositioned flaps with or without tunnel preparation, root amputation, hemi-/trisection or root separation. Conventional two dimensional radiographs can be deceptive in evaluating periodontal tissue support and inter radicular bone due to superposition of anatomical structures. However, 3D images provide detailed information about areas of multi rooted teeth. Intrasurgical furcation involvement measurements were compared by using CBCT images and it was reported that CBCT images demonstrated a high accuracy in assessing the loss of periodontal tissue and classifying the degree of furcation involvement in maxillary molars. In another study author had compared CBCT to intraoral radiography and concluded that the detection of crater and furcation involvements had failed in 29% and 44% for the intraoral radiograph, respectively, as compared to 100% detectability for both defects with CBCT.[19]

Regenerative periodontal therapy and bone grafts

Bone grafting is commonly used for maxillary sinus lifting and treatment of intra bony defects but evaluation of osseous defect regeneration with conventional radiography can be limited due to superimpositions. Furthermore, histological evaluation of a sample of the graft is not a preferred method due to its quite invasive procedure. CBCT was found to be significantly more accurate than digital intraoral radiographs when direct surgical measurements served as the gold standard for the evaluation of intra-bony defects' regenerative treatment outcomes. CBCT can replace surgical re-entry by providing 3D images and measurements that are almost equivalent to direct surgical measurements.[19,20] Dimensions of alveolar process should be examined in detail prior to dental implant placement to avoid various complications and evaluation of CBCT images has a major importance in preoperative planning and postoperative localization of dental implant.[21]

Role In Implant Site Assessment:

Implant placement requires technique which is capable of obtaining highly accurate alveolar and implant site measurement to assist with treatment planning and avoid damage to adjacent vital structure during surgery. Earlier alveolar and implant site measurement was done either using 2-D radiographs and in some instance using conventional CT (Figure 2). When compared, CBCT is preferable option for implant dentistry, providing greater accuracy in measuring with utilization of lower radiation dose.

Uses[22]

1. To assess the quantity and quality of bone in edentulous ridges.
2. To assess the relation of planned implants to neighboring structures.
3. To assess the success of implant osseointegration.
4. To provide information on correct placement of implants.
5. Before ridge augmentation in anodontia
6. Before bone reconstruction and sinus lifting
7. During planning and in designing a surgical guidance template.

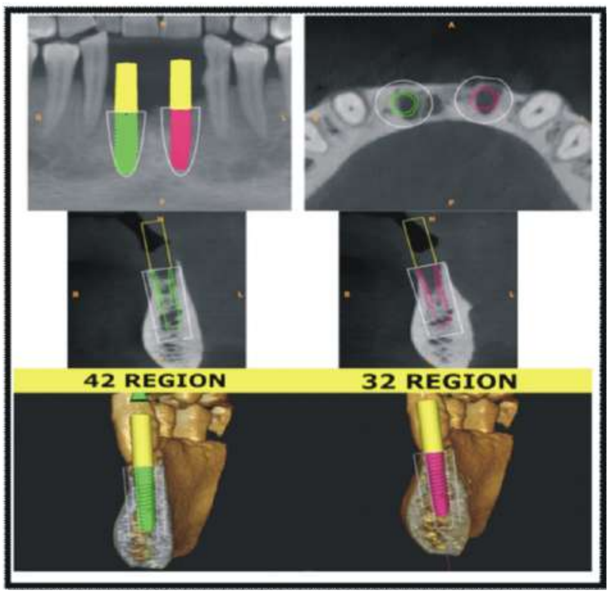

Figure 2: Implant site assessment

Role of CBCT in detecting anterior looping during implant placement:

Apostolakis D and Brown JE (2012) stated that the final part of the inferior alveolar nerve sometimes passes below the lower border and the anterior wall of the mental foramen.[23] After giving off the smaller mandibular incisive branch, the main branch curves back to enter the foramen and emerge to the soft tissues, as the mental nerve. The section of the nerve in front of the mental foramen and just before its ramification to the incisive nerve can be defined as the anterior loop of the inferior alveolar nerve. Selective surgery in the area of the anterior mandible such as implant installation in the interforaminal region or symphysis bone harvesting, may violate the anterior loop resulting in neurosensory disturbances in the area of the lower lip and chin. To avoid such a sequel a 5-mm safe distance to the most distal fixture from the anterior loop and a 5-mm distance from the mental foramen for chin bone harvesting have been proposed.[23,24]

Tolstunov identified and described four alveolar jaw regions—functional implant zones (Figure 3)[21] with unique characteristics of anatomy, blood supply, pattern of bone resorption, bone quality and quantity, need for bone grafting and other supplemental surgical procedures, and a location related implant success rate.

Four functional implant zones identified by Tolstunov[21,22,23]:

i. Functional Implant Zone 1 (Traumatic zone)consists of alveolar ridge of premaxilla and eight anterior teeth: 4 incisors, 2 canines, and 2 first premolars. Any bone loss in the anterior maxillary area is vital due to the esthetic implications on dental implant supported restorations. Loss of teeth in this area is mostly due to trauma and if the teeth are not replaced immediately following trauma, the bone loss continues, leading to difficulty in dental implant placement in a prosthetically favorable position.

ii. Functional Implant Zone 2(Sinus zone): bilateral maxillary posterior zone extends from the maxillary second premolar to the pterygoid plates and is located at the base of the maxillary sinuses.

iii. Functional Implant Zone 3 (Inter-foraminal zone): comprised of the area of the mandibular alveolar ridge between mental foramen and first premolar on each side. This zone is also associated with a thin alveolar ridge. There is abundant evidence in the literature reporting severe bleeding with the formation of expanding sublingual hematomas due to the perforation of the lingual cortex.

iv. Functional Implant Zone 4:- This zone of the alveolar process of the mandible behind the mental foramen on each side and extends from the second premolar to retromolar pad. The distance of the alveolar bone height from the inferior alveolar canal is evaluated when dental implants are considered in the posterior mandible. Careful assessment of the height must be made to avoid injury to the inferior alveolar canal. If there is a violation of the inferior alveolar nerve (IAN), depending on the degree of nerve injury, alteration in sensation, from mild paresthesia to complete anesthesia, is reported.

Figure 3: Functional implant zones identified by Tolstunov

Conclusion

Cone beam computed tomography is a diagnostic imaging technology that is changing the way dental practitioners view the oral and maxillofacial complex as well as the teeth and the surrounding tissues. CBCT has been specifically designed to produce undistorted three dimensional images similar to computed tomography (CT), but at a lower equipment cost, simpler image acquisition, and lower patient radiation dose. However the two-dimensional diagnostic imaging has served dentistry well and will continue to do so for the foreseeable future. Intraoral and panoramic radiographs are the basic imaging techniques used in dentistry and are quite often the only imaging techniques required for the detection of dental pathology.

For periodontal disease, CBCT promises to be superior to 2Dimaging for the visualization of bone topography and lesion architecture but no more accurate than 2D for bone height. This factor should be tempered with awareness that restoration in the dentition may obscure views of the alveolar crest. No doubt, future improvements in CBCT technology will result in systems with even more favorable diagnostic yields and lower doses.

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A Review

Piezo Surgery: A Boon For Modern Periodontics

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Abstract

Piezosurgery is a novel technique that uses piezoelectric ultrasonic vibration to provide safe and precise osteotomy. Recently this technique has gained importance Fatimbecause of its ease of use and safety. Professor Vercelloti in 1988 invented this technique known as piezosurgery or piezoelectric bone surgery. The piezoelectric effect occurs when an electric current is passed around a stack of crystals and they start to vibrate at a modulated ultrasonic frequency of 24-29 Hz. and microvibration amplitude between 60 and 200 mm per second. This technique allows a clean precise and controlled cut of bony structures without causing destruction of soft tissue. This article focuses on the broad range of applications of this novel technique in Periodontology.

Introduction

The past two decades has seen rapid development in various dental surgical techniques. Traditionally, osseous surgery was performed by using hand instruments and various rotary instruments with different burs which required external copious irrigation because of the production of heat .Using these instruments, a pressure was also exerted with a limitation in the case of brittle bone. In order to overcome the limitation of traditional techniques in oral bone surgery a relatively new technique for ostectomy and osteoplasty that uses ultrasonic vibrations was introduced by Professor Tomaso Vercelloti in 1988 and developed by Mectron Medical Technology.[1] This device is known as Piezoelectric device and the surgery is known as Piezosurgery. The piezosurgery device consists of a novel piezoelectric ultrasonic transducer powered by ultrasonic generator capable of driving a range of resonant cutting inserts[1].The philosophy behind the development of piezoelectric bone surgery is based on two fundamental concepts i.e. minimal invasive surgery, which improves tissue healing and reduce discomfort to the patient and the surgical predictably which increases treatment effectiveness.[2]

Historical background

The term "piezo" originates from the Greek word`` peizein" which means "to press tight, squeeze". Jacques and Pierre Curie first discovered piezoelectricity in the year 1880 ,when pressure is applied on crystals, ceramics or bone electricity is created. Dr. Tomaso Vercellotti, an Italian periodontist felt the need to change the osseous surgery procedures to make the results more predictable, improve healing, minimize trauma and provide greater safety for patients .In year 1999 he invented piezoelectric bone surgery in collaboration with Metron Spa. This technology has been used commercially in Europe since 2000.In 2005, the US Food and Drug administration extended the use of ultrasonics in dentistry to include bone surgery.

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3. Parts of Piezoelectric Device

The device consists of a hand piece and a foot switch that are connected to a main unit, which supplies power and has a holder for hand piece and irrigation fluids. The unit consists of hand piece, foot switch, ultrasound, control, dynamometric wrench and peristaltic pump. This piezoelectric device works in the range of 25-29KHz and can be modulated further by 30 Hz digital modulation and series of inserts of different forms with a linear vibration ranging from 60 to 200µm. (Figure 1)

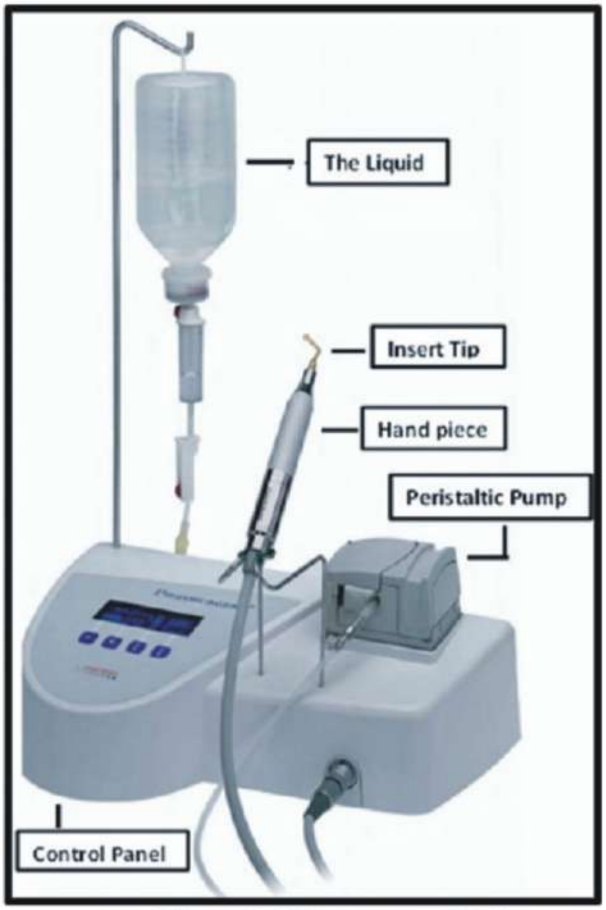


Figure 1: Piezosurgery Unit

Main Body

It has a display, an electronic touch pad, a peristaltic pump, one stand for the handle and another to hold the bag containing irrigation fluid. It has two operating modes, to select either the BONE or ROOT operating modes. The BONE cutting mode is used to cut bone with selections that are specific to bone type or density. The ROOT mode is used to shape, debride, and smooth root surfaces (both external: periodontal and internal: endodontic)[3]

Bone Mode- The vibrations generated by selecting bone mode are characterized as extremely high ultrasonic power compared to root mode.[3] Several sophisticated software and hardware controls monitor the performance. Frequency over modulation gives the ultrasonic mechanical vibrations its unique nature for cutting different kinds of bone.

The selection recommended is: -

- ✍ **Quality 1:** for cutting the cortical bone or high-density spongy bone.
- ✍ **Quality 3:** for cutting low density spongy bone.

Root Mode The vibrations generated by selecting root mode are characterized by average ultrasonic power without frequency over modulation. Root operating mode consists of two different programs:

i. NDO Program: A limited level of power provided by applying reduced electrical ension to the transducer, generates inset oscillation by a few microns which re optimal for washing out the apical part of the root canal in endodontic surgery.

ii. ERIO Program: A intermediate level of power between the endo program and the bone program. The ultrasonic wave is transmitted through the transducer in continuous sinusoidal manner characterized by a frequency equal to the resonance frequency of the insert used.

Dynamometric Wrench

It is used to tighten the insert tips to the hand piece which applies a predefined force to obtain energy transmission.

Handpiece

Each piezo surgery unit comes with two handpieces and is permanently connected to handpiece cord which can be sterilized together.

The Peristaltic Pump

It is a part which consists of irrigating solution discharging from the insert with a adjustable flow of 0-60 ml /minute he solution is refrigerated at 4°C for cooling effect . The power of device is 5W[ultrasonic scaler 2W].[6]

Insert Tips

The design and features of all insert tips used in Piezoelectric Bone Surgery have been developed by the Mectron Medical Technology. The inserts have been defined and organized according to a dual classification system, taking into consideration morphological-functional and clinical factors. This system helps understand the cutting characteristics and clinical instructions for each insert. (Figure 2). Various insert tips have been summarized in Table 1.

BASE UNIT / MAIN UNIT ROOT MODE	1. **Feature mode** i). Root mode ii) Bone mode **2. Specific program** i) Perio Program ii) Bone Mode iii) Special Program **3. Flow of the fluid from cooling system**
INSERT TIPS	
BASED ON MORPHOLOGY/FUNCTION	**1.Sharp insert tips** - for osteotomy and osteoplasty where fine and well-defined cutting of bone is required. **2.Smoothing insert tips** - for precise and controlled cutting effect during osteotomy. **3. Blunt insert tips**- to prepare the soft tissues. In periodontics these insert tips are used for root planing.
BASED ON COLOUR	➤ **Gold tips** • Used to treat bone. • titanium nitride coatings to improve surface hardness and also for longer working life. ➤ **Steel tips** • Used to treat soft tissues or delicate structures.

Table 1: Piezoelectric Device Parts

Principle of Piezosurgery

It works on the principle of pressure electrification according to which piezoelectricity is found in certain crystals like quartz, Rochelle salt and ceramics which when subjected to electric charges, acquire electric polarization, expand and contract alternatively to produce ultrasonic waves. Since ultrasonic waves are mechanical in nature, they can induce disorganization and fragmention of different bodies. The ultrasonic waves also allow segmentation of interfaces from solid –solid by means of distinct vibrations and solid-liquid by means of cavitation(micro boiling phenomenon that occurs in liquids on any solid-liquid interface vibrating to an intermediate frequency, corresponding to a rupture of molecular cohesion in liquids and the appearance of zones of depression that fill up vapor until they form bubbles that are about to implode).When the water spray contacts the insert vibrating to intermediate frequency ;cavitation occurs. The cavitation effect also shows an anti-bacterial property by fragmenting bacterial cell wall, which helps in obtaining high predictability and low morbidity in bone surgery. (Figure 2)

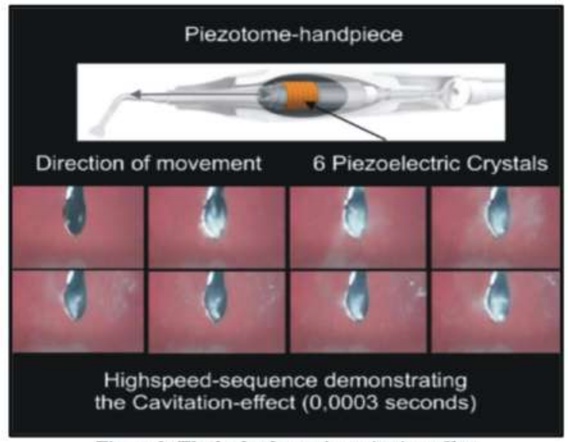


Figure 2: The hydrodynamic cavitation-effect

Mechanism of Action

Ultrasonic is a branch of acoustic dealing with sound vibration in a frequency that ranges above the audible level i.e., >20KHZ where sonic is an ultrasound wave of high amplitude produced by three different methods.

Mechanical method-upto100KHz
Magnetostatic method-18-25 Khz
Piezoelectric effect-25-50KHz

In piezoelectric device the frequency is created by driving an electric current from a generator over piezoceramic rings, which leads to their deformation .the ultrasonic frequency usually ranges from 24-36KHZ, capable of cutting mineralized tissue in dental applications. Thus the accruing movement from the deformation of ring sets up a vibration in the transducer, which creates the ultrasound output. These waves are transmitted to hand piece tip, also called an insert where longitudinal movement occurs resulting in the cutting of osseous tissue by microscopic shattering of bone .The transducer is a very important part of the instrument system because it incorporates a piezoelectric element ,which convert electric signals into mechanical vibrations and finally mechanical vibrations into mechanical energy. (Figure 3)

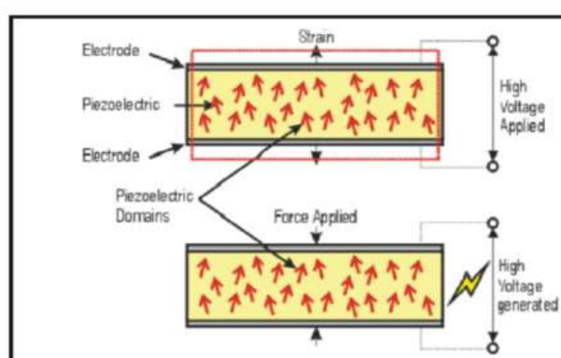


Figure 3: Mechanism of Piezoelectric Device

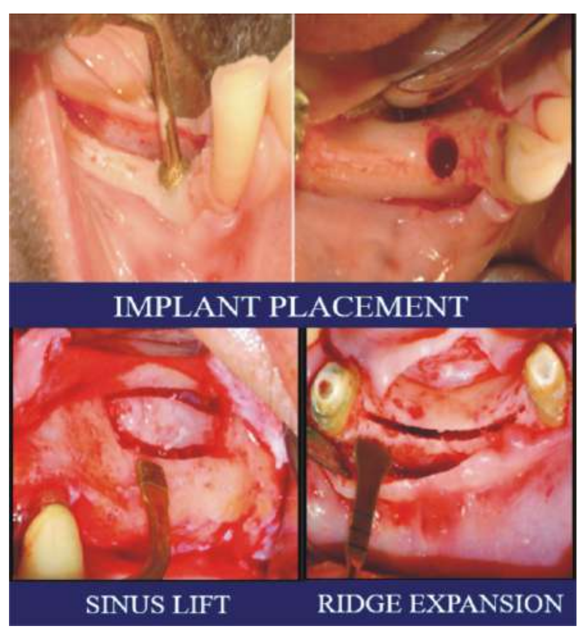
Applications of Peizosurgery In Periodontics

- ☆ **Scaling and root planing:** The piezosurgery device with a vibrating tip is employed for removal of supra and subgingival debris, calculus and stains from teeth. The piezosurgery ultrasonic scaler set on function on/Mode Periodontics (ROOT), with the insert PS1 and PP1, applied at a medium power of two for 15 sec is used on all the surfaces for removal of deposits.
- ☆ **Curettage:** Piezosurgery device because of its thin tapered tips and altered power setting is used for the efficient removal of diseased soft tissue and root calculus along with the debridement of epithelial lining of pocket wall resulting in micro cauterization.
- ☆ **Clinical crown lengthening:** Piezosurgery is used for precise cutting of hard tissues while preserving root surface integrity .It involves performing a peri-radicular ostectomy of a few millimeters, which allows repositioning of the periodontal flap in a more apical position.
- ☆ **Resective Surgery:** In interproximal bone defects, diamond coated insert enables thorough cleaning of the bone defects by producing an ultrasonic wave at the base of the defect to aid in better healing.
- ☆ **Periodontally accelerated orthodontics:** Piezo-electric device is used to perform corticotomy by making small vertical incisions between the teeth which allows more expedient orthodontic movement thus considerable reduction in treatment time .[10]
- ☆ **Block Harvesting Technique:** Piezosurgery provides high precision, operating sensitivity and easy differentiation between cortical and cancellous bone while removing blocks of monocortical cancellous bone in bone block harvesting technique.[11]
- ☆ **Osteoplasty and bone grafting:** Piezoelectric devices can be used for grafting infrasonic defects.[12] The device enables gentle scrubbing of the bone surface to obtain sufficient quantities of graft material. The function of the obtained bony chips vary with size (i) Small sized chips aid in early remodelling and (ii) Larger particles provide mechanical support and act as scaffold for bone formation.

Application In Implantology

The peizosurgery is a new and modern technique in bone surgery in implantology. Implantology offers a variety of techniques to increase bone volume,[13,14] including transplantation of particles and blocks of bone grafts from the chin and the mandibular ramus, iliac crest, and calvaria.[15,16] The techniques make use of rotary drills; oscillating saws; and more recently, piezosurgery, a process that uses ultrasonic vibrations in the application of cutting bone tissue.

- ¤ **Implant Site Preparation:** Piezosurgery used to prepare osteotomy site in the bone and for insertion of implant. Special piezo surgery inserts developed for bone perforation have enabled the development of a new technique for ultrasonic implant site preparation (UISP),which facilitate differential preparation of the cortical and cancellous bone. The differential implant site preparation (DISP) technique can be used within the initial osteotomy site to correct the implant axis by selectively directing the cutting action in the desired direction.[17]
- ¤ **Ridge expansion:** Piezosurgery is an indispensable tool used to create a horizontal osteotomy through the alveolar bone crest caused by its precise (narrow) cutting action. In some cases (e.g., areas of dense bone with little elasticity), it may also be necessary to make one or two vertical cuts in the alveolar bone to allow ridge expansion.[18].
- ¤ **Sinus lift or augmentation:** Sinus augmentation is performed in following situations; pneumatised sinus, atrophy of alveolar ridge, and poor bone quality especially in the posterior maxilla. The surgical technique performance depends on the remaining bone between the alveolar crest and the floor of the maxillary sinus. Using piezoelectric ultrasonic vibration range between 25-30 kHz, the device cuts only mineralized structures without cutting the soft tissue. The cavitation effect of the system induces a hydropneumatics pressure of saline irrigant that contributes to the atraumatic elevation of the sinus membrane as perforation of schneiderian membrane resulting in poor graft stabilization, sinus infection, epistaxis and extensive bleeding. (figure4)[19]



Advantages

Peizosurgery offers the following characteristics:

- **Micrometric:** the inserts vibrates with the range of 60-200 micrometer thus avoiding excessive temperatures.
- **Selective:** the vibration frequency is optimal for the mineralized tissue.
- **Safe:** using of a modulated ultrasonic frequency allows a highly precise and safe cutting of hard tissues whereas adjacent soft tissue and nerve remain unharmed making it superior compared to conventional rotating instrument.[5]
- **Precision:** the accuracy and selectivity of pesosurgery is superior to conventional rotating instruments. with pesosurgery we can osteotmize hard tissue as precisely as possible.
- **Surgical control:** pesosurgery provides surgical control with maximum strength required by the surgeon to effect a cut is far less compared to that with the drill or with oscillating saws
- **Cavitation effect:** created by interaction between the irrigant solution and the oscillating tips makes the surgical site clear during osteotomy.

Limitation:

- Increase in operative time compared to traditional cutting instrument.
- Gentle touch and dexterity is required for this type of procedure with a different learning curve.
- In deeper osteotomies it's difficult to insert proper length and thickness to avoid the increasing pressure of the hand preventing microvibration of the insert.
- Not cost effective
- Inserts get warm very rapidly.
- Increase operative time compared to traditionally cutting instrument.

Conclusion

By using technique of piezoelectric ultrasonic vibrations the critical operations can be done in simpler and safer way with less post-operative complications. This technique can be used in oral surgical procedures to have better results. It aids in bone healing minimal intra-operative bleeding etc. The piezosurgery units because of its variable frequency and variable power are used for range of application in periodontology implantology etc. making it highly efficacious tool in clinical practice.

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Review Article

Changing trends in implant designs: A review

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CBCT

A B S T R A C T

Implantology is an ever-evolving scientific field that undergoes continuous refinement and innovation. Dedicated research and development efforts are focused on consistently improving the success rates of implants through innovative redesign and advancements. The introduction of advanced technologies has revolutionized the evaluation of patients in three dimensions, enabling clinicians to utilize precise and predictable approaches for diagnosis, planning, and treatment. This multidisciplinary patient-centric framework has opened new avenues for providing tailored and effective healthcare solutions. Therefore, it is of utmost importance for clinicians to conduct a comprehensive analysis of each patient's condition, ensuring meticulous selection of the suitable implant design and material, and making informed decisions regarding the most appropriate technique to be employed.

1. Introduction

Dental implants are widely recognized as one of the most promising and effective solutions for replacing missing teeth. With long-term success rates surpassing 90%, they have proven to be highly effective in restoring oral function and aesthetics in both partially and fully edentulous patients.[1] Thanks to the current availability of advanced diagnostic tools that assist in treatment planning, along with the ongoing research leading to improved implant designs, materials, and techniques, a wide range of challenging clinical situations can now be effectively managed with a high level of predictability and success.[2] Implant design features are vital factors that have a significant impact on the initial stability of implants and their ability to endure loading throughout the osseointegration process and beyond. These design elements play a fundamental role in ensuring the long-term stability and durability of dental implants. Furthermore, dental implants are engineered with specific textures and shapes that can promote cellular activity and facilitate direct bone apposition, facilitating successful integration with the surrounding tissues.[3]

Dental implant design has undergone significant advancements in recent years. In the past, primitive dental implants such as blade, staple, and periosteal types were used, but they had inherent biomechanical limitations, leading to high failure rates.[4] Recent advancements have brought about significant improvements in the morphology, structure, and design of dental implants, aimed at enhancing their biomechanical properties, stability, and long-term success. These developments reflect the ongoing commitment to innovation and the continuous pursuit of excellence in the field of dental implantology.

Implant design encompasses the comprehensive three-dimensional structure of the implant, including its various elements and characteristics. It encompasses factors such as form, shape, configuration, as well as the surface macrostructure and macro irregularities, all of which

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contribute to the overall attributes of the implant's three-dimensional structure.

2. Implant Shape

Implant shape directly influences the surface area available for stress transfer, playing a critical role in determining the implant's initial stability. The predominating macro structure for root-form endosseous implants is the screw shape, which consists of parallel-sided screw and the tapered screw.[2] Smooth-sided cylindrical implants offer a convenient advantage when it comes to surgical placement.[4] A tapered implant with smooth sides enables the transfer of a comprehensive load to the interface between the bone and the implant, the extent of which depends on the taper's degree. Implants with threaded design and circular cross sections facilitate easy surgical placement and enable enhanced optimization of the functional surface area to effectively transmit compressive loads to the bone-to-implant interface.[2]

3. Implant Geometry

The primary criterion for developing the treatment plan is still the size of the implant, including its diameter and length, primarily determined by the amount of available alveolar bone. For a given implant length, increasing the implant diameter will increase the implant surface area that is available for force transfer to the bone.[5] Provided there is sufficient bone volume, a larger diameter implant is better able to resist occlusal forces, particularly in the molar region. When designing the treatment plan, it is important to consider the drawbacks associated with bone augmentation, which used to be considered the "gold standard" in severe atrophy cases. These drawbacks include morbidity at the donor site, elevated risks of complications, extended time and increased costs, as well as potential resorption of the bone graft. Additionally, the advancing capabilities of smaller-sized implants should be considered when formulating the treatment approach.[6]

Several new concepts may provide other options for implantation, aiming to reduce treatment duration, minimize complication rates, and simplify the overall treatment procedure, such as:

4. One-piece Implant

In a one-piece implant the endosseous and abutment portions form a single unit. By eliminating the abutment interface, the one-piece implant enhances the strength and stability of the prosthesis. It is a suitable option for patients or surgical sites with insufficient bone to adequately support a prosthesis. In spite of these advantages, one-piece dental implants do have a limitation in terms of flexibility compared to two-piece implants. Their single-unit construction restricts the ability to make precise adjustments once placed.

The design of one-piece implants allows for uninterrupted healing of the soft tissues surrounding the implant and avoids any disruption to the soft tissue seal when placing the final prosthetic restoration.[7]

5. Mini-Implants

Compared to standard dental implants, mini-implants are characterized by their reduced diameter, typically less than 3 mm, and shorter length. Despite their smaller size, they are typically made from the same biocompatible materials as standard implants. These implants are particularly useful when achieving acceptable and satisfactory function with conventional prostheses is challenging. Clinical situations like flabby ridges, atrophic ridges, or inadequate residual bone where denture retention is less, are likely to do well with mini-implants.[8]

6. Short Implants

Placing conventional implants can be challenging in cases of atrophic alveolar ridges due to various anatomical restrictions. These include the presence of the maxillary sinus, nasal floor, nasopalatine canal, and inferior alveolar canal. These structures can limit the available bone volume and affect the feasibility of conventional implant placement. To address these and other vertical bone deficits, additional surgical procedures are often employed to facilitate the placement of standard implants. These may include guided bone regeneration, block bone grafting, maxillary sinus lift, distraction osteogenesis, and nerve repositioning. These techniques aim to augment the available bone volume, create a favorable environment for implant placement, and overcome the challenges presented by the anatomical restrictions.

Short implants are often regarded as a simpler and more effective solution for rehabilitating the atrophic alveolar ridge. By minimizing the likelihood of complications, patient discomfort, procedure costs, and overall treatment time, they offer several advantages. In this context, however, it is worth mentioning that the categorization of a dental implant as "short" is subjective, and there are no universally defined criteria for determining the specific length that qualifies as a short dental implant. Recently, less than 8 mm- long short implants have been offered by implant companies.[9]

7. Tilted and Zygomatic implants

The utilization of a tilted or angulated implant in the posterior maxilla has been suggested as a potential alternative to sinus augmentation procedures. In the All-on-4 concept (a theory that uses four implants to restore total edentulism) for completely edentulous maxilla patients trans-sinus tilted implants are employed.

Zygomatic implants present an alternative to sinus augmentation procedures. They are lengthy implants travelling through the sinus or laterally into the sinus and are almost identical to trans-sinus tilting implants.[10]

8. Pterygoid implants

Pterygoid implants were introduced as another method of increasing the amount of bone that can be used for placement of implants in posterior maxillary region. The typical implant size for this method is between 15 and 20 mm. The implant enters the maxilla in the first or second molar region, following an oblique mesio-cranial direction. From there, the implant trajectory proceeds posteriorly toward the pyramidal process. Thereafter, it ascends between wings of the pterygoid processes and continues its course in the sphenoid bone to find anchorage in pterygoido scaphoid fossa.

The presence of dense cortical bone provides excellent engagement and stability for the pterygoid implants. That and an opportunity to obviate the requirement for maxillary sinus augmentation and other grafting procedures are two benefits of employing these implants.[11]

9. Tuberosity implants

Tuberosity implants are designed to be placed at the most distal aspect of the maxillary alveolar process, specifically targeting the tuberosity region. They are positioned to potentially engage the pyramidal process of the maxilla. Because of the dense bone present in this region, the difference in bony support for a pterygoid implant and a tuberosity implant can be significant.[11]

10. Utilizing three-dimensional printing for customized implants

The initial adoption of three-dimensional printing (3DP) for custom implants took place in the domains of rapid tooling and rapid prototyping. Digital scanning was combined with a CAD/CAM design and using 3DP, dental labs produced dental prostheses and patient models in significantly less time and with a precision that was unmatched by most traditional procedures. The combination of cone beam computed tomography (CBCT) and CAD/CAM was proposed to generate a surgical guide for precise implant placement.[12]

11. Transitional Implant

Their length varies from 7 to 14 mm, and diameter is between 1.8 and 2.8 mm. Transitional implants are manufactured using pure titanium and consist of a single-body design with a treated surface. They play an important role by absorbing the masticatory stress during the healing phase. This stress absorption helps promote a stress-free environment for the maturation of bone around the submerged implants, allowing them to heal smoothly and without complications.

Some commercially available Transitional Implant System include the Immediate Provisional Implant System–IPI by Nobel Biocare; Modular Transitional Implant System -MTI by Dentatus; and TRN/ TRI Implants by Hi Tec implants.[13]

12. Ligaplant

This technology involves the integration of periodontal ligament (PDL) cells with implant biomaterial. Research is currently being done to make this implant honourable. In Ligaplant, the PDL cells serve as a soft, vascular tissue that distributes forces, absorbs shocks, and provides proprioception for the tooth within its socket.[14]

13. Design Variables in Surface Area Optimization Thread Geometry

The market today offers a variety of implant systems with different implant thread configurations (Figure 1). The number of threads, width of the thread, depth of the thread, face angle of the thread and its pitch are among the various geometric combinations that affect final bone-implant contact (BIC) and distribution of load. A greater number of threads and increased thread depth provides greater available surface area for load distribution.[15]

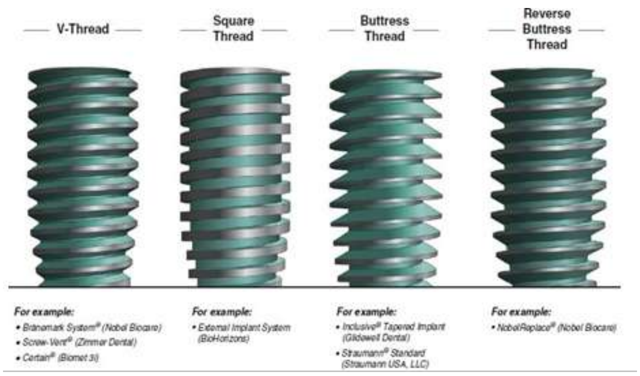

Fig. 1: Thread shapes of dental implants (V-thread, square, buttress, and reverse buttress).
Source: Grant Bullis .Functional Basis for Dental Implant Design. In: Misch,s Contemporary Implant Dentistry .4th ed. St Louis, USA: Mosby.;2021. p.48-68.

Implant threads are crucial for achieving primary stability, particularly in areas where bone quality is not good and for dissipating stresses at the bone-implant interface. This aids in minimizing the risk of complications and supports successful healing and integration of the implant with the bone.

The implant apical region should be tapered to assist insertion into the osteotomy and initial engagement of

threads of the implant. It should be either rounded or flattened to reduce the probability of perforating membranes during placement. It will have flat regions or grooves circumferentially arranged on the implant body to stabilize the implant against rotation after healing and to aid in insertion.[16]

14. Implant Crest Module and Abutment (Figures 2 and 3)

Current knowledge of prosthetic connections suggests that an internal prosthetic connection offers the best functionality. Of the internal prosthetic connection types in use today, the conical prosthetic connection have the best feature set, also conical prosthetic connections provide a stable abutment connection, lower peak bone stresses when positioned level to the marginal bone, and have a high resistance to axial loads. The Morse taper implant abutment connection features a tapered projection on the abutment that fits into a tapered recess in the implant. This creates a friction fit and cold welding to prevent rotation, providing stability during function. Taper angles vary, such as 8° in ITI Straumann or Ankylos, or 11° in Astra. The Bicon implant system has rounded channels with a 1.5 degree taper. When the cross section of the implant permits, platform shifting should be used to redistribute the stress away from the bone-implant interface. Platform shifting or using abutments with a diameter less than the implant collar is thought to be advantageous to maintain marginal bone levels while providing a biomechanical advantage in osseointegrated implants as it redirects the concentration of stress, taking it away from the cervical region of bone-implant interface; with an inverse relationship between the amount of implant-abutment diameter mismatch and cortical bone stress concentration.

Angled abutments, UCLA Abutment, Ceramic abutments, CERADAPT Abutment, and Multi- Unit abutment are recent advancements in implant abutments.[17]

Fig. 2: a): CAD/ CAM custom abutments. Left to right, posterior milled titanium abutment, anterior milled titanium abutment, and hybrid milled zirconia bonded to titanium abutment base. **b):** Multiunit abutments with screws.

Fig. 3: a): Stock/standardized healing abutments **b):** Custom healing abutment with ideal contours.
Source: Park NI, and Kerr M. Terminology in Implant Dentistry. In: Misch,s Contemporary Implant Dentistry .4th ed. St Louis, USA: Mosby.;2021.p.20-4

15. Implant Materials

Dental implants have been tested using various materials, including metals, alloys, ceramics, polymers, glasses, and carbon. Biocompatibility, bio functionality, availability, and the ability to Osseo integrate are specific characteristics needed for their manufacturing.

Materials for dental implants and the prosthetic components they support must adhere to several strict requirements. For dental implants, titanium alloys continue to have the finest mechanical and biocompatibility qualities, and their usage is recommended. Currently, commercially pure titanium, titanium alloys, and zirconia (zirconium dioxide, $ZrO2$), ceramic implants are the representative biomaterials in wide use for dental implant applications. Additional other advanced material are Zirconia Toughened Alumina (ZTA) and Alumina Toughened Zirconia (AZT), Poly-Ether-Ether-Ketone (PEEK), Powder Injection Molding (PIM), Tantalum Implants, Porous Tantalum Trabecular Metal (PTTM), LASER- LOK Technology.[18]

16. Surface Modification of Implants

Research has shown that microrough surfaces had higher degrees of bone-to-implant contact or BIC. These modifications can be divided into subtractive and additive processes, depending on whether material is removed or deposited on the implant surface in the development of the surface.[19] Plasma arc is an additive process that involves depositing a bioactive hydroxyapatite (HA) material onto the implant surface. Polishing, machining, and acid etching are subtractive procedures used for implant surface treatment. These treatments can be classified into various methods, including mechanical, chemical, electrochemical, electropolishing, vacuum, thermal, and laser techniques (Figure 4). Various modifications have been implemented to enhance the biological surface of dental implants, aiming to achieve optimal bone-to-implant contact.[20]

Surface treatments involving calcium deposition have shown increasing bioactivity over time, with the highest deposition observed in the sandblasted, acid-etched, and thermally oxidized group. This is in lieu of greater surface roughness that promotes cell adhesion, proliferation, and differentiation.[20]

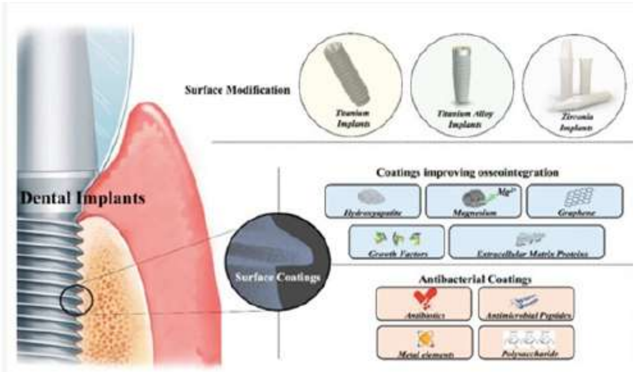

Fig. 4: Schematic illustration depicting surface modification and coatings of dental implants Source: Dong H, Liu H, Zhou N, Li Q, Yang G, Chen L, MouY. Surface Modified techniques & Emerging Functional Coating of Dental Implants. Coatings 2020, 10(11),1012:3-25

Recent studies have explored bioactive surface modifications of dental implants using inorganic materials (e.g., HA, calcium phosphate), growth factors, peptides, and extracellular matrix components. These approaches aim to enhance implant osseointegration and improve biological responses.[20] Research has shown the potential of utilizing stem cell-mediated bone regeneration for the treatment of peri-implant defects. However, stem cell implant technology is still in its early stages and is not currently a viable option for replacing missing teeth. Ongoing research hopes to enhance these techniques and develop more cost-effective procedures involving stem cells.[21]

17. Current Technologies for Implant Design and Placement Analysis

The success of dental implantation depends on accurate imaging. Cone Beam Computed Tomography (CBCT) utilising three-dimensional images is one of the newest technologies in dentistry imaging. This technology offers a continuous flow of data that allows dental surgeons to reconstruct images as needed, while minimizing radiation exposure for patients.[22,23]

18. Current developments in computed tomography technology include

1. (a) *Cone beam Computed Tomography:* This technology utilises a cone shaped beam of radiations. The image is reconstructed with special software. Comprehensive information like a Computed Tomography is obtained, albeit with 1/8th of radiation exposure and at minimal cost.
   (b) *Microtomograph:* This device helps in obtaining serial sections of the interface between implant and bone.
   (c) *Multislice helical CT:* This device has the advantage of providing high quality images when compared to Computed Tomography. It is referred as Dentascan Imaging.
   (d) *Interactive Computed Tomography:* This device develops image files that can be transferred from Radiologist to dentist's computer, who can work upon the case with precision and ease. Both the dentist and the radiologist work together and simulate placement of cylinders of arbitrary sizes in images, replicating root form implants, allowing for virtual surgical planning and an "Electronic Surgery".
   (e) *Magnetic resonance imaging (MRI):* This 3D non-invasive imaging method uses an electronic image acquisition process where image is produced digitally.

Better stability is made possible by the shape and configuration of implants, which is essential for the osseo-integration process. Refinement of drilling machines has led to better control over drilling speed and associated torque, which reduces risk of overheating the surrounding bone.[24] Improved control of water irrigation and the incorporation of internal implant irrigation systems also play a crucial role in minimizing the elevation of bone temperature during implant procedures. Additionally, the use of custom-made surgical splints, guided by CT data, assists in accurately defining the implant location and angulation, ensuring precise and optimal placement.[25]

Dental professionals and specifically prosthodontists have greater concern of the occlusal load on given prosthesis. Achieving precise dental implant alignment and connecting implants in a triangular configuration is crucial for the successful placement of fixed bridges in some cases. This configuration enhances stability and helps to resist lateral displacement forces.[26]

19. Peri implant surgery

It is common for tooth loss to be accompanied by the simultaneous resorption of the alveolar bone. As adequate implant width and length are crucial for long-term success of any implant, cases with insufficient remaining bone often pose a problem. The volume of the bone can be increased by varied techniques. For slight depressions, a simple onlay bone graft can be used while an inlay bone

graft can be employed where a sandwich osteotomy is required. Maxillary sinus floor augmentation can be used to increase bone volume in the upper jaw. Distraction osteogenesis is also a state-of-the-art procedure used for augmenting areas of bone. Now a days, osteo-inductive and osteo-conductive substances can help accelerate the healing process. Vestibuloplasty and palatal graft transplant are getting popular in cases where ablative surgery or tissue atrophy decreases the amount of available soft tissue. Free gingival graft transplant is a simpler procedure that produces less overall patient morbidity. Thus, the issues linked to either the soft tissue or bone deficit around the implant can likely be treated by combining several peri- implant operations.[27,28]

20. Image Guided Implantology

Image-guided implant surgery has experienced remarkable advancements in recent years. It involves two main types that utilize dedicated software for precise implant planning to define implant angulation and position, while avoiding contact with the maxillary sinus or with the inferior alveolar nerve. While one procedure consists of real-time navigational implant surgery, the other inserts implants using a surgical splint created using stereo lithography.[29]

Computer-designed surgical splints significantly expedite the implant placement process. However, any errors in planning or splint fabrication cannot be easily corrected during surgery. In such cases, surgeons may need to forgo the use of the splint altogether, potentially leading to incorrect implant placement.[30]

21. Conclusion

The future of dental implantology holds immense potential through continuous innovation and progress. Areas such as biomaterials, implant design, surface modification, and functionalization are critical for improving patient care and enhancing treatment outcomes. Advancements at every stage, including diagnosis, treatment planning, surgery, grafting, and implant designs, are essential for achieving successful long-term results in restoring missing dentition. By focusing on these areas of improvement, we can strive towards better patient outcomes and advancements in dental implant technology.

22. Source of Funding

None.

23. Conflict of Interest

None.

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ATHENAEUM SCIENTIFIC PUBLISHERS

Review Article

Current Concepts in Alveolar Ridge Augmentation

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Abstract

Ridge augmentation is a predictable procedure that can correct the defects caused by bone loss in areas with missing teeth. More importantly, this procedure allows the chance to return the natural contours of the soft tissues that existed before the loss of the tooth. It is done in patients with insufficient bone height and width by using various bone substitute materials and bone graft procedures where the successful placement of dental implants is difficult with regards to maintaining an ideal pathway and avoiding important anatomical structures. This review article will be carried out to describe the various techniques of ridge augmentation.

Keywords: Ridge Augmentation; Deficient Ridge; Hard and Soft Tissue Ridge Augmentation

Introduction

Periodontium is an important structure that provides support to the tooth necessary to maintain its function and is affected by any changes that the tooth may undergo, including eruption and extraction [1]. It consists of four principal components which includes gingiva, periodontal ligament, cementum and alveolar bone. Healing process occurring post extraction follows uneventful changes in the alveolar bone causing structural and dimensional changes in the overlying soft tissue [2]. These changes can occur in horizontal and vertical dimensions or both and may hamper with the functional and aesthetic success of prosthetic replacements including implants [3].

The predictability and technical difficulty of surgically reconstructing the ridge can be guided by classifications of ridge defects which are helpful to appreciate treatment modality chosen. According to Glossary of Prosthodontic Terms (GPT) 2009, Ridge augmentation is defined as a procedure designed to enlarge or increase the size, extent or quality of a deformed residual ridge [4]. Ridge augmentation is intended to augment the alveolar ridge volume beyond the existing skeletal envelop on the edentulous site of a deficient alveolar ridge with the variety of materials and techniques to optimize the ridge profile, to re-establish inter maxillary ridge correlation, confirm esthetic outcomes, achieve the biomechanical requisite of the prosthesis and to confirm osseointegration and persistence of Implant. The purpose of soft tissue preservation and bone formation is to provide stability and support for the future dental prosthesis. The sufficient horizontal as well as vertical bone dimensions are a prerequisite to warranty the success of implants.

Techniques For Ridge Augmentation

Ridge augmentation procedures are divided into vertical or horizontal ridge augmentation, which are performed simultaneously and are broadly classified into surgical procedures which undertakes hard tissue procedures, soft tissue procedures and both. Particulate or block autogenous bone grafts with ridge splitting or ridge expansion combined with Guided Bone Regeneration (GBR) are widely used in horizontal ridge augmentations. The outcomes and success rates are more predictable and higher when compared to vertical ridge augmentation. The reconstruction amount has an average 3 to 4 mm target in horizontal ridge

augmentations [5]. Historically, onlay grafts are performed as GBR with particulate or block type autogenous bone grafts in vertical augmentation which involves reconstruction of one wall defects.

1. Socket Preservation

Socket grafting is a preventive procedure for socket preservation at the time of extraction, which does not inhibit the resorption but limits it [6]. The minimal amount of resorption happens after socket grafting but in a predictable manner and the magnitude of volume loss is less in the grafted socket versus the naive socket. The rationale is that it should be performed in aesthetic areas in case of buccal bone thickness ≤2 mm or when there is a proximity to anatomic structures, i.e., maxillary sinus or mandibular canal [7].

2. Hard Tissue Augmentation Procedures

a. Guided Bone Regeneration

The application of GBR was described in 1988 by Dahlin, et al., in an experimental study on animals to see the results of healing of bone defects in which the defect on one side of the jaw was covered with a porous Polytetrafluoroethylene (PTFE) membrane and the other side served as the control, without a membrane covering [8]. The results showed that there was increase in bone regeneration on the membrane side as compared to the control after 3, 6 and 9 weeks of healing. GBR, also known as guided bone regeneration, is an evidence based predictable approach for separating the bone graft material (usually particulate) from neighboring soft tissues to allow unimpeded bone formation. The graft material is covered by securing a membrane to stabilize the material, parting it from adjacent connective tissues and limiting resorption. The volume stability of the graft in defect is the main factor on which the choice of membrane depends. Osseous regeneration by GBR depends on the migration of pluripotent and osteogenic cells (e.g. osteoblasts derived from the periosteum and/or adjacent bone and/or bone marrow) to the bone defect site and exclusion of cells impeding bone formation (e.g. epithelial cells and fibroblasts) [8-11]. There are few principles which need to be met to ensure successful GBR: Cell exclusion in which the barrier membrane is used to prevent gingival fibroblasts and/or epithelial cells from gaining access to the wound site and forming fibrous connective tissue; Space maintenance (Tenting) in which the membrane is carefully fitted and applied in such a manner that a space is created beneath the membrane which completely isolates the defect to be regenerated from the overlying soft tissue and also the membrane should be trimmed so that it extends 2 to 3 mm beyond the margins of the defect in all directions. The corners of the membrane should also be rounded to prevent inadvertent flap perforation; Scaffolding is one of the principles of GBR in which tented space initially becomes occupied by a fibrin clot, which serves as a scaffold for the in-growth of progenitor cells; Stabilization in which the membrane must protect the clot from being disturbed by movement of the overlying flap during healing and then fixed into position with sutures, mini bone screws or bone tacks. The edges of the membrane are simply tucked beneath the margins of the flaps at the time of closure, providing stabilization; Framework is necessary in cases of dehiscences or fenestrations where the membrane must be supported to prevent collapse [12]. Bone regeneration follows a specific sequence of events after GBR procedures. After the bone graft, the graft material/barrier created space is filled with the blood clot within the first 24 hours, which releases growth factors (e.g., platelet derived growth factor) and cytokines (e.g., IL-8) to attract neutrophils and macrophages. The clot is absorbed and replaced with granulation tissue which is rich in newly formed blood vessels. Through these blood vessels, nutrients and mesenchymal stem cells capable of osteogenic differentiation are transported and contribute to osteoid formation [13,14].

b. Onlay Grafting

Onlay grafting is indicated in cases of inadequate palatal vault morphology which is caused by excessive bone resorption. It can either be block onlay grafting or particulate onlay grafting. The latter can further be categorized as subperiosteal tunnel grafting or direct particulate onlay grafting

i. Block Onlay Grafting

Indication

It is done for horizontal or vertical deficiency or combined horizontal and vertical deficiency.

Technique

This is one of the most commonly employed technique. The block graft can be autogenous graft harvested from neighbouring intraoral donor sites, distant extraoral donor sites or commercially available xenografts or alloplastic grafts [15]. The recipient bed is prepared by drilling multiple holes after raising the mucoperiosteal flap till the underlying spongiosa is reached (Fig. 1).

Depending on the type of defect, the graft is contoured to adapt in proximity to the recipient site as veneer, block or inverted J Block graft which is placed for the vertical defects while veneer graft is used in the case of horizontal defects. For combined defects, the graft is modified to the shape of the inverted letter J [16-18]. Defects augmented using autogenous onlay grafts provide a labial cortex of bone capable of resisting occlusal loads, especially in the anterior dentition [19].

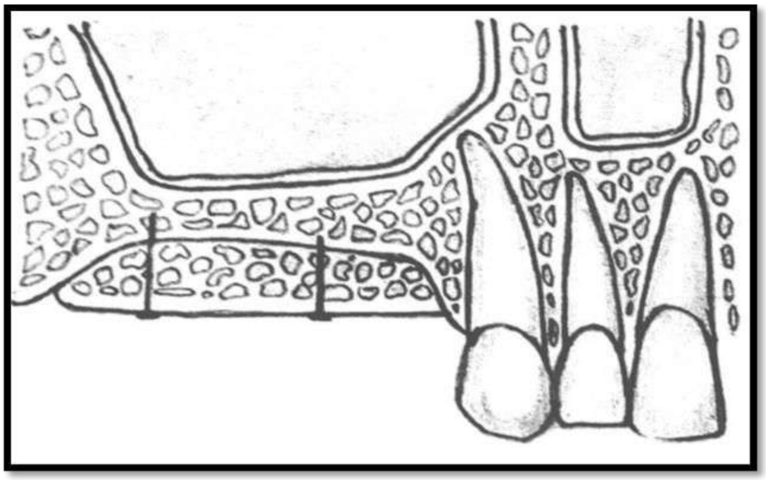

Figure 1: Block Onlay graft (Source: Goyal M, Mittal N, Gupta GK, Singhal M. Ridge augmentation in implant dentistry. J Int Clin Dent Res Organ 2015;7:94-112).

ii. Direct Particulate Onlay Grafting

Indication

It is performed to correct horizontal deficiencies in the anterior maxilla and for saddle depressions, i.e., vertical deficiency. Three-walled and four-walled defect morphology recipient sites with an apical stop are considered to be best amenable to direct particulate onlay grafting.

Technique

It is performed as a staged or simultaneous procedure (Fig. 2). To visualize the defect, the planned recipient area is exposed by raising a mucoperiosteal flap. The releasing incisions should be placed to ensure direct visualization of the defect and tension-free closure. The particulate graft is condensed over the defect after drilling holes in the recipient bed to ensure osseointegration. Demineralized grafts are preferred over mineralized grafts for defects with poorly contained boundaries, (i.e., maxillary sinus) due to their slower resorption [12]. The coverage with membranes is often recommended but can be omitted for small defects with sufficient neighbouring walls to provide volume stability [20,21]. The malleability and workability of particulate graft can be enhanced with tissue adhesives, i.e., fibrin sealants or protein-based regenerative gels.

Figure 2: Particulate graft (Source: Goyal M, Mittal N, Gupta GK, Singhal M. Ridge augmentation in implant dentistry. J Int Clin Dent Res Organ 2015;7:94-112).

iii. Subperiosteal Tunnel Grafting

Indication

It is indicated for small to moderate buccal plate defects. The morphology of such defects is characterized by wider buccal base with narrow crestal width (≤4 mm) and intact lingual wall with optimum vertical dimensions [22].

Technique

Access incision is placed distant (often mesially) from the recipient site after administration of local anesthesia, Subperiosteal tunnelling from the incision to graft site is performed with the help of a periosteal elevator. The demineralized particulate bone graft is placed in this subperiosteal tunnel with the help of modified 1 ml carrier syringe. To conform to the recipient bed in the desired form, the graft may need digital manipulation. The mesial incision is closed in a tension-free manner to ensure uneventful healing with minimal risks of dehiscence and graft exposure.

c. Interpositional Bone Graft (Sandwich Grafting)

Indication

It is indicated for vertical ridge defects with alveolar dimensions of 4-5 mm by placing two different layers of bone grafts and then cover them with a barrier membrane, creating a structure like the cross-section of the bone [22].

Technique

The facial aspect of the planned area of augmentation is exposed by giving a vestibular incision in nonkeratinized mucosa. Vertical corticotomies and osteotomies are performed using micro reciprocating and sees to the preservation of ≈2 mm of bone around the roots of neighbouring teeth followed by horizontal corticotomy and osteotomy to mobilize the segment.

There should be a minimum clearance of ≈3-5 mm from vital structures such as the maxillary sinus or mandibular canal. It is critical to perform only as much advancement as permitted by the soft tissue envelope to achieve tension-free closure. After careful transportation preserving soft tissue attachments, the bone graft block is sandwiched between the transported segment and basal bone with the advantages of reducing the need for compliance and less infection [23]. The graft fixation is achieved with miniplates. Periosteal releasing incisions are placed to aid tension free closure.

d. Ridge Split Procedure (RSP) (Fig. 3)

Indication

It was introduced in 1970s by Dr. Hilt Tatum to expand the existing residual ridge of the atrophic maxilla and mandible for implant insertion and augmentation has been referred to as ridge splitting, bone spreading, ridge expansion or the osteotome technique [24]. It is also known as Book Bone Flap. It is a technique-sensitive procedure that may be performed with many different instruments, ranging from chisel and mallet to scalpel blades, spatula, osteotomes, piezoelectric surgical systems, lasers and ultra-fine fissure burs. Osteotomes are the most popular used for ridge expansion ones amongst the various instruments and chisel and (hand) mallet are traditionally used devices [25,26].

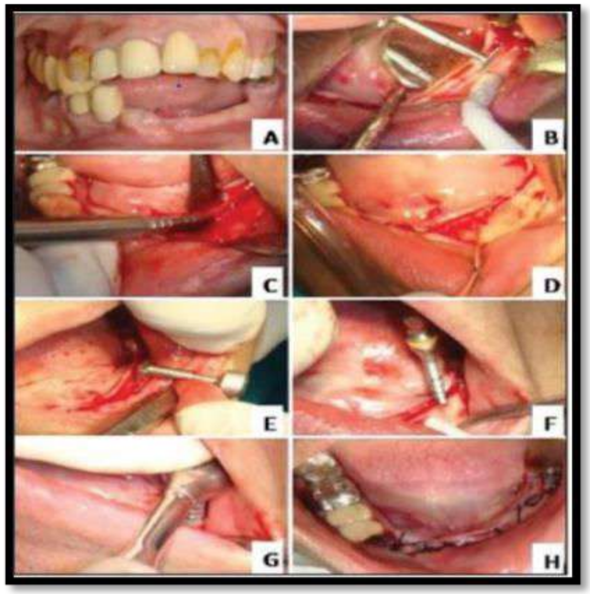

Figure 3: Ridge split. (A) thin alveolar ridge; (B) ridge split using MCT disk (3-mm radius); (C)expansion using rigid osteotome; (D)flexible chillet; (E) MCT ridge splitter; (F) bone expanders; (G) implant placement; (H)closure (Source: Goyal M, Mittal N, Gupta GK, Singhal M. Ridge augmentation in implant dentistry. J Int Clin Dent Res Organ 2015;7:94-112).

Technique I: Maxillary Single-Stage Alveolar RSP

This procedure usually consists of a single-stage, though occasionally a two-stage technique can be performed with the delayed placement of implant. 3 mm of alveolar width and 7 mm of alveolar length (between teeth) should be present for a single-tooth edentulous ridge to undergo RSP. The buccal-palatal dimension can be decreased and a full thickness incision of the appropriate length is performed in the edentulous area at the crest of the ridge. It is recommended to use a papilla-preservation approach. The developed flap is a limited crestal (not buccal) full-thickness flap just large enough to see the top of the alveolar crest with no formation or wide reflection of the buccal flap should occur.

Technique II: Mandibular Two-Stage Alveolar RSP

In the mandible, the procedure usually has 2 stages: stage 1 consists of corticotomy and stage 2 consists of splitting and grafting, which is performed 3-5 weeks later.

Stage 1: Corticotomy

The goal of corticotomy is to section through the exposed buccal cortex around the periphery of the buccal bony plate, which is to be laterally repositioned at the stage-2 surgery.

Stage 2: Splitting and Grafting

This procedure is done in a manner similar to a single stage of the maxillary ridge split, using a limited-reflection flap. A crestal incision just wide enough to see the crestal corticotomy is performed (closed approach). The operator should feel for the crestal groove created at the stage-1 surgery with the scalpel blade. The blade should be held firmly in this groove and run the full extension of this bony groove. Papilla-sparing curved incisions should be created toward the buccal and lingual side at the mesial and distal extensions of the groove. Tissue should be reflected to the lingual side as needed, but the tissue on the buccal side should only be elevated at the points where the buccal curved incisions are carried onto the adjacent bone. The spatula osteotome is tapped to depth with the osteotome of the next thickness and a controlled lateral force should begin to be used to mobilize the buccal plate. Thus, a buccal mucoosteo-periosteal flap with its own buccal soft-tissue blood supply is created and can be manipulated (widened). An overall ridge expansion up to 8-10 mm is usually adequate and grafting is performed. Primary closure of the wound is not needed nor is it usually possible. A 4 to 6 month waiting period is suggested before an implant treatment. The most common regions of the jaws that undergo RSP are the anterior and posterior maxilla and the posterior mandible [27].

RSP Using Piezosurgery

A papillary sparing crestal incision is performed on the atrophic ridge under local or general anaesthesia followed by two vertical releasing incisions beyond the mucogingival line. A full thickness mucoperiosteal flap is raised and when the bone surface is exposed, the planned osteotomies are outlined using tip number one at low power, in order to avoid oscillation of the tip and obtain a cut depth 1 mm [28]. Care must be taken to keep the lingual/palatal periosteum attached to the bony surface. The first osteotomy is carried out at the centre of the occlusal aspect of the ridge by tracing it, extending the incision in anteroposterior direction for the planned length. Subsequently, the vertical osteotomies are performed on the proximal and distal ends of the crestal incision. In surgical procedure, the vertical osteotomies are convergent and oblique, going from the outer surface of the vestibular cortex to the cancellous bone. The distance between the two vertical osteotomies is greater on the outer side than on the inner side of the vestibular cortical plate. The osteotomy lines should be traced using the tips progressively in order of size, varying the power level of the characteristics of the incision change too [29]. The tips are used in progression from number one to number five to deepen the osteotomies. As the groove on the bone surface becomes retentive, the tips can be used at high power resulting in more aggressive and faster cutting. The tips are calibrated to achieve the exact depth of cut desired but, if the cortical width exceeds 5 mm, a normal tip or chisels can be used to complete the osteotomy. Once the desired depth of the crestal and vertical osteotomies are achieved, the caudal ends of the vertical osteotomies are connected by a horizontal incision and the incision is a partial thickness osteotomy. The greenstick fracture is made using chisels. A cortical bone graft of appropriate size and shape is harvested from the ipsilateral mandibular ramus by means of the aforementioned tips and chisels. Bone chips are collected from the same donor site. The cortical graft is gently hammered between the vestibular and lingual cortex, acting as a bone wedge until the desired separation of the two cortices is reached. It is then stabilized using titanium osteosynthesis screws. In order to obtain supracrestal regeneration, the bone graft between the vestibular and lingual/palatal cortices can be fixed at a higher level in order to let it protrude from the occlusal aspect of the two bone plates. Finally, the grafted site is covered by a resorbable collagen membrane. The mucoperiosteal flap is repositioned and sutured.

e. Distraction Osteogenesis

Indication

It was developed by Gavriel Ilizarov in 1989 to treat skeletal deformities which works on principle of "tension-stress" with slowly incorporated tensile stress promoting histogenesis [30]. Bone traction generates tension and promotes osteogenesis, which occurs parallel to the distraction site and can be in vertical and/or a horizontal direction.

Technique

This technique allows significant augmentation of both hard and soft tissues in areas with extensive tissue loss in a staged manner [31-34]. A transport segment is mobilized in a similar manner as for interpositional bone grafting, preserving attachment to the crestal and lingual tissues.30 The distractor is fixed to transport basal bone segments with approximately 1-2 mm gap between the two segments. This is left in situ for a latency period of 5-7 days to allow the formation of soft tissue callus between the two segments and then activation is started at the rate of 0.5-2 mm/day for periodic distraction. After completion of the desired amount of distraction, the distraction device is removed and quality of the bone is explored. The newly formed bone is hourglass shaped and placement of additional grafts may be required for proper implant placement at this time. The implant placement is performed after a period of 4-6 months. It undergoes a more active remodeling process because of the better vascularization when compared to a block graft and minor complications could be averted using an appropriate technique [35,36].

f. Orthodontic Extrusion

In this method, forces are applied to the periodontally hopeless teeth, which brings the alveolar bone along with it. Elongation of the tooth in its alveolus causes shifting of gingival and Periodontal Ligament (PDL) fibres. The slow orthodontic extrusion technique is used to obtain a good amount of hard and soft tissue before dental implant placement. This technique avoids the surgical steps of the bone regeneration technique and is more simply managed by the clinicians. However, this technique requires more time to see the final results compared with surgical Guided Bone Regeneration (GBR). It is a non-traumatic technique whereas GBR is usually associated with pain and swelling in the immediate post op period [37,38].

g. Sinus Lift Procedure

It was proposed by Tatum for implant placement when there is insufficient bone between the maxillary alveolus and sinus [24]. The two procedures of sinus lift available are lateral window technique (lateral or direct sinus lift) and crestal approach (crestal or indirect sinus lift) [39-44].

Crestal Approach (Indirect Sinus Lift)

Indication

It is indicated when the Residual Alveolar Bone (RAB) is less than 6-8 mm.

Technique

After local anaesthesia is given, a pilot drill is used, followed by drills in increasing diameters and the osteotomy site is prepared. Care is taken to ensure that the drill length is maintained at 2 mm away from the floor of the sinus. As drills of higher diameter are introduced, it is observed that the sinus floor gets fractured and the sinus is slowly elevated to avoid injury to the Schneiderian membrane, by using a surgical mallet/osteotome with controlled force. Autogenous graft material is inserted within the socket, if required.

Lateral Window Technique (Direct Sinus Lift)

Indication

It is indicated when the residual alveolar bone is 5 mm or less.

Technique

A full-thickness flap is raised giving a crestal incision and a vertical releasing incision. The bone is exposed and sometimes a bluish hue is seen on the bony surface, which is indicative of the sinus. Then a window is made either using bur or piezosurgical instruments to delineate the sinus. After the window is prepared, it is slowly disengaged to expose the sinus. Care is taken to avoid perforation of the Schniederian membrane that lines the sinus. The sinus is then slowly elevated using the appropriate sinus lift instruments. If the window created has not been totally disengaged, it could be placed below the relocated sinus to form its floor. The empty void created between the elevated sinus and the basal bone is filled with either autologous or allogeneic graft material and a membrane is stabilized over it.

3. Soft Tissue Augmentation Procedures

a. Onlay Graft Procedures

Indication

It was first described by Seibert in 1983 for correcting horizontal deficiencies in the anterior maxillary arch and for saddle depressions, i.e. vertical deficiency [45,46].

Technique

A recipient bed is prepared with two parallel split-thickness incisions in the lamina propria of the edentulous area and the epithelium is removed in order to expose the underlying connective tissue. A free gingival graft is then harvested from the palate and secured on the recipient vascular bed with interrupted and compressive sutures, with the amount of augmentation depending on the thickness of the applied graft. There is no shrinkage of the tissue grafted, but a varying amount of volume is lost during the healing phase for which, it is frequently necessary to repeat the surgical procedure at 2 to 3 month intervals in order to reach the desired ridge height [45-48].

b. Roll Flap Technique:

Indication

It was introduced by Abrams in 1980 to correct small or moderate soft tissue defects associated with buccolingual defects of ridge [49].

Technique

It involves a connective tissue pedicle flap that originates from the de epithelialization of the palatal tissue close to the edentulous area in which two parallel incisions are made from the occlusal edentulous area towards the palate and connected with a horizontal incision. A split-thickness palatal flap is then elevated and a pouch is prepared in the defect area with a split dissection of the supra periosteal connective tissue. The palatal flap is 'rolled' into the pouch area and then sutured [50].

Modified Roll Technique

Indication

This technique is a modification of the roll technique which was introduced by Scharf and Tarnow for class I deformities wherein the epithelium over the connective tissue is not scraped but preserved to cover the donor site [51].

Technique

An incision is made using a Bard-Parker blade from the crest to the palatal area to include a sufficient length of the tissue to be rolled to the desired area on the buccal aspect. A similar incision is made on the other side to include sufficient width of the graft and the two vertical incisions are connected by a horizontal incision. A partial-thickness trap door-type flap is reflected. The pedicle is rolled on the buccal aspect and stabilized using a horizontal mattress suture.

c. Interpositional (Inlay) Graft Procedures

Indication

It was described in 1979 by Meltzer which involves the placement of graft without scraping the epithelium from the connective tissue to treat buccolingual and apicocoronal ridge defects [52].

Technique

A pouch is prepared in the defect area and a free graft derived from the palatal or maxillary tuberosity is harvested which is partially de-epithelialized and the exposed connective tissue is inserted in the pouch area like a wedge (inlay graft). Thus, the epithelialized part of the graft remained outside the pouch and sutured at the level of the epithelial surface of the surrounding tissues [45,46,52-54].

d. Combination Onlay-Inlay Grafts

Indication

It was introduced by Seibert and Louis in 1996 to treat buccolingual and apicocoronal ridge defects [55].

Technique

It is done to obtain simultaneous tissue augmentation in the horizontal and vertical dimensions. The donor site is prepared with a full-thickness coronal dissection and a partial thickness apical dissection. The graft is thus composed of two parts: the coronal part, which is epithelialized and the apical part, which is formed of connective tissue only. On the defect area, the crestal surface is de-epithelialized with a beveled incision and the apical surface is prepared with a partial-thickness dissection with two vertical-releasing incisions extended apically, without involving the adjacent papillae to create a pouch area. The onlay section (epithelialized area) of the graft is sutured on the crestal surface of the defect, while the inlay section (connective tissue) is inserted and secured in the vestibular pouch area.

e. Pouch Procedures

Indication

It was put forward by Burton Langer and Lawrence Calagna to treat ridge deformities in which a connective tissue graft was procured from the palatal area or maxillary tuberosity to increase the thickness of the soft tissue on the buccal surface of ridge [56,57].

Technique

A pouch is prepared with a split dissection of the supra periosteal connective tissue and the connective tissue graft is sutured to

the periosteum and then the flap is sutured in its original position and covers the connective tissue graft completely.

Discussion

The onlay technique is done mostly with an autogenous bone graft. Before the year 2000, most implants were immediately placed together with the bone grafts. The implants were used to secure the graft. The capacity and volume of the bone grafts are variable between the studies. These differences could be explained by different follow-up periods, timing of implants placement, different sites and different bone grafting material. Over all the resorption rate is higher in the first year, but stabilizes after it [18].

Alveolar distraction is only indicated for the mandible because of the pneumatization of the sinus in the maxilla. A disadvantage is the early resorption of the distracted bone. It undergoes a more active remodeling process because of the better vascularization when compared to a block graft as reported by Hodges NE [35].

The ridge split technique has been used in horizontal deficiency requiring 2-5 mm of augmentation. It is a minimally invasive technique indicated for alveolar ridges with adequate height, which enables immediate implant placement and eliminates morbidity and overall treatment time. The classical approach of the technique involves splitting the alveolar ridge into 2 parts with use of ostetomes and chisels. Tatum developed specific instruments including tapered channel formers and D-shaped osteotomes to expand the resorbed residual ridges of both the upper and lower jaws having a ridge width of <3 mm [24-26].

Ridge Expansion is indicated in patients with ridge width <6 mm. A full-thickness flap is raised to expose the bone. Scipioni, et al., reported a 98% 5-year implant survival rate when utilizing ridge expansion with simultaneous implant placement [58]. The split-crest technique had previously been compared to lateral ridge augmentation with autogenous bone block graft disclosing no significant differences in implant survival between the two treatment modalities, although the gain in alveolar ridge width was significantly higher with lateral ridge augmentation with autogenous bone block graft [59].

Liu J, et al., stated that guided bone regeneration is a surgical procedure that uses barrier membranes with or without particulate bone grafts or/and bone substitutes [60]. Wang HL, et al., stated that four principles need to be met to ensure successful GBR [13]. Sandwich grafting is done with vertical ridge deficiency with preexisting minimal vertical alveolar dimensions of 4-5 mm and without any soft tissue deficit. Choi BH, et al., concluded that sandwich osteotomy combined with interpositional allografts technique was safe although it leads to some resorption of the superior and anterior parts of the alveolar fragment [23].

Interpositional graft procedures were described by Meltzer which involves the placement of graft without scraping the epithelium from the connective tissue to treat buccolingual and apicocoronal ridge defects [52]. Tatum proposed a technique, "sinus lift procedure", for implant placement when there is insufficient bone between the maxillary alveolus and sinus [24]. Alveolar height <10 mm is often an indication for sinus lift surgery via the crestal (indirect) approach, while alveolar height <5 mm via is an indication for the lateral (direct) approach.

In orthodontic extrusion, forces are applied to the periodontally hopeless teeth, which will bring the alveolar bone along with it. Salama and Salama have documented clinical cases employing forced eruption on hopeless teeth to augment bony tissues in implant sites and also proposed a classification for extraction socket according to their morphology and placement of the implant into the socket [37]. PDL cells play a crucial role at a molecular level, thereby aiding in optimal results after implant placement [38].

The Roll technique introduced by Abrams was employed to correct small or moderate soft tissue defects associated with buccolingual defects of ridge [49]. Padhye, et al., compared the Subepithelial Connective Tissue Graft (SCTG) and buccally displaced flap [61]. The results showed that there was an increase in the width and thickness of keratinized mucosa in the buccally displaced flap group than the SCTG group, with reduced surgical sites, less postoperative pain and good blood supply. Pouch procedures were put forward by Burton Langer and Lawrence Calagna to treat ridge deformities in which a connective tissue graft was used which was procured from the palatal area or maxillary tuberosity to increase the thickness of the soft tissue on the buccal surface of ridge [56,57].

Conclusion

Reconstructive surgical procedures aimed at restoration of the alveolar ridge to its former dimensions are increasingly prescribed, particularly in the anterior region where esthetic issues are concerned. Nevertheless, there is a lack of clinical studies in the literature investigating this concern and therefore evidence- based conclusions cannot be drawn. Furthermore, because of the high esthetic impact it is advised that patient-centered outcomes be incorporated in clinical trials.

Conflict of Interests

The authors have no conflict of interest to declare.

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(57) Abstract :
Recent days have seen a steep rise in oral and dental diseases among people living especially in low- and middle- income countries, where the access to oral and dental health diagnosis and treatment are limited. According to World Health Organization Oral Health Status Report, nearly 3.5 billion people are affected by oral and dental health diseases worldwide on 2022. Dental Plaques may lead to various other diseases such as periodontitis, gingivitis and caries. Hence, devising a system and method for plaque detection is very important to ensure oral health of children. Proposed is a System and Method for Plaque Detection on Primary Teeth in Children using Machine Learning. Intraoral camera captures the photo of primary teeth image and the same is subject to data preprocessing to remove any unnecessary noise signals. Convolutional Neural Networks consists of alternative convolution and pooling layers for plaque detection on primary teeth. Initial weights of the neural networks are obtained using transfer learning methods. Developed Machine Learning model detects plaque using Backpropagation Learning.

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(57) Abstract :
One of the most common non-commutable types of chronic inflammatory disease is Periodontitis. It is the sixth most common disease affecting nearly 750 million population worldwide every year. It is very important to treat such Intrabony Osseous Defects, as if left untreated, it may lead to increased risk of disease progression sometimes leading to loss of teeth. Research studies suggest that piezoelectric surgical instruments with accurate precision would provide correct prediction of periodontal osseous defects. Any immediate reduction in periodontal dental angulation could be detected by bone swaging. Proposed is a System and Method to Detect the Depth of Intrabony Osseous Defect using Machine Learning. Input Cone Beamed Computed Tomography (CBCT) which provides inter-relational images in three orthogonal planes namely axial, sagittal and coronal and also customized planes are subject to Image Pre-Processing. Images are converted to Gray Scale and Binarization of images is carried out using Social Edge Detection to increase the object recognition rate. Target object recognition is trained using Convolutional Neural Networks. Multiclass Classifier and Bounding Box Regressor employed for each convolutional and pooling layers for accurate detection of depth of intrabony osseous defects.

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Date of Issue : 18/04/2024

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प्रमाणित किया जाता है कि संलग्न प्रति में वर्णित डिजाइन जो *MOUTH PROP FOR MOUTH OPENING IN LOCKED JAW CONDITION* से संबंधित है, का पंजीकरण, श्रेणी 24-02 में 1.Dr. Deepankar Misra 2. Dr. Akansha Misra 3.Dr. Manish Khatri 4.Dr. Nutan Tyagi 5.Dr. Gaurav Issar 6.Dr. Mansi Bansal 7.Dr. Sumit Bhateja 8.Dr. Akansha Budakoti 9.Dr. Jasdeep Kaur 10.Dr. Vashishtha Singh के नाम में उपर्युक्त संख्या और तारीख में कर लिया गया है।

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A Review

Cone Beam Computed Tomography & Its Application In Periodontics

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Abstract

The presence of periodontal diseases is diagnosed on the basis of evaluation of clinical signs and symptoms followed by radiographs. Radiographs provide diagnostic information about the quality localization of the bone defect and the pattern of the bone resorption, changes in the bony trabeculae, condition of the lamina dura, length and shape of the root, furcation defects, subgingival calculus, and additional pathology. Two dimensional periapical and panoramic radiographs are routinely used for diagnosing periodontal bone levels.The amount of information obtained from conventional film and digitally-captured periapical radiographs is limited by the fact that the three-dimensional anatomy of the area being radiographed is compressed into a two-dimensional image. As a result of superimposition, periapical radiographs reveal limited aspects of the three-dimensional anatomy. Three dimensional imaging (3D) evolved to meet the demands of advanced technologies in delivering the treatment and at the same time responsible for the evolution of new treatment strategies. Cone beam computed tomography (CBCT) generates 3D volumetric images and is also commonly used in dentistry. All CBCT units provide axial, coronal and sagittal multi-planar reconstructed images without magnification. CBCT displays 3D images that are necessary for the diagnosis of intra bony defects, furcation involvements and buccal/lingual bone destructions. CBCT applications provide obvious benefits in periodontics, however; it should be used only in correct indications considering the necessity and the potential hazards of the examination.

Keywords: cone beam computed tomography (CBCT); 3D radiography; periodontal defects; periodontal diagnosis; furcation; intrabony defects

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Introduction

The periodontium is a functional unit of the tooth that consists of the gingiva, periodontal ligament, cementum, and alveolar bone. Radiographically, the periodontal ligament space appears as a dark line surrounding the root and an increased radio density of alveolar bone is visible adjacent to the periodontal ligament space, referred to as the lamina dura which is an extension of cortical bone into the alveolus.[1]

Periodontal diseases can be broadly classified as gingival diseases (gingivitis) and periodontitis. The bone destruction in periodontal disease occurs when the inflammation extends from the marginal gingiva into supporting periodontal tissues.

Although periodontitis is always preceded by gingivitis, gingivitis does not always progress to periodontitis.[2] The periodontium is first evaluated clinically followed by radiographic study.

Dental radiographs are a valuable non-invasive tool used as an adjunct to clinical examination for assessment of the periodontal conditions of the teeth.[3] Radiographs provide diagnostic information about the quality localization of the bone defect and the pattern of the bone resorption, changes in the bony trabeculae, condition of the lamina dura, length and shape of the

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root and the crown root ratio, plaque retention factors, caries, furcation defects, subgingival calculus, and additional pathology.[4]

Broadly, imaging techniques used in dentistry can be categorized as: intraoral and extraoral, analogue and digital, ionizing and non-ionizing imaging and two-dimensional (2-D) and three-dimensional (3-D) imaging. Traditional analog imaging modalities are two dimensional systems that use image receptors like radiographic films or intensifying screens. These include periapical views, panoramic, occlusal and cephalometric radiography.[5]

The interpretation of an image can be altered by the anatomy of both the teeth and surrounding structures. The amount of information obtained from conventional film and digitally-captured periapical radiographs is limited by the fact that the three-dimensional anatomy of the area being radiographed is compressed into a two-dimensional image. As a result of superimposition, periapical radiographs reveal limited aspects of the three-dimensional anatomy.[6] Three dimensional imaging (3D) evolved to meet the demands of advanced technologies in delivering the treatment and at the same time responsible for the evolution of new treatment strategies. G.N. Houns field, in 1972 introduced computerized transverse axial scanning which lead to introduction of Computed Tomography (CT). The high radiation dose, cost, availability, poor resolution and difficulty in interpretation have resulted in limited use of CT imaging in dentistry. These problems may be overcome using small volume cone-beam computed tomography (CBCT) imaging techniques.[7]

CBCT is also known as CBVT (Cone Beam Volumetric Tomography), CBVI (Cone Beam Volumetric Imaging) dental 3D CT, dental CT and DVT (Digital Volume Tomography) has touched every aspect of medical and dental profession. In periodontology as well as implantology, CBCT scanning has become a valuable imaging technique, for the diagnosis of intrabony defects, furcation involvements, and buccal/lingual bone destructions.

Principles of CBCT

The principal feature of CBCT is that multiple planar projections are acquired by rotational scan to produce a volumetric data set from which interrelation images can be generated.[8] Cone-beam scanners use a two-dimensional digital array providing an area detect or rather than a linear detect or as conventional CT does. This is combined with a three-dimensional X-ray beam with circular collimation so that the result ant beam is in the shape of a cone, hence the name "cone-beam". Because the exposure incorporates the entire region of interest (ROI), only one rotational scan of the gantry is necessary to acquire enough data for image reconstruction.[9]

Steps in Cone Beam Computed Tomography Image Production

Image production by CBCT involves four steps[10]:

A. Image Acquisition
B. Image detection
C. Image reconstruction
D. Image display

A. Image Acquisition

The cone-beam technique involves a rotational scan exceeding 180 degrees of an x-ray source and a reciprocating are a detect or moving synchronously around the patient's head. During the rotation, many exposures are made at fixed intervals, providing single projection images known as —basis", —frame" or "raw" images similar to lateral cephalometric radiographic images, each slightly off set from one another. The complete series of basis images is referred to as the projection data. Software programs incorporating sophisticated algorithms including back-filtered projection are applied to the projection data to generate a 3D volumetric data set that will provide primary reconstruction images in three orthogonal planes (axial, sagittal, and coronal).[11]

There are four components to image acquisition in CBCT:

1. Acquisition mechanics: Full/ partial rotation scan
2. X-ray generation: continuous/ pulsed
3. Field of view
4. Scan factor

1. Acquisition Mechanics:

The CBCT technique involves a single scan from an X-ray source which can be a partial or full rotational scan, exposing a reciprocating area detector that moves synchronously around the patient's head.

2. X-ray generation

Although CBCT is technically simple in that, only a single scan of the patient is made to acquire a data set, a number of clinically important parameters should be considered in x-ray generation.

Patient Positioning:

CBCT can be performed with the patient in three possible positions: Supine, Standing and Sitting.

X-ray generator

During the scan rotation, each projection image is made by sequential single image capture of the remnant x-ray beam by the detector.

3. Field of view

Ideally, the FOV should be adjusted in height and width which mainly depends on the size and shape of the detector, projection of the X-ray beam, and collimation of the X-ray beam. CBCT systems can be grouped according to the available FOV or selected scan volume height as follows:

1. **Localized region:** Approximately 5 cm or less (e.g., dento alveolar and TMJ)
2. **Single arch:** 5–7 cm (e.g., maxilla or mandible)
3. **Interarh:** 7–10 cm (e.g., mandible and superiorly to**c** include the inferior concha)
4. **Maxillofacial:** 10–15 cm (e.g., mandible and extending to nasion)
5. **Craniofacial:** >15 cm (e.g., from the lower border of the mandible to the vertex of the head).

4. Scan Factors

The speed with which individual images are acquired is called the frame rate and is measured in frames, projected images, per second. The maximum frame rate of the detector and rotational speed determines the number of projections that may be acquired. The number of projection images comprising a single scan may be fixed or variable. With a higher frame rate, more information is available to reconstruct the image; therefore, primary reconstruction time is increased. Higher frame rates are usually accomplished with a longer scan time and hence higher patient dose.[9,10,11]

A. Image Detection:

Current CBCT units can be divided into two groups on the basis of detector type:

- An image intensifier tube/ charge couple device combination (IIT/CCD)or
- Flat-panel imager.

B. Image Reconstruction

The reconstruction process consists of two stages:

Acquisition stage

Raw images from CBCT detectors exhibit spatial variations of dark image offset and pixel gain due to varying physical properties of the photodiodes and the switching elements in the flat panel detector and also due to variations in the X-ray sensitivity of the scintillator layer. These raw images need systematic offset and gain calibration and a correction of defect pixels which is done by "detector preprocessing."

Reconstruction stage

After the correction of the images, the images are transformed into sinogram which is done by reconstruction filter algorithm, the modified Feldkamp algorithm, that converts the image into a complete 2D CT slice. All the slices are finally recombined into a single volume for visualization.[11]

C. Image Display

The volumetric data set comprises of collection of all available voxels and projected on the screen as secondary reconstructed images in three orthogonal planes - axial, sagittal, and coronal.

Advantages of CBCT

CBCT technology in clinical practice has important advantages such as minimization of the radiation dose, image accuracy, rapids can time, fewer image artefacts, chair-side image display, and real-time analysis.

Disadvantages of CBCT

Although there has been enormous interest in CBCT, this technology has limitations related to the cone-beam projection geometry, detect or sensitivity and contrast resolution that produce images that lack the clarity and utility of conventional images. The patient must be motion less during the scanning to achieve a good image; other wise the image may display streaking.[12]

Diagnostic Application In Periodontics

The clinical applications of three-dimensional craniofacial imaging are one of the most exciting and revolutionary topics in dentistry.[13] (Figure1)

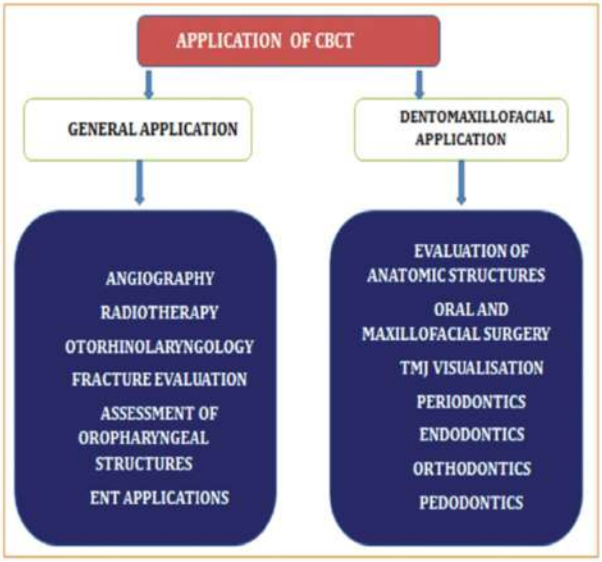

Figure 1: Application of CBCT

Role in Periodontics

Identification of periodontal landmarks

Periodontal Ligament Space

Radiographically lamina dura appears as a thin radiopaque line around the length of root. The space present between lamina dura and adjacent tooth is termed as PDL space. Any break in the continuity of lamina dura and a wedge shape radiolucenly at the mesial or distal aspect of the PDL space indicates periodontitis. Ozmeric et al did a study and compared CBCT with conventional radiography in terms of their ability to produce images of periodontal ligament space on a phantom model with artificially created periodontal ligament of various thicknesses and had found that the Periapical radiographs were superior to CBCT for the measurement of periodontal ligament space. But conflicting results were reported by the authors of another in vitro study that found CBCT to be better than conventional radiography in visualizing the periodontal ligament space. A phantom demonstrating variable periodontal ligament spaces was radiographed using CBCT and intraoral radiographs. This study found that CBCT provided better visualization of simulated periodontal ligament space in this phantom.[14]

Alveolar Bone Defect

The extent of periodontal marginal bone loss is necessary to determine the periodontal destruction. CBCT images provide better information on periodontal bone levels in 3D view than conventional radiography. CBCT is considered a superior technique in detecting the buccal and lingual defects and the interproximal lesions.Radiographs are mainly used to diagnose the amount and shape of alveolar bone destruction that affects treatment planning in periodontal therapy.[14,15]Two Dimensional radiographs can be insufficient for the detection of intrabony alveolar defects due to the obstruction of spongious bone changes by cortical plate. Thus, three-dimensional imaging is required for mapping of alveolar defects. Vandenberghe et al studied thirty periodontal bone defects of 2 adult human skulls using intraoral digital radiography and CBCT and concluded that the intraoral radiography was significantly better for contrast, bone quality, and delineation of lamina dura, but CBCT was superior for assessing crater defects and furcation involvements.[16]In Misch and colleagues study they demonstrated that CBCT was as accurate as direct measurements using a periodontal probe and as reliable as radiographs for interproximal areas.[17]Stavropoulos and Wenzel evaluated the accuracy of CBCT scanning with intraoral periapical radiography for the detection of periapical bone defects. CBCT was found to have better sensitivity compared to intraoral radiography.[18]

Furcation Involvement

Radicular bone assessment is anessential step in furcation involvement treatment planning procedures such as apically repositioned flaps with or without tunnel preparation, root amputation, hemi-/trisection or root separation. Conventional two dimensional radiographs can be deceptive in evaluating periodontal tissue support and inter radicular bone due to superposition of anatomical structures. However, 3D images provide detailed information about areas of multi rooted teeth. Intrasurgical furcation involvement measurements were compared by using CBCT images and it was reported that CBCT images demonstrated a high accuracy in assessing the loss of periodontal tissue and classifying the degree of furcation involvement in maxillary molars. In another study author had compared CBCT to intraoral radiography and concluded that the detection of crater and furcation involvements had failed in 29% and 44% for the intraoral radiograph, respectively, as compared to 100% detectability for both defects with CBCT.[19]

Regenerative periodontal therapy and bone grafts

Bone grafting is commonly used for maxillary sinus lifting and treatment of intra bony defects but evaluation of osseous defect regeneration with conventional radiography can be limited due to superimpositions. Furthermore, histological evaluation of a sample of the graft is not a preferred method due to its quite invasive procedure. CBCT was found to be significantly more accurate than digital intraoral radiographs when direct surgical measurements served as the gold standard for the evaluation of intra-bony defects' regenerative treatment outcomes. CBCT can replace surgical re-entry by providing 3D images and measurements that are almost equivalent to direct surgical measurements.[19,20] Dimensions of alveolar process should be examined in detail prior to dental implant placement to avoid various complications and evaluation of CBCT images has a major importance in preoperative planning and postoperative localization of dental implant.[21]

Role In Implant Site Assessment:

Implant placement requires technique which is capable of obtaining highly accurate alveolar and implant site measurement to assist with treatment planning and avoid damage to adjacent vital structure during surgery. Earlier alveolar and implant site measurement was done either using 2-D radiographs and in some instance using conventional CT (Figure 2). When compared, CBCT is preferable option for implant dentistry, providing greater accuracy in measuring with utilization of lower radiation dose.

Uses[22]

1. To assess the quantity and quality of bone in edentulous ridges.
2. To assess the relation of planned implants to neighboring structures.
3. To assess the success of implant osseointegration.
4. To provide information on correct placement of implants.
5. Before ridge augmentation in anodontia
6. Before bone reconstruction and sinus lifting
7. During planning and in designing a surgical guidance template.

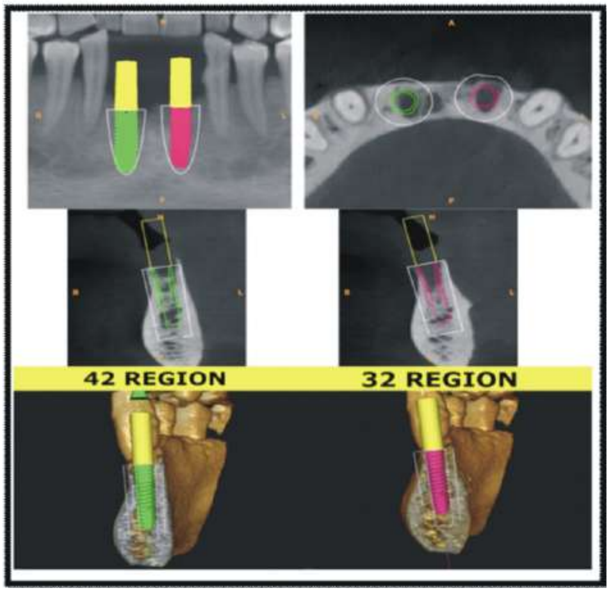

Figure 2: Implant site assessment

Role of CBCT in detecting anterior looping during implant placement:

Apostolakis D and Brown JE (2012) stated that the final part of the inferior alveolar nerve sometimes passes below the lower border and the anterior wall of the mental foramen.[23] After giving off the smaller mandibular incisive branch, the main branch curves back to enter the foramen and emerge to the soft tissues, as the mental nerve. The section of the nerve in front of the mental foramen and just before its ramification to the incisive nerve can be defined as the anterior loop of the inferior alveolar nerve. Selective surgery in the area of the anterior mandible such as implant installation in the interforaminal region or symphysis bone harvesting, may violate the anterior loop resulting in neurosensory disturbances in the area of the lower lip and chin. To avoid such a sequel a 5-mm safe distance to the most distal fixture from the anterior loop and a 5-mm distance from the mental foramen for chin bone harvesting have been proposed.[23,24]

Tolstunov identified and described four alveolar jaw regions—functional implant zones (Figure 3)[21] with unique characteristics of anatomy, blood supply, pattern of bone resorption, bone quality and quantity, need for bone grafting and other supplemental surgical procedures, and a location related implant success rate.

Four functional implant zones identified by Tolstunov[21,22,23]:

i. Functional Implant Zone 1 (Traumatic zone)consists of alveolar ridge of premaxilla and eight anterior teeth: 4 incisors, 2 canines, and 2 first premolars. Any bone loss in the anterior maxillary area is vital due to the esthetic implications on dental implant supported restorations. Loss of teeth in this area is mostly due to trauma and if the teeth are not replaced immediately following trauma, the bone loss continues, leading to difficulty in dental implant placement in a prosthetically favorable position.

ii. Functional Implant Zone 2(Sinus zone): bilateral maxillary posterior zone extends from the maxillary second premolar to the pterygoid plates and is located at the base of the maxillary sinuses.

iii. Functional Implant Zone 3 (Inter-foraminal zone): comprised of the area of the mandibular alveolar ridge between mental foramen and first premolar on each side. This zone is also associated with a thin alveolar ridge. There is abundant evidence in the literature reporting severe bleeding with the formation of expanding sublingual hematomas due to the perforation of the lingual cortex.

iv. Functional Implant Zone 4:- This zone of the alveolar process of the mandible behind the mental foramen on each side and extends from the second premolar to retromolar pad. The distance of the alveolar bone height from the inferior alveolar canal is evaluated when dental implants are considered in the posterior mandible. Careful assessment of the height must be made to avoid injury to the inferior alveolar canal. If there is a violation of the inferior alveolar nerve (IAN), depending on the degree of nerve injury, alteration in sensation, from mild paresthesia to complete anesthesia, is reported.

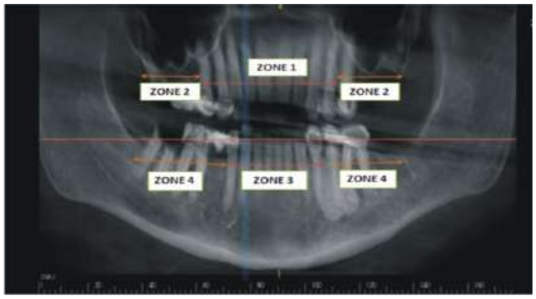

Figure 3: Functional implant zones identified by Tolstunov

Conclusion

Cone beam computed tomography is a diagnostic imaging technology that is changing the way dental practitioners view the oral and maxillofacial complex as well as the teeth and the surrounding tissues. CBCT has been specifically designed to produce undistorted three dimensional images similar to computed tomography (CT), but at a lower equipment cost, simpler image acquisition, and lower patient radiation dose. However the two-dimensional diagnostic imaging has served dentistry well and will continue to do so for the foreseeable future. Intraoral and panoramic radiographs are the basic imaging techniques used in dentistry and are quite often the only imaging techniques required for the detection of dental pathology.

For periodontal disease, CBCT promises to be superior to 2Dimaging for the visualization of bone topography and lesion architecture but no more accurate than 2D for bone height. This factor should be tempered with awareness that restoration in the dentition may obscure views of the alveolar crest. No doubt, future improvements in CBCT technology will result in systems with even more favorable diagnostic yields and lower doses.

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(57) Abstract :
One of the most common non-commutable types of chronic inflammatory disease is Periodontitis. It is the sixth most common disease affecting nearly 750 million population worldwide every year. It is very important to treat such Intrabony Osseous Defects, as if left untreated, it may lead to increased risk of disease progression sometimes leading to loss of teeth. Research studies suggest that piezoelectric surgical instruments with accurate precision would provide correct prediction of periodontal osseous defects. Any immediate reduction in periodontal dental angulation could be detected by bone swaging. Proposed is a System and Method to Detect the Depth of Intrabony Osseous Defect using Machine Learning. Input Cone Beamed Computed Tomography (CBCT) which provides inter-relational images in three orthogonal planes namely axial, sagittal and coronal and also customized planes are subject to Image Pre-Processing. Images are converted to Gray Scale and Binarization of images is carried out using Social Edge Detection to increase the object recognition rate. Target object recognition is trained using Convolutional Neural Networks. Multiclass Classifier and Bounding Box Regressor employed for each convolutional and pooling layers for accurate detection of depth of intrabony osseous defects.

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Review Article

Piezosurgery in periodontology

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ABSTRACT

Piezosurgery is a relatively new method derived from the Greek term "piezein" which means "to press tight or to squeeze". Tomaso Vercellotti an italian physician invented it. He teamed up with Mectron Medical Technology, a medical device company was founded by Italian engineers Fernando Bianchetti and Domenico Vercellotti. It is a technique conceived to overcome the limitations of traditional bone cutting instruments in order achieve the most effective treatment with minimal amount of morbidity. It is used for bone removal and bone recontouring procedure on the principle of ultrasonic vibration. Piezoelectric effect generates an electrical charge when subjected to mechanical stress.

1. Introduction

Over the past years dentistry has underwent lots of advancement in day to day life. Various diagnostic imagining technique such as Ultrasonography, Cone Beam Computed Tomography, LASERS, Implants, Microsurgery and Nanotechnology had made the dentistry front runners in the medical field. Traditionally, osseous surgery has been performed with hand instruments (chisel, osteotome or mallet) or various motorized equipment that can be powered by air pressure or electrical energy. Manual hand cutting instruments take much longer time to yield desired results and often difficult to apply in many osseous surgical procedures. Motorized devices have rotary, reciprocal or oscillatory movements that have certain disadvantages such as: necrosis occurs due to overheating of bone tissue; loss of perceptivity to a gentle touch due to pressure on the handpiece; cutting depth is difficult to determine; iatrogenic impairment in undesirable areas due to a failure in the accurate adjustment of the speed of a rotating head or saw; and the risk of soft tissue injury to important anatomical structures such as the inferior alveolar nerve or the maxillary sinus.[1]

2. Objectives

To overcome the limitation of traditional instruments, researchers have surpassed advanced therapeutic devices that function on the idea of ultrasonic microvibrations to cut bone precisely in harmony with the surrounding tissue.[2]

Rationale of the study is to delinate the piezosurgery invention, its indication and contraindication, armamentarium, application of piezosurgery in periodontology and its limitation.

3. Piezosurgery

Piezosurgery is a method used for bone removal and bone recontouring that uses the principle of ultrasonic vibration. The word "piezo" derived from the Greek word piezein which means "to press tight or to squeeze."[3] The Piezoelectric effect is the property of certain materials to

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produce an electrical charge in response to an applied mechanical stress. It was innovated in 1988 by Professor Tomaso Vercellotti and was developed by Mectron Medical Technology.[4] He proposed the idea of using sharpened instruments fitted on ultrasonic device for ablation to perform peri radicular osteotomy to extract an ankylosed tooth. Vercellotti et al. (2000) have revised this method for nerve and soft tissue protecting surgery that has overcame the limitations of traditional instruments in oral bone surgery. Mectron (2000) developed the first generation piezosurgery device.[5,6]

4. Historical Background

Piezoelectrical device was first discovered in 1880 by Jacques and Pierre Curie. They found that applying pressure to different crystals, ceramics, and bone produces electricity. In 1881, Gabriel Lippmann found the converse piezoelectric effect.[7] In 1927, Wood and Loomis explained the physical and biological impacts of high frequency soundwaves.[8] Pohlman used ultrasound on human tissues to treat myalgias and neuropathic pain in 1950.[9,10]In the same year, Maintz demonstrated a beneficial effect on bone regeneration and healing.[11]In 1952, Blamuth introduced an ultrasonic device which was used in dentistry for cavity preparation.[12] Catuna was the first person to use ultrasound in the field of dentistry specifically for preparing dental cavities. This resulted in the introduction of high-speed rotary instruments. In 1955, Zinner introduced the first ultrasonic scalers in periodontal procedures. Richman MJ was the first to disclose the surgical use of an ultrasonic chisel without slurry to remove bone and resect roots in apicoectomies in 1957.[13] Mcfall TA et al in 1961 evaluate distinction of healing by comparing of rotating instruments and oscillating scalpel blades and found a slow healing with no severe complications by use of these scalpel blades.[14]Horton JE et al in 1980 ultrasonic devices improves bone regeneration.[15]

In 1997, Vercellotti was the first who introduced the use of an ultrasonic device for ablation fitted with a sharpened insert, such as a scalpel blade, to perform periradicular osteotomy to extract an ankylosed root of a maxillary canine. Piezosurgery an ultrasound device in 1998 was introduced in medical field by Vercellotti for different procedures such as for hard tissue surgery. In 1999, Tomaso Vercellotti invented Piezoelectric bone surgery in collaboration with Mectron Spa and published about this topic in year 2000.[16]

In 2000, Vercellotti et al. renewed the approach for nerve and soft tissue protecting surgery to overcome the limitations of traditional instruments in oral bone surgery. It was first reported for pre-prosthetic surgery, alveolar crest expansion, and sinus grafting. Mectron developed first generation piezosurgery device in 2000. Vercellotti et al developed a suitable device for routine work in oral surgery that replaced conventional osteotomy instruments in 2001. The first sinus lift and bone block grafting surgeries employing piezosurgery was performed in 2001 and 2002. In 2003, Vercellotti used piezosurgery in animal studies to compare its traumatic impact with that of traditional orthopaedic surgery and reported that it allows for more accurate cuts and a clearer view of the operative field.

In 2004, Mectron introduced Second generation of piezosurgery device. Ultrasonic osteotomy was utilised to relocate the inferior alveolar nerve (IAN) by Bovi in 2005.

The same year first implant site preparation was performed by using piezosurgical device. In the same year, the US Food and Drug Administration extended the use of ultrasonics in dentistry to encompass bone surgeries.[17] In 2006, first ultrasound osteotomy in hand surgery was performed by Hoigne et al.[18] Third generation piezosurgery device was introduced in 2009, and a clean, precise technique of harvesting bone grafts from mandibular ramus was given by Happe A.

5. The Piezosurgical Armamentarium

Piezoelectric devices consists of:

5.1. *Main body*

Display screen, electronic touchpad, peristaltic pump, stand for handle, and stand for irrigation fluid bag are the constituents of the main body. For selecting the operating mode, particular programme, and coolant flow, the interactive touchpad comprises four keys. Every command is displayed on the screen.[18]

The main unit has three different power levels:[19]

1. Low Mode: It is utilised for orthodontic treatment and apico-endo-canal cleaning procedures
2. High Mode: It is used to clean and smooth the radicular surfaces
3. Boosted Mode: Is used in bone surgeries, osteotomy and osteoplasty procedures.

5.2. *Peristaltic pump*

Peristaltic pump contains an irrigation solution that flows at an adjustable rate of 0–60 ml/min to cool the cutting area and remove debris. The solution is refrigerated at 4°C to provide a cooling effect, and the volume of liquid can be adjusted with the + and - buttons.

5.3. *Hand piece*

Piezosurgical device consist of two hand pieces. The handpiece is firmly connected to the cord, which may be sterilised together.[20]

5.4. Handle

The cutting action is based on ultrasonic waves that travelling via piezoelectric ceramic within. These ceramic plates are created by an external generator and alter in volume to produce ultrasonic vibrations. They are channelled into the amplifier, which transmits them to the handle pointed end. A specific key is used to clamp the insert for this function.In this manner, the optimum efficiency for cutting and insert duration is accomplished.[21]

5.5. Foot pedal

Handpiece is controlled by an adjustable pedal on the base.

5.6. Base unit

The power is supplied by the base unit which also have the holder for handpiece and irrigation fluids. The device has display that allows the operator to select between the BONE cutting mode and ROOT operating modes. Using a specific selection for the type or density of the bone, the BONE cutting mode is utilised to cut bone. For endodontic and periodontal root treatments, the ROOT mode is utilised to shape, clean and smooth the root surfaces.

5.6.1. Bone mode

Bone mode are characterized as extremely high ultrasonic power compared to root mode.[22] Its performance is monitored by several advanced software and hardware controls. Due to excessive frequency modulation, mechanical ultrasonic vibration are unique for cutting different kinds of bone.

The selection recommended are:[23]

1. Quality 1: Cutting cortical bone or high density cancellous bone.
2. Quality 3: Cutting low density cancellous bone.

5.6.2. Root mode

The vibrations generated by selecting root mode have an average ultrasonic power without frequency over modulation.[22]

Root operating mode consists of two different programs:[23]

1. Endo program: A limited level of power provided by applying a reduced electrical tension to the transducer, which generates insert oscillation by a few microns. These mechanical micro-vibrations are ideal for irrigating the apical part of the root canal in endodontic surgery.
2. Perio program: An intermediate power level between the endo program and the bone program. The ultrasonic wave is continuosly transmitted through the transducer in a continuous sinusoidal manner, characterized by a frequency equal to the resonance frequency of the insert used.

A special program is designed with a slightly lower standard power than the bone programs has the same frequency over modulation. A special program is dedicated to a limited series of particularly thin and delicate surgical insertstips. These are only recommended for surgeons experienced in piezosurgery and who want an extremely thin and efficient incision.

5.6.3. Inserts tips

The Mectron Medical Technology has developed the design and function of all insert tips used in Piezoelectric bone surgery. Taking into account morphological-functional and clinical factors, the inserts tips have been defined and organized according to a dual classification system.

Various insert tips are classified as:

5.7. According to insert tip coating:[20]

1. Titanium Nitride coated tips are effective in osteoplasty procedure and for harvesting of bone chips as they provide maximum cutting efficiency, resist corrosion and last longer.
2. Diamond coated tips are used for osteotomy of thin bone and/or proximity to anatomic structures.

   They are classified as follows:

   (a) Sharp Insert tips are designed for maximum cutting efficiency and are used for osteoplasty procedures and to harvest bone chips.
   (b) Smooth Insert tips have diamond coated surfaces that enables precise and controlled work on the bone structures. They are used in osteotomy procedures to prepare difficult and delicate structures such as preparation of the sinus window and/or nerve access.
   (c) Blunt Insert tips are used for preparing soft tissues, e.g., elevation Schneider's membrane and/or, lateralization of the inferior alveolar nerve. In periodontics, these tips are used for root planing.

5.8. According to insert tip color

1. Gold Insert tips are utilised specifically for bone surgery. The gold color of the insert tips is obtained from the titanium nitride which improves the hardness of the surface for longer working life.[24]
2. Steel Insert tips are used specifically for treating soft tissue and/or delicate tooth structures (roots of teeth).[25]

5.9. Clinical classification

Clinical classification comprises insert tips (sharp, smooth, blunt) based on surgical techniques such as osteotomy,

osteoplasty, extraction.[26]

1. Osteotomy OT - OT1, OT2, OT3, OT4, OT5, OT6, OT7, OT7S4, OT7S3, OT8R/L
2. Osteoplasty OP - OP1, OP2, OP3, OP4, OP5, OP6, OP7
3. Extraction EX - EX1, EX2, EX3
4. Implant site preparation IM - IM1(OP5 -IM2A-IM2P OT4-IM3A-IM3P
5. Periodontal Surgery PS - PS2-OP5-OP3-OP3A- Pp1
6. Endodontic Surgery EN - OP3-PS2-EN1-EN2-OP7
7. Sinus Lift- OP3-OT1-OP5 - EL1-EL2-EL3
8. Ridge Expansion- OT7-OT7S4-OP5- IM1 -IM2-OT4 -Im3
9. Bone Grafting- OT7, OT7S4, OP1, OP5
10. Orthodontic Microsurgery- OT7S4-OT7S3

5.9.1. Indications

1. Implantology:[26]
   - (a) Implant site development (socket preparation)
   - (b) Splintting and expansion of the alveolar ridge
   - (c) Alveolar crest recontouring
   - (d) Mental nerve repositioning
   - (e) Distraction osteogenesis with subsequent implant placement
   - (f) Retrieval of blade implants
   - (g) Placement of implants
   - (h) Harvesting block grafts
2. Maxillary sinus bone grafting surgery:[26]
   - (a) Creating lateral bone window
   - (b) Sinus mucosa atraumatic dissection
   - (c) Elevation of internal sinus floor elevation
3. Periodontal treatment procedures:[26]
   - (a) Supragingival and subgingival scaling
   - (b) Irrigation of periodontal pockets
   - (c) Crown lengthening
   - (d) Soft tissue debribement
   - (e) Resective and regenerative surgerical procedure
4. Others:[27]
   - (a) Retrograde root canal preparation
   - (b) Apicectomy
   - (c) Cystectomy
   - (d) Extraction
   - (e) Tooth extraction with osteogenic distraction Ankylosed tooth
   - (f) Extraction
   - (g) Orthodontic surgery
   - (h) Removal of cyst

5.10. Contraindications[28]

No absolute contraindications

1. Patients or the clinician with electrical implants such as pacemakers.
2. Certain systemic diseases such as cardiovascular diseases, diabetes and bone disease or in patients undergoing radiotherapy, all of which can hinder the dental implant surgery.
3. Alterations that may or may not be related to systemic diseases, bone structure and vascularization.
4. Behaviours such as smoking and excessive drinking.

6. Application of Piezosurgery in Periodontology

6.1. Scaling and root planing

The piezosurgery device is used to remove supragingival and subgingival calculus as well as stains from teeth. It has been discovered that employing cavitation alone without the touch of the vibrating tip is insufficient for removing the calculus; direct contact between the vibrating tip and the calculus is required. The piezosurgery ultrasonic scaler, set to function On/Mode Periodontics (ROOT), with the insert PS1 and PP1, is used for deposit removal on all tooth surfaces for 15 seconds at a medium power of two. Parallel movements were used, with working strokes perpendicular to the tooth axis.[29]

Busslinger et al.[30] conducted a study to compare magnetostrictive and piezoelectric devices and found a substantial difference in time required. The SEM pictures after instrumentation were utilised to compare the four groups. SEM examination of tooth surface roughness revealed that the C100 group had a smoother surface than the C200 group and that the P100 group had a smoother surface than the P200 group, although the difference was not significant. The difference between the C200 and P200 groups was statistically significant. According to Santos et al[31] there were no changes in the results of magnetostrictive and piezoelectric devices uder SEM.

6.2. Curettage

When compared to manual tools, a piezosurgery device is employed for debridement of the epithelial lining of the pocket wall, resulting in microcauterization and removal of root calculus by employing thin tapered tips with an adjusted power setting.[32]

6.3. Clinical crown lengthening

Raising a full-thickness flap, conducting an ostectomy with manual instruments, osteoplasty with a bur for crest bone architecture recontouring, periradicular bone removal, root planing, and ultimately restoring the flap in an apical position are all part of the conventional surgical approach. The crown lengthening procedure done with piezosurgery for successful bone reduction while maintaining root surface integrity.[33,34]

A controlled clinical split mouth study was conducted by Dayoub ST et al[35] to evaluate the clinical results of a minimally invasive flapless method versus an open-flap approach in aesthetic crown lengthening for the treatment of gingival smile up to three months following piezoelectric bone surgery. The study demonstrated that utilising piezosurgery in bone resection is successful with both surgical techniques and resulted in a considerable increase in clinical crown length as compared to baseline. They concluded that the minimally invasive flapless approach and piezosurgery provide alternatives to traditional procedures of aesthetic crown lengthening.

6.4. *Resective surgery*

In comparision to other instruments, the piezosurgery device is beneficial in periodontal surgery. After the primary flap is raised during resective surgery the device makes it simpler to accompany with the secondary flap and remove the inflammatory granulation tissue. This process results in minor bleeding but by applying the proper ultrasonic vibration, bleeding is prevented.

6.5. *Periodontally accelerated orthodontics*

Small vertical bone incisions between the teeth were done as part of the periodontally accelerated orthodontics procedure that allows more expedient orthodontic movement. With acceptable levels of pain and discomfort, the corticotomy procedure conducted with a piezosurgical equipment reduce the treatment duration by 60 to 70%. For selective alveolar corticotomies using the Peizosurgical device, surgical control was reported to be simpler than with traditional surgical burs.[36]

6.6. *Block harvesting technique*

Traditional rotary cutting instruments for bone block harvesting reduce the width of the cortical bone by at least 1 mm circumferentially and are unable to cut the internal cancellous bone effectively. Piezosurgery provides high accuracy and operational sensitivity, as well as simple distinction between cortical and cancellous bone while removing blocks of monocortical cancellous bone.[37]

6.7. *Autogenous bone grafting*

Due to absence of osteocytes and prevalence of non-vital bone, utilising manual or motor-driven devices for bone surgery may not be suited for grafting. The Piezosurgery inserts tips that are used for bone harvesting process creates a vibration with a width of 60 to 210 in an oscillation controlled module. In contrast to rotary burs or reciprocating saws, the utilisation of ultrasonic vibration creates controlled osteotomies by micrometric bone slices.

6.8. *Osteoplasty and bone grafting*

Piezosurgical device enables gentle scrubbing of the bone surface in order to obtain appropriate amount of graft material and can be used for gafting infrabony defects.

The function of the bony chips that are obtained vary with size

1. Small size chips aids in early remodelling
2. Larger size chips particles provide mechanical support and act as scaffold for bone growth.

7. Limitations

1. Difficulty to perform the deeper osteotomies.
2. Requires longer time for bone cutting or preparing osteotomy site than traditional cutting instruments.
3. Have longer and different learning curve.
4. Technique sensitive.

8. Conclusion

When compared to traditional rotational devices, ultrasound application to hard tissue is considered a slow procedure. Because it necessitats specialised surgical abilities associated with a certain learning curve. When compared to conventional procedures and soft tissues, piezosurgery is an advanced and conservative approach. Because, device precisely cuts bone, significant nerve damage may be avoided, and minimally invasive operations are conceivable. Using the fine tip enables curved cutting and provides an opportunity for new osteotomy technique. Predictability, Less Postoperative Pain, And Increased Patients Compliance are three P's of piezosurgery.

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None.

10. Conflict of Interest

None.

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A Review

Cone Beam Computed Tomography & Its Application In Periodontics

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Abstract

The presence of periodontal diseases is diagnosed on the basis of evaluation of clinical signs and symptoms followed by radiographs. Radiographs provide diagnostic information about the quality localization of the bone defect and the pattern of the bone resorption, changes in the bony trabeculae, condition of the lamina dura, length and shape of the root, furcation defects, subgingival calculus, and additional pathology. Two dimensional periapical and panoramic radiographs are routinely used for diagnosing periodontal bone levels.The amount of information obtained from conventional film and digitally-captured periapical radiographs is limited by the fact that the three-dimensional anatomy of the area being radiographed is compressed into a two-dimensional image. As a result of superimposition, periapical radiographs reveal limited aspects of the three-dimensional anatomy. Three dimensional imaging (3D) evolved to meet the demands of advanced technologies in delivering the treatment and at the same time responsible for the evolution of new treatment strategies. Cone beam computed tomography (CBCT) generates 3D volumetric images and is also commonly used in dentistry. All CBCT units provide axial, coronal and sagittal multi-planar reconstructed images without magnification. CBCT displays 3D images that are necessary for the diagnosis of intra bony defects, furcation involvements and buccal/lingual bone destructions. CBCT applications provide obvious benefits in periodontics, however; it should be used only in correct indications considering the necessity and the potential hazards of the examination.

Keywords: cone beam computed tomography (CBCT); 3D radiography; periodontal defects; periodontal diagnosis; furcation; intrabony defects

Introduction

The periodontium is a functional unit of the tooth that consists of the gingiva, periodontal ligament, cementum, and alveolar bone. Radiographically, the periodontal ligament space appears as a dark line surrounding the root and an increased radio density of alveolar bone is visible adjacent to the periodontal ligament space, referred to as the lamina dura which is an extension of cortical bone into the alveolus.[1]

Periodontal diseases can be broadly classified as gingival diseases (gingivitis) and periodontitis. The bone destruction in periodontal disease occurs when the inflammation extends from the marginal gingiva into supporting periodontal tissues.

Although periodontitis is always preceded by gingivitis, gingivitis does not always progress to periodontitis.[2] The periodontium is first evaluated clinically followed by radiographic study.

Dental radiographs are a valuable non-invasive tool used as an adjunct to clinical examination for assessment of the periodontal conditions of the teeth.[3] Radiographs provide diagnostic information about the quality localization of the bone defect and the pattern of the bone resorption, changes in the bony trabeculae, condition of the lamina dura, length and shape of the

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root and the crown root ratio, plaque retention factors, caries, furcation defects, subgingival calculus, and additional pathology.[4]

Broadly, imaging techniques used in dentistry can be categorized as: intraoral and extraoral, analogue and digital, ionizing and non-ionizing imaging and two-dimensional (2-D) and three-dimensional (3-D) imaging. Traditional analog imaging modalities are two dimensional systems that use image receptors like radiographic films or intensifying screens. These include periapical views, panoramic, occlusal and cephalometric radiography.[5]

The interpretation of an image can be altered by the anatomy of both the teeth and surrounding structures. The amount of information obtained from conventional film and digitally-captured periapical radiographs is limited by the fact that the three-dimensional anatomy of the area being radiographed is compressed into a two-dimensional image. As a result of superimposition, periapical radiographs reveal limited aspects of the three-dimensional anatomy.[6] Three dimensional imaging (3D) evolved to meet the demands of advanced technologies in delivering the treatment and at the same time responsible for the evolution of new treatment strategies. G.N. Houns field, in 1972 introduced computerized transverse axial scanning which lead to introduction of Computed Tomography (CT). The high radiation dose, cost, availability, poor resolution and difficulty in interpretation have resulted in limited use of CT imaging in dentistry. These problems may be overcome using small volume cone-beam computed tomography (CBCT) imaging techniques.[7]

CBCT is also known as CBVT (Cone Beam Volumetric Tomography), CBVI (Cone Beam Volumetric Imaging) dental 3D CT, dental CT and DVT (Digital Volume Tomography) has touched every aspect of medical and dental profession. In periodontology as well as implantology, CBCT scanning has become a valuable imaging technique, for the diagnosis of intrabony defects, furcation involvements, and buccal/lingual bone destructions.

Principles of CBCT

The principal feature of CBCT is that multiple planar projections are acquired by rotational scan to produce a volumetric data set from which interrelation images can be generated.[8] Cone-beam scanners use a two-dimensional digital array providing an area detect or rather than a linear detect or as conventional CT does. This is combined with a three-dimensional X-ray beam with circular collimation so that the result ant beam is in the shape of a cone, hence the name "cone-beam". Because the exposure incorporates the entire region of interest (ROI), only one rotational scan of the gantry is necessary to acquire enough data for image reconstruction.[9]

Steps in Cone Beam Computed Tomography Image Production

Image production by CBCT involves four steps[10]:

A. Image Acquisition
B. Image detection
C. Image reconstruction
D. Image display

A. Image Acquisition

The cone-beam technique involves a rotational scan exceeding 180 degrees of an x-ray source and a reciprocating are a detect or moving synchronously around the patient's head. During the rotation, many exposures are made at fixed intervals, providing single projection images known as —basis", —frame" or "raw" images similar to lateral cephalometric radiographic images, each slightly off set from one another. The complete series of basis images is referred to as the projection data. Software programs incorporating sophisticated algorithms including back-filtered projection are applied to the projection data to generate a 3D volumetric data set that will provide primary reconstruction images in three orthogonal planes (axial, sagittal, and coronal).[11]

There are four components to image acquisition in CBCT:

1. Acquisition mechanics: Full/ partial rotation scan
2. X-ray generation: continuous/ pulsed
3. Field of view
4. Scan factor

1. Acquisition Mechanics:

The CBCT technique involves a single scan from an X-ray source which can be a partial or full rotational scan, exposing a reciprocating area detector that moves synchronously around the patient's head.

2. X-ray generation

Although CBCT is technically simple in that, only a single scan of the patient is made to acquire a data set, a number of clinically important parameters should be considered in x-ray generation.

Patient Positioning:

CBCT can be performed with the patient in three possible positions: Supine, Standing and Sitting.

X-ray generator

During the scan rotation, each projection image is made by sequential single image capture of the remnant x-ray beam by the detector.

3. Field of view

Ideally, the FOV should be adjusted in height and width which mainly depends on the size and shape of the detector, projection of the X-ray beam, and collimation of the X-ray beam. CBCT systems can be grouped according to the available FOV or selected scan volume height as follows:

1. **Localized region:** Approximately 5 cm or less (e.g., dento alveolar and TMJ)
2. **Single arch:** 5–7 cm (e.g., maxilla or mandible)
3. **Interarh:** 7–10 cm (e.g., mandible and superiorly to**c** include the inferior concha)
4. **Maxillofacial:** 10–15 cm (e.g., mandible and extending to nasion)
5. **Craniofacial:** >15 cm (e.g., from the lower border of the mandible to the vertex of the head).

4. Scan Factors

The speed with which individual images are acquired is called the frame rate and is measured in frames, projected images, per second. The maximum frame rate of the detector and rotational speed determines the number of projections that may be acquired. The number of projection images comprising a single scan may be fixed or variable. With a higher frame rate, more information is available to reconstruct the image; therefore, primary reconstruction time is increased. Higher frame rates are usually accomplished with a longer scan time and hence higher patient dose.[9,10,11]

A. Image Detection:

Current CBCT units can be divided into two groups on the basis of detector type:

- An image intensifier tube/ charge couple device combination (IIT/CCD)or
- Flat-panel imager.

B. Image Reconstruction

The reconstruction process consists of two stages:

Acquisition stage

Raw images from CBCT detectors exhibit spatial variations of dark image offset and pixel gain due to varying physical properties of the photodiodes and the switching elements in the flat panel detector and also due to variations in the X-ray sensitivity of the scintillator layer. These raw images need systematic offset and gain calibration and a correction of defect pixels which is done by "detector preprocessing."

Reconstruction stage

After the correction of the images, the images are transformed into sinogram which is done by reconstruction filter algorithm, the modified Feldkamp algorithm, that converts the image into a complete 2D CT slice. All the slices are finally recombined into a single volume for visualization.[11]

C. Image Display

The volumetric data set comprises of collection of all available voxels and projected on the screen as secondary reconstructed images in three orthogonal planes - axial, sagittal, and coronal.

Advantages of CBCT

CBCT technology in clinical practice has important advantages such as minimization of the radiation dose, image accuracy, rapids can time, fewer image artefacts, chair-side image display, and real-time analysis.

Disadvantages of CBCT

Although there has been enormous interest in CBCT, this technology has limitations related to the cone-beam projection geometry, detect or sensitivity and contrast resolution that produce images that lack the clarity and utility of conventional images. The patient must be motion less during the scanning to achieve a good image; other wise the image may display streaking.[12]

Diagnostic Application In Periodontics

The clinical applications of three-dimensional craniofacial imaging are one of the most exciting and revolutionary topics in dentistry.[13] (Figure1)

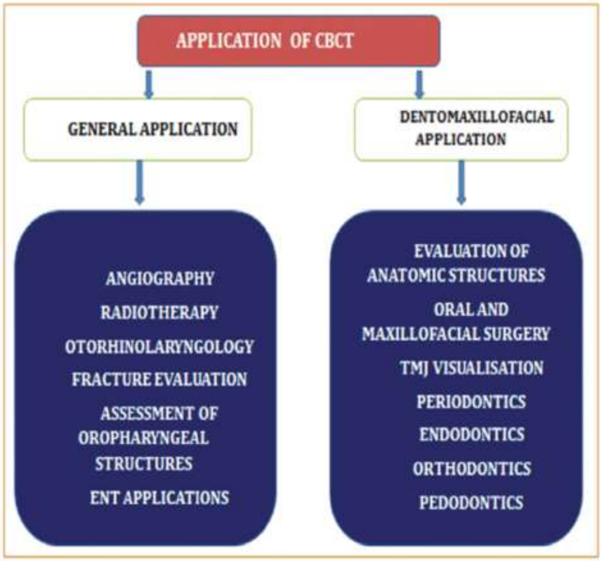

Figure 1: Application of CBCT

Role in Periodontics

Identification of periodontal landmarks

Periodontal Ligament Space

Radiographically lamina dura appears as a thin radiopaque line around the length of root. The space present between lamina dura and adjacent tooth is termed as PDL space. Any break in the continuity of lamina dura and a wedge shape radiolucenly at the mesial or distal aspect of the PDL space indicates periodontitis. Ozmeric et al did a study and compared CBCT with conventional radiography in terms of their ability to produce images of periodontal ligament space on a phantom model with artificially created periodontal ligament of various thicknesses and had found that the Periapical radiographs were superior to CBCT for the measurement of periodontal ligament space. But conflicting results were reported by the authors of another in vitro study that found CBCT to be better than conventional radiography in visualizing the periodontal ligament space. A phantom demonstrating variable periodontal ligament spaces was radiographed using CBCT and intraoral radiographs. This study found that CBCT provided better visualization of simulated periodontal ligament space in this phantom.[14]

Alveolar Bone Defect

The extent of periodontal marginal bone loss is necessary to determine the periodontal destruction. CBCT images provide better information on periodontal bone levels in 3D view than conventional radiography. CBCT is considered a superior technique in detecting the buccal and lingual defects and the interproximal lesions.Radiographs are mainly used to diagnose the amount and shape of alveolar bone destruction that affects treatment planning in periodontal therapy.[14,15]Two Dimensional radiographs can be insufficient for the detection of intrabony alveolar defects due to the obstruction of spongious bone changes by cortical plate. Thus, three-dimensional imaging is required for mapping of alveolar defects. Vandenberghe et al studied thirty periodontal bone defects of 2 adult human skulls using intraoral digital radiography and CBCT and concluded that the intraoral radiography was significantly better for contrast, bone quality, and delineation of lamina dura, but CBCT was superior for assessing crater defects and furcation involvements.[16]In Misch and colleagues study they demonstrated that CBCT was as accurate as direct measurements using a periodontal probe and as reliable as radiographs for interproximal areas.[17]Stavropoulos and Wenzel evaluated the accuracy of CBCT scanning with intraoral periapical radiography for the detection of periapical bone defects. CBCT was found to have better sensitivity compared to intraoral radiography.[18]

Furcation Involvement

Radicular bone assessment is anessential step in furcation involvement treatment planning procedures such as apically repositioned flaps with or without tunnel preparation, root amputation, hemi-/trisection or root separation. Conventional two dimensional radiographs can be deceptive in evaluating periodontal tissue support and inter radicular bone due to superposition of anatomical structures. However, 3D images provide detailed information about areas of multi rooted teeth. Intrasurgical furcation involvement measurements were compared by using CBCT images and it was reported that CBCT images demonstrated a high accuracy in assessing the loss of periodontal tissue and classifying the degree of furcation involvement in maxillary molars. In another study author had compared CBCT to intraoral radiography and concluded that the detection of crater and furcation involvements had failed in 29% and 44% for the intraoral radiograph, respectively, as compared to 100% detectability for both defects with CBCT.[19]

Regenerative periodontal therapy and bone grafts

Bone grafting is commonly used for maxillary sinus lifting and treatment of intra bony defects but evaluation of osseous defect regeneration with conventional radiography can be limited due to superimpositions. Furthermore, histological evaluation of a sample of the graft is not a preferred method due to its quite invasive procedure. CBCT was found to be significantly more accurate than digital intraoral radiographs when direct surgical measurements served as the gold standard for the evaluation of intra-bony defects' regenerative treatment outcomes. CBCT can replace surgical re-entry by providing 3D images and measurements that are almost equivalent to direct surgical measurements.[19,20] Dimensions of alveolar process should be examined in detail prior to dental implant placement to avoid various complications and evaluation of CBCT images has a major importance in preoperative planning and postoperative localization of dental implant.[21]

Role In Implant Site Assessment:

Implant placement requires technique which is capable of obtaining highly accurate alveolar and implant site measurement to assist with treatment planning and avoid damage to adjacent vital structure during surgery. Earlier alveolar and implant site measurement was done either using 2-D radiographs and in some instance using conventional CT (Figure 2). When compared, CBCT is preferable option for implant dentistry, providing greater accuracy in measuring with utilization of lower radiation dose.

Uses[22]

1. To assess the quantity and quality of bone in edentulous ridges.
2. To assess the relation of planned implants to neighboring structures.
3. To assess the success of implant osseointegration.
4. To provide information on correct placement of implants.
5. Before ridge augmentation in anodontia
6. Before bone reconstruction and sinus lifting
7. During planning and in designing a surgical guidance template.

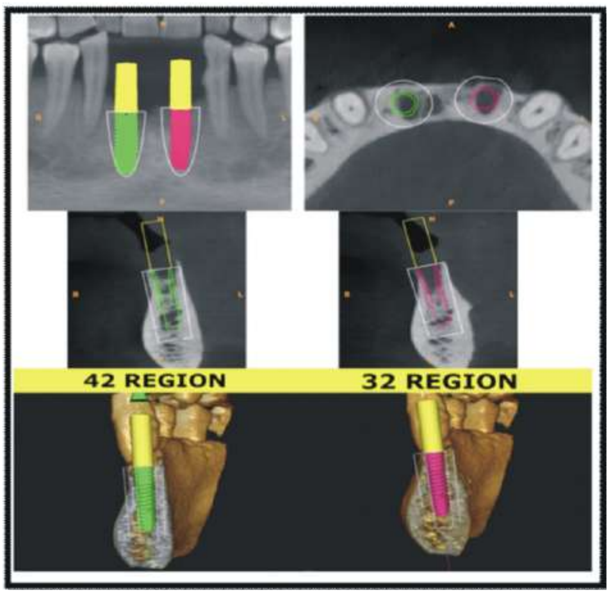

Figure 2: Implant site assessment

Role of CBCT in detecting anterior looping during implant placement:

Apostolakis D and Brown JE (2012) stated that the final part of the inferior alveolar nerve sometimes passes below the lower border and the anterior wall of the mental foramen.[23] After giving off the smaller mandibular incisive branch, the main branch curves back to enter the foramen and emerge to the soft tissues, as the mental nerve. The section of the nerve in front of the mental foramen and just before its ramification to the incisive nerve can be defined as the anterior loop of the inferior alveolar nerve. Selective surgery in the area of the anterior mandible such as implant installation in the interforaminal region or symphysis bone harvesting, may violate the anterior loop resulting in neurosensory disturbances in the area of the lower lip and chin. To avoid such a sequel a 5-mm safe distance to the most distal fixture from the anterior loop and a 5-mm distance from the mental foramen for chin bone harvesting have been proposed.[23,24]

Tolstunov identified and described four alveolar jaw regions—functional implant zones (Figure 3)[21] with unique characteristics of anatomy, blood supply, pattern of bone resorption, bone quality and quantity, need for bone grafting and other supplemental surgical procedures, and a location related implant success rate.

Four functional implant zones identified by Tolstunov[21,22,23]:

i. Functional Implant Zone 1 (Traumatic zone)consists of alveolar ridge of premaxilla and eight anterior teeth: 4 incisors, 2 canines, and 2 first premolars. Any bone loss in the anterior maxillary area is vital due to the esthetic implications on dental implant supported restorations. Loss of teeth in this area is mostly due to trauma and if the teeth are not replaced immediately following trauma, the bone loss continues, leading to difficulty in dental implant placement in a prosthetically favorable position.

ii. Functional Implant Zone 2(Sinus zone): bilateral maxillary posterior zone extends from the maxillary second premolar to the pterygoid plates and is located at the base of the maxillary sinuses.

iii. Functional Implant Zone 3 (Inter-foraminal zone): comprised of the area of the mandibular alveolar ridge between mental foramen and first premolar on each side. This zone is also associated with a thin alveolar ridge. There is abundant evidence in the literature reporting severe bleeding with the formation of expanding sublingual hematomas due to the perforation of the lingual cortex.

iv. Functional Implant Zone 4:- This zone of the alveolar process of the mandible behind the mental foramen on each side and extends from the second premolar to retromolar pad. The distance of the alveolar bone height from the inferior alveolar canal is evaluated when dental implants are considered in the posterior mandible. Careful assessment of the height must be made to avoid injury to the inferior alveolar canal. If there is a violation of the inferior alveolar nerve (IAN), depending on the degree of nerve injury, alteration in sensation, from mild paresthesia to complete anesthesia, is reported.

Figure 3: Functional implant zones identified by Tolstunov

Conclusion

Cone beam computed tomography is a diagnostic imaging technology that is changing the way dental practitioners view the oral and maxillofacial complex as well as the teeth and the surrounding tissues. CBCT has been specifically designed to produce undistorted three dimensional images similar to computed tomography (CT), but at a lower equipment cost, simpler image acquisition, and lower patient radiation dose. However the two-dimensional diagnostic imaging has served dentistry well and will continue to do so for the foreseeable future. Intraoral and panoramic radiographs are the basic imaging techniques used in dentistry and are quite often the only imaging techniques required for the detection of dental pathology.

For periodontal disease, CBCT promises to be superior to 2Dimaging for the visualization of bone topography and lesion architecture but no more accurate than 2D for bone height. This factor should be tempered with awareness that restoration in the dentition may obscure views of the alveolar crest. No doubt, future improvements in CBCT technology will result in systems with even more favorable diagnostic yields and lower doses.

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Piezo Surgery: A Boon For Modern Periodontics

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Abstract

Piezosurgery is a novel technique that uses piezoelectric ultrasonic vibration to provide safe and precise osteotomy. Recently this technique has gained importance Fatimbecause of its ease of use and safety. Professor Vercelloti in 1988 invented this technique known as piezosurgery or piezoelectric bone surgery. The piezoelectric effect occurs when an electric current is passed around a stack of crystals and they start to vibrate at a modulated ultrasonic frequency of 24-29 Hz. and microvibration amplitude between 60 and 200 mm per second. This technique allows a clean precise and controlled cut of bony structures without causing destruction of soft tissue. This article focuses on the broad range of applications of this novel technique in Periodontology.

Introduction

The past two decades has seen rapid development in various dental surgical techniques. Traditionally, osseous surgery was performed by using hand instruments and various rotary instruments with different burs which required external copious irrigation because of the production of heat .Using these instruments, a pressure was also exerted with a limitation in the case of brittle bone. In order to overcome the limitation of traditional techniques in oral bone surgery a relatively new technique for ostectomy and osteoplasty that uses ultrasonic vibrations was introduced by Professor Tomaso Vercelloti in 1988 and developed by Mectron Medical Technology.[1] This device is known as Piezoelectric device and the surgery is known as Piezosurgery. The piezosurgery device consists of a novel piezoelectric ultrasonic transducer powered by ultrasonic generator capable of driving a range of resonant cutting inserts[1].The philosophy behind the development of piezoelectric bone surgery is based on two fundamental concepts i.e. minimal invasive surgery, which improves tissue healing and reduce discomfort to the patient and the surgical predictably which increases treatment effectiveness.[2]

Historical background

The term "piezo" originates from the Greek word`` peizein" which means "to press tight, squeeze". Jacques and Pierre Curie first discovered piezoelectricity in the year 1880 ,when pressure is applied on crystals, ceramics or bone electricity is created. Dr. Tomaso Vercellotti, an Italian periodontist felt the need to change the osseous surgery procedures to make the results more predictable, improve healing, minimize trauma and provide greater safety for patients .In year 1999 he invented piezoelectric bone surgery in collaboration with Metron Spa. This technology has been used commercially in Europe since 2000.In 2005, the US Food and Drug administration extended the use of ultrasonics in dentistry to include bone surgery.

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3. Parts of Piezoelectric Device

The device consists of a hand piece and a foot switch that are connected to a main unit, which supplies power and has a holder for hand piece and irrigation fluids. The unit consists of hand piece, foot switch, ultrasound, control, dynamometric wrench and peristaltic pump. This piezoelectric device works in the range of 25-29KHz and can be modulated further by 30 Hz digital modulation and series of inserts of different forms with a linear vibration ranging from 60 to 200µm. (Figure 1)

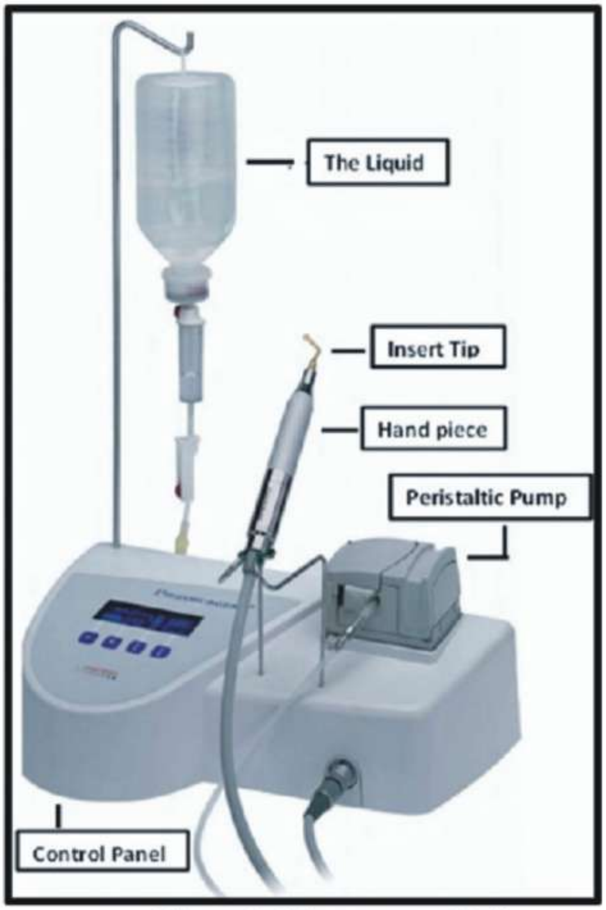


Figure 1: Piezosurgery Unit

Main Body

It has a display, an electronic touch pad, a peristaltic pump, one stand for the handle and another to hold the bag containing irrigation fluid. It has two operating modes, to select either the BONE or ROOT operating modes. The BONE cutting mode is used to cut bone with selections that are specific to bone type or density. The ROOT mode is used to shape, debride, and smooth root surfaces (both external: periodontal and internal: endodontic)[3]

Bone Mode- The vibrations generated by selecting bone mode are characterized as extremely high ultrasonic power compared to root mode.[3] Several sophisticated software and hardware controls monitor the performance. Frequency over modulation gives the ultrasonic mechanical vibrations its unique nature for cutting different kinds of bone.

The selection recommended is: -

- ✍ **Quality 1:** for cutting the cortical bone or high-density spongy bone.
- ✍ **Quality 3:** for cutting low density spongy bone.

Root Mode The vibrations generated by selecting root mode are characterized by average ultrasonic power without frequency over modulation. Root operating mode consists of two different programs:

i. NDO Program: A limited level of power provided by applying reduced electrical ension to the transducer, generates inset oscillation by a few microns which re optimal for washing out the apical part of the root canal in endodontic surgery.

ii. ERIO Program: A intermediate level of power between the endo program and the bone program. The ultrasonic wave is transmitted through the transducer in continuous sinusoidal manner characterized by a frequency equal to the resonance frequency of the insert used.

Dynamometric Wrench

It is used to tighten the insert tips to the hand piece which applies a predefined force to obtain energy transmission.

Handpiece

Each piezo surgery unit comes with two handpieces and is permanently connected to handpiece cord which can be sterilized together.

The Peristaltic Pump

It is a part which consists of irrigating solution discharging from the insert with a adjustable flow of 0-60 ml /minute he solution is refrigerated at 4°C for cooling effect . The power of device is 5W[ultrasonic scaler 2W].[6]

Insert Tips

The design and features of all insert tips used in Piezoelectric Bone Surgery have been developed by the Mectron Medical Technology. The inserts have been defined and organized according to a dual classification system, taking into consideration morphological-functional and clinical factors. This system helps understand the cutting characteristics and clinical instructions for each insert. (Figure 2). Various insert tips have been summarized in Table 1.

BASE UNIT / MAIN UNIT ROOT MODE	1. **Feature mode** i). Root mode ii) Bone mode **2. Specific program** i) Perio Program ii) Bone Mode iii) Special Program **3. Flow of the fluid from cooling system**
INSERT TIPS	
BASED ON MORPHOLOGY/FUNCTION	**1.Sharp insert tips** - for osteotomy and osteoplasty where fine and well-defined cutting of bone is required. **2.Smoothing insert tips** - for precise and controlled cutting effect during osteotomy. **3. Blunt insert tips**- to prepare the soft tissues. In periodontics these insert tips are used for root planing.
BASED ON COLOUR	➤ **Gold tips** • Used to treat bone. • titanium nitride coatings to improve surface hardness and also for longer working life. ➤ **Steel tips** • Used to treat soft tissues or delicate structures.

Table 1: Piezoelectric Device Parts

Principle of Piezosurgery

It works on the principle of pressure electrification according to which piezoelectricity is found in certain crystals like quartz, Rochelle salt and ceramics which when subjected to electric charges, acquire electric polarization, expand and contract alternatively to produce ultrasonic waves. Since ultrasonic waves are mechanical in nature, they can induce disorganization and fragmention of different bodies. The ultrasonic waves also allow segmentation of interfaces from solid –solid by means of distinct vibrations and solid-liquid by means of cavitation(micro boiling phenomenon that occurs in liquids on any solid-liquid interface vibrating to an intermediate frequency, corresponding to a rupture of molecular cohesion in liquids and the appearance of zones of depression that fill up vapor until they form bubbles that are about to implode).When the water spray contacts the insert vibrating to intermediate frequency ;cavitation occurs. The cavitation effect also shows an anti-bacterial property by fragmenting bacterial cell wall, which helps in obtaining high predictability and low morbidity in bone surgery. (Figure 2)

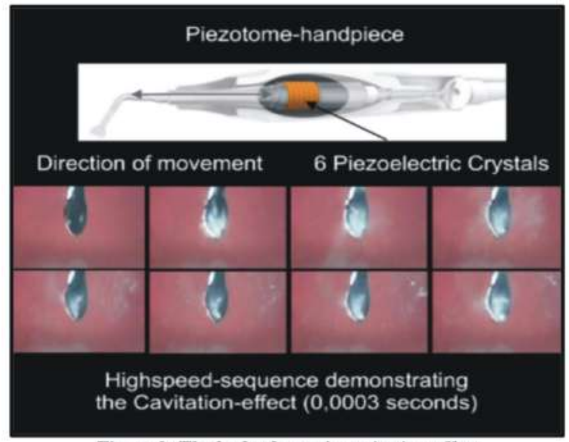


Figure 2: The hydrodynamic cavitation-effect

Mechanism of Action

Ultrasonic is a branch of acoustic dealing with sound vibration in a frequency that ranges above the audible level i.e., >20KHZ where sonic is an ultrasound wave of high amplitude produced by three different methods.

Mechanical method-upto100KHz
Magnetostatic method-18-25 Khz
Piezoelectric effect-25-50KHz

In piezoelectric device the frequency is created by driving an electric current from a generator over piezoceramic rings, which leads to their deformation .the ultrasonic frequency usually ranges from 24-36KHZ, capable of cutting mineralized tissue in dental applications. Thus the accruing movement from the deformation of ring sets up a vibration in the transducer, which creates the ultrasound output. These waves are transmitted to hand piece tip, also called an insert where longitudinal movement occurs resulting in the cutting of osseous tissue by microscopic shattering of bone .The transducer is a very important part of the instrument system because it incorporates a piezoelectric element ,which convert electric signals into mechanical vibrations and finally mechanical vibrations into mechanical energy. (Figure 3)

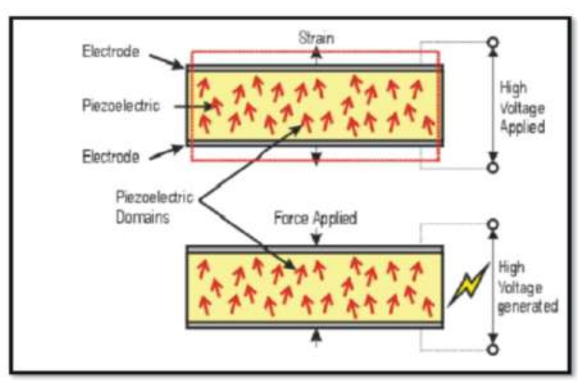


Figure 3: Mechanism of Piezoelectric Device

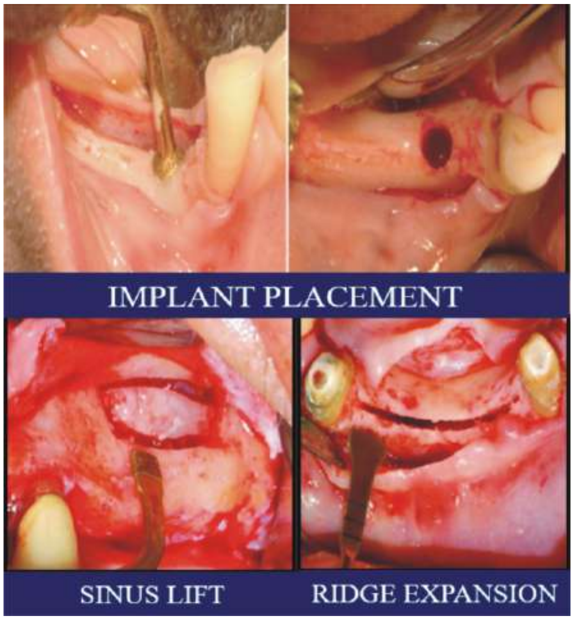
Applications of Peizosurgery In Periodontics

- **Scaling and root planing:** The piezosurgery device with a vibrating tip is employed for removal of supra and subgingival debris, calculus and stains from teeth. The piezosurgery ultrasonic scaler set on function on/Mode Periodontics (ROOT), with the insert PS1 and PP1, applied at a medium power of two for 15 sec is used on all the surfaces for removal of deposits.
- **Curettage:** Piezosurgery device because of its thin tapered tips and altered power setting is used for the efficient removal of diseased soft tissue and root calculus along with the debridement of epithelial lining of pocket wall resulting in micro cauterization.
- **Clinical crown lengthening:** Piezosurgery is used for precise cutting of hard tissues while preserving root surface integrity .It involves performing a peri-radicular ostectomy of a few millimeters, which allows repositioning of the periodontal flap in a more apical position.
- **Resective Surgery:** In interproximal bone defects, diamond coated insert enables thorough cleaning of the bone defects by producing an ultrasonic wave at the base of the defect to aid in better healing.
- **Periodontally accelerated orthodontics:** Piezoelectric device is used to perform corticotomy by making small vertical incisions between the teeth which allows more expedient orthodontic movement thus considerable reduction in treatment time .[10]
- **Block Harvesting Technique:** Piezosurgery provides high precision, operating sensitivity and easy differentiation between cortical and cancellous bone while removing blocks of monocortical cancellous bone in bone block harvesting technique.[11]
- **Osteoplasty and bone grafting:** Piezoelectric devices can be used for grafting infrasonic defects.[12] The device enables gentle scrubbing of the bone surface to obtain sufficient quantities of graft material. The function of the obtained bony chips vary with size (i) Small sized chips aid in early remodelling and (ii) Larger particles provide mechanical support and act as scaffold for bone formation.

Application In Implantology

The peizosurgery is a new and modern technique in bone surgery in implantology. Implantology offers a variety of techniques to increase bone volume,[13,14] including transplantation of particles and blocks of bone grafts from the chin and the mandibular ramus, iliac crest, and calvaria.[15,16] The techniques make use of rotary drills; oscillating saws; and more recently, piezosurgery, a process that uses ultrasonic vibrations in the application of cutting bone tissue.

- **Implant Site Preparation:** Piezosurgery used to prepare osteotomy site in the bone and for insertion of implant. Special piezo surgery inserts developed for bone perforation have enabled the development of a new technique for ultrasonic implant site preparation (UISP),which facilitate differential preparation of the cortical and cancellous bone. The differential implant site preparation (DISP) technique can be used within the initial osteotomy site to correct the implant axis by selectively directing the cutting action in the desired direction.[17]
- **Ridge expansion:** Piezosurgery is an indispensable tool used to create a horizontal osteotomy through the alveolar bone crest caused by its precise (narrow) cutting action. In some cases (e.g., areas of dense bone with little elasticity), it may also be necessary to make one or two vertical cuts in the alveolar bone to allow ridge expansion.[18].
- **Sinus lift or augmentation:** Sinus augmentation is performed in following situations; pneumatised sinus, atrophy of alveolar ridge, and poor bone quality especially in the posterior maxilla. The surgical technique performance depends on the remaining bone between the alveolar crest and the floor of the maxillary sinus. Using piezoelectric ultrasonic vibration range between 25-30 kHz, the device cuts only mineralized structures without cutting the soft tissue. The cavitation effect of the system induces a hydropneumatics pressure of saline irrigant that contributes to the atraumatic elevation of the sinus membrane as perforation of schneiderian membrane resulting in poor graft stabilization, sinus infection, epistaxis and extensive bleeding. (figure4)[19]



Advantages

Peizosurgery offers the following characteristics:

- **Micrometric:** the inserts vibrates with the range of 60-200 micrometer thus avoiding excessive temperatures.
- **Selective:** the vibration frequency is optimal for the mineralized tissue.
- **Safe:** using of a modulated ultrasonic frequency allows a highly precise and safe cutting of hard tissues whereas adjacent soft tissue and nerve remain unharmed making it superior compared to conventional rotating instrument.[5]
- **Precision:** the accuracy and selectivity of pesosurgery is superior to conventional rotating instruments. with pesosurgery we can osteotmize hard tissue as precisely as possible.
- **Surgical control:** pesosurgery provides surgical control with maximum strength required by the surgeon to effect a cut is far less compared to that with the drill or with oscillating saws
- **Cavitation effect:** created by interaction between the irrigant solution and the oscillating tips makes the surgical site clear during osteotomy.

Limitation:

- Increase in operative time compared to traditional cutting instrument.
- Gentle touch and dexterity is required for this type of procedure with a different learning curve.
- In deeper osteotomies it's difficult to insert proper length and thickness to avoid the increasing pressure of the hand preventing microvibration of the insert.
- Not cost effective
- Inserts get warm very rapidly.
- Increase operative time compared to traditionally cutting instrument.

Conclusion

By using technique of piezoelectric ultrasonic vibrations the critical operations can be done in simpler and safer way with less post-operative complications. This technique can be used in oral surgical procedures to have better results. It aids in bone healing minimal intra-operative bleeding etc. The piezosurgery units because of its variable frequency and variable power are used for range of application in periodontology implantology etc. making it highly efficacious tool in clinical practice.

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Review Article

Changing trends in implant designs: A review

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ABSTRACT

Implantology is an ever-evolving scientific field that undergoes continuous refinement and innovation. Dedicated research and development efforts are focused on consistently improving the success rates of implants through innovative redesign and advancements. The introduction of advanced technologies has revolutionized the evaluation of patients in three dimensions, enabling clinicians to utilize precise and predictable approaches for diagnosis, planning, and treatment. This multidisciplinary patient-centric framework has opened new avenues for providing tailored and effective healthcare solutions. Therefore, it is of utmost importance for clinicians to conduct a comprehensive analysis of each patient's condition, ensuring meticulous selection of the suitable implant design and material, and making informed decisions regarding the most appropriate technique to be employed.

1. Introduction

Dental implants are widely recognized as one of the most promising and effective solutions for replacing missing teeth. With long-term success rates surpassing 90%, they have proven to be highly effective in restoring oral function and aesthetics in both partially and fully edentulous patients.[1] Thanks to the current availability of advanced diagnostic tools that assist in treatment planning, along with the ongoing research leading to improved implant designs, materials, and techniques, a wide range of challenging clinical situations can now be effectively managed with a high level of predictability and success.[2] Implant design features are vital factors that have a significant impact on the initial stability of implants and their ability to endure loading throughout the osseointegration process and beyond. These design elements play a fundamental role in ensuring the long-term stability and durability of dental implants. Furthermore, dental implants are engineered with specific textures and shapes that can promote cellular activity and facilitate direct bone apposition, facilitating successful integration with the surrounding tissues.[3]

Dental implant design has undergone significant advancements in recent years. In the past, primitive dental implants such as blade, staple, and periosteal types were used, but they had inherent biomechanical limitations, leading to high failure rates.[4] Recent advancements have brought about significant improvements in the morphology, structure, and design of dental implants, aimed at enhancing their biomechanical properties, stability, and long-term success. These developments reflect the ongoing commitment to innovation and the continuous pursuit of excellence in the field of dental implantology.

Implant design encompasses the comprehensive three-dimensional structure of the implant, including its various elements and characteristics. It encompasses factors such as form, shape, configuration, as well as the surface macrostructure and macro irregularities, all of which

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contribute to the overall attributes of the implant's three-dimensional structure.

2. Implant Shape

Implant shape directly influences the surface area available for stress transfer, playing a critical role in determining the implant's initial stability. The predominating macro structure for root-form endosseous implants is the screw shape, which consists of parallel-sided screw and the tapered screw.[2] Smooth-sided cylindrical implants offer a convenient advantage when it comes to surgical placement.[4] A tapered implant with smooth sides enables the transfer of a comprehensive load to the interface between the bone and the implant, the extent of which depends on the taper's degree. Implants with threaded design and circular cross sections facilitate easy surgical placement and enable enhanced optimization of the functional surface area to effectively transmit compressive loads to the bone-to-implant interface.[2]

3. Implant Geometry

The primary criterion for developing the treatment plan is still the size of the implant, including its diameter and length, primarily determined by the amount of available alveolar bone. For a given implant length, increasing the implant diameter will increase the implant surface area that is available for force transfer to the bone.[5] Provided there is sufficient bone volume, a larger diameter implant is better able to resist occlusal forces, particularly in the molar region. When designing the treatment plan, it is important to consider the drawbacks associated with bone augmentation, which used to be considered the "gold standard" in severe atrophy cases. These drawbacks include morbidity at the donor site, elevated risks of complications, extended time and increased costs, as well as potential resorption of the bone graft. Additionally, the advancing capabilities of smaller-sized implants should be considered when formulating the treatment approach.[6]

Several new concepts may provide other options for implantation, aiming to reduce treatment duration, minimize complication rates, and simplify the overall treatment procedure, such as:

4. One-piece Implant

In a one-piece implant the endosseous and abutment portions form a single unit. By eliminating the abutment interface, the one-piece implant enhances the strength and stability of the prosthesis. It is a suitable option for patients or surgical sites with insufficient bone to adequately support a prosthesis. In spite of these advantages, one-piece dental implants do have a limitation in terms of flexibility compared to two-piece implants. Their single-unit construction restricts the ability to make precise adjustments once placed.

The design of one-piece implants allows for uninterrupted healing of the soft tissues surrounding the implant and avoids any disruption to the soft tissue seal when placing the final prosthetic restoration.[7]

5. Mini-Implants

Compared to standard dental implants, mini-implants are characterized by their reduced diameter, typically less than 3 mm, and shorter length. Despite their smaller size, they are typically made from the same biocompatible materials as standard implants. These implants are particularly useful when achieving acceptable and satisfactory function with conventional prostheses is challenging. Clinical situations like flabby ridges, atrophic ridges, or inadequate residual bone where denture retention is less, are likely to do well with mini-implants.[8]

6. Short Implants

Placing conventional implants can be challenging in cases of atrophic alveolar ridges due to various anatomical restrictions. These include the presence of the maxillary sinus, nasal floor, nasopalatine canal, and inferior alveolar canal. These structures can limit the available bone volume and affect the feasibility of conventional implant placement. To address these and other vertical bone deficits, additional surgical procedures are often employed to facilitate the placement of standard implants. These may include guided bone regeneration, block bone grafting, maxillary sinus lift, distraction osteogenesis, and nerve repositioning. These techniques aim to augment the available bone volume, create a favorable environment for implant placement, and overcome the challenges presented by the anatomical restrictions.

Short implants are often regarded as a simpler and more effective solution for rehabilitating the atrophic alveolar ridge. By minimizing the likelihood of complications, patient discomfort, procedure costs, and overall treatment time, they offer several advantages. In this context, however, it is worth mentioning that the categorization of a dental implant as "short" is subjective, and there are no universally defined criteria for determining the specific length that qualifies as a short dental implant. Recently, less than 8 mm- long short implants have been offered by implant companies.[9]

7. Tilted and Zygomatic implants

The utilization of a tilted or angulated implant in the posterior maxilla has been suggested as a potential alternative to sinus augmentation procedures. In the All-on-4 concept (a theory that uses four implants to restore total edentulism) for completely edentulous maxilla patients trans-sinus tilted implants are employed.

Zygomatic implants present an alternative to sinus augmentation procedures. They are lengthy implants travelling through the sinus or laterally into the sinus and are almost identical to trans-sinus tilting implants.[10]

8. Pterygoid implants

Pterygoid implants were introduced as another method of increasing the amount of bone that can be used for placement of implants in posterior maxillary region. The typical implant size for this method is between 15 and 20 mm. The implant enters the maxilla in the first or second molar region, following an oblique mesio-cranial direction. From there, the implant trajectory proceeds posteriorly toward the pyramidal process. Thereafter, it ascends between wings of the pterygoid processes and continues its course in the sphenoid bone to find anchorage in pterygoido scaphoid fossa.

The presence of dense cortical bone provides excellent engagement and stability for the pterygoid implants. That and an opportunity to obviate the requirement for maxillary sinus augmentation and other grafting procedures are two benefits of employing these implants.[11]

9. Tuberosity implants

Tuberosity implants are designed to be placed at the most distal aspect of the maxillary alveolar process, specifically targeting the tuberosity region. They are positioned to potentially engage the pyramidal process of the maxilla. Because of the dense bone present in this region, the difference in bony support for a pterygoid implant and a tuberosity implant can be significant.[11]

10. Utilizing three-dimensional printing for customized implants

The initial adoption of three-dimensional printing (3DP) for custom implants took place in the domains of rapid tooling and rapid prototyping. Digital scanning was combined with a CAD/CAM design and using 3DP, dental labs produced dental prostheses and patient models in significantly less time and with a precision that was unmatched by most traditional procedures. The combination of cone beam computed tomography (CBCT) and CAD/CAM was proposed to generate a surgical guide for precise implant placement.[12]

11. Transitional Implant

Their length varies from 7 to 14 mm, and diameter is between 1.8 and 2.8 mm. Transitional implants are manufactured using pure titanium and consist of a single-body design with a treated surface. They play an important role by absorbing the masticatory stress during the healing phase. This stress absorption helps promote a stress-free environment for the maturation of bone around the submerged implants, allowing them to heal smoothly and without complications.

Some commercially available Transitional Implant System include the Immediate Provisional Implant System–IPI by Nobel Biocare; Modular Transitional Implant System -MTI by Dentatus; and TRN/ TRI Implants by Hi Tec implants.[13]

12. Ligaplant

This technology involves the integration of periodontal ligament (PDL) cells with implant biomaterial. Research is currently being done to make this implant honourable. In Ligaplant, the PDL cells serve as a soft, vascular tissue that distributes forces, absorbs shocks, and provides proprioception for the tooth within its socket.[14]

13. Design Variables in Surface Area Optimization Thread Geometry

The market today offers a variety of implant systems with different implant thread configurations (Figure 1). The number of threads, width of the thread, depth of the thread, face angle of the thread and its pitch are among the various geometric combinations that affect final bone-implant contact (BIC) and distribution of load. A greater number of threads and increased thread depth provides greater available surface area for load distribution.[15]

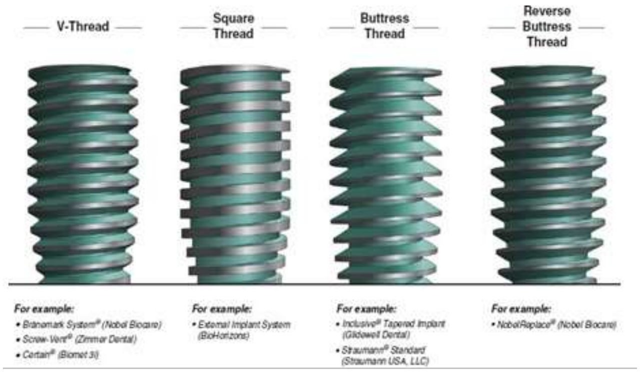

Fig. 1: Thread shapes of dental implants (V-thread, square, buttress, and reverse buttress).
Source: Grant Bullis .Functional Basis for Dental Implant Design. In: Misch,s Contemporary Implant Dentistry .4th ed. St Louis, USA: Mosby.;2021. p.48-68.

Implant threads are crucial for achieving primary stability, particularly in areas where bone quality is not good and for dissipating stresses at the bone-implant interface. This aids in minimizing the risk of complications and supports successful healing and integration of the implant with the bone.

The implant apical region should be tapered to assist insertion into the osteotomy and initial engagement of

threads of the implant. It should be either rounded or flattened to reduce the probability of perforating membranes during placement. It will have flat regions or grooves circumferentially arranged on the implant body to stabilize the implant against rotation after healing and to aid in insertion.[16]

14. Implant Crest Module and Abutment (Figures 2 and 3)

Current knowledge of prosthetic connections suggests that an internal prosthetic connection offers the best functionality. Of the internal prosthetic connection types in use today, the conical prosthetic connection have the best feature set, also conical prosthetic connections provide a stable abutment connection, lower peak bone stresses when positioned level to the marginal bone, and have a high resistance to axial loads. The Morse taper implant abutment connection features a tapered projection on the abutment that fits into a tapered recess in the implant. This creates a friction fit and cold welding to prevent rotation, providing stability during function. Taper angles vary, such as 8° in ITI Straumann or Ankylos, or 11° in Astra. The Bicon implant system has rounded channels with a 1.5 degree taper. When the cross section of the implant permits, platform shifting should be used to redistribute the stress away from the bone-implant interface. Platform shifting or using abutments with a diameter less than the implant collar is thought to be advantageous to maintain marginal bone levels while providing a biomechanical advantage in osseointegrated implants as it redirects the concentration of stress, taking it away from the cervical region of bone-implant interface; with an inverse relationship between the amount of implant-abutment diameter mismatch and cortical bone stress concentration.

Angled abutments, UCLA Abutment, Ceramic abutments, CERADAPT Abutment, and Multi- Unit abutment are recent advancements in implant abutments.[17]

Fig. 2: a): CAD/ CAM custom abutments. Left to right, posterior milled titanium abutment, anterior milled titanium abutment, and hybrid milled zirconia bonded to titanium abutment base. **b):** Multiunit abutments with screws.

Fig. 3: a): Stock/standardized healing abutments **b):** Custom healing abutment with ideal contours.
Source: Park NI, and Kerr M. Terminology in Implant Dentistry. In: Misch,s Contemporary Implant Dentistry .4th ed. St Louis, USA: Mosby.;2021.p.20-4

15. Implant Materials

Dental implants have been tested using various materials, including metals, alloys, ceramics, polymers, glasses, and carbon. Biocompatibility, bio functionality, availability, and the ability to Osseo integrate are specific characteristics needed for their manufacturing.

Materials for dental implants and the prosthetic components they support must adhere to several strict requirements. For dental implants, titanium alloys continue to have the finest mechanical and biocompatibility qualities, and their usage is recommended. Currently, commercially pure titanium, titanium alloys, and zirconia (zirconium dioxide, ZrO2), ceramic implants are the representative biomaterials in wide use for dental implant applications. Additional other advanced material are Zirconia Toughened Alumina (ZTA) and Alumina Toughened Zirconia (AZT), Poly-Ether-Ether-Ketone (PEEK), Powder Injection Molding (PIM), Tantalum Implants, Porous Tantalum Trabecular Metal (PTTM), LASER- LOK Technology.[18]

16. Surface Modification of Implants

Research has shown that microrough surfaces had higher degrees of bone-to-implant contact or BIC. These modifications can be divided into subtractive and additive processes, depending on whether material is removed or deposited on the implant surface in the development of the surface.[19] Plasma arc is an additive process that involves depositing a bioactive hydroxyapatite (HA) material onto the implant surface. Polishing, machining, and acid etching are subtractive procedures used for implant surface treatment. These treatments can be classified into various methods, including mechanical, chemical, electrochemical, electropolishing, vacuum, thermal, and laser techniques (Figure 4). Various modifications have been implemented to enhance the biological surface of dental implants, aiming to achieve optimal bone-to-implant contact.[20]

Surface treatments involving calcium deposition have shown increasing bioactivity over time, with the highest deposition observed in the sandblasted, acid-etched, and thermally oxidized group. This is in lieu of greater surface roughness that promotes cell adhesion, proliferation, and differentiation.[20]

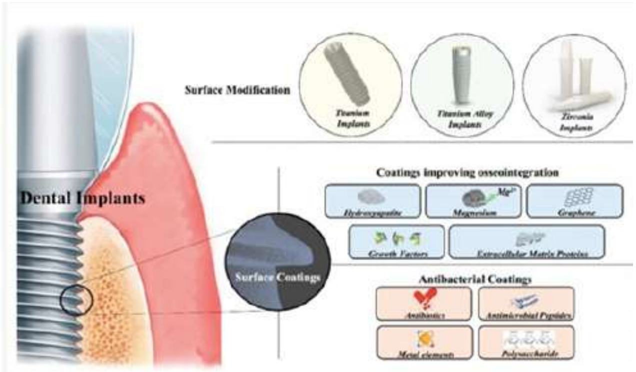

Fig. 4: Schematic illustration depicting surface modification and coatings of dental implants Source: Dong H, Liu H, Zhou N, Li Q, Yang G, Chen L, MouY. Surface Modified techniques & Emerging Functional Coating of Dental Implants. Coatings 2020, 10(11),1012:3-25

Recent studies have explored bioactive surface modifications of dental implants using inorganic materials (e.g., HA, calcium phosphate), growth factors, peptides, and extracellular matrix components. These approaches aim to enhance implant osseointegration and improve biological responses.[20] Research has shown the potential of utilizing stem cell-mediated bone regeneration for the treatment of peri-implant defects. However, stem cell implant technology is still in its early stages and is not currently a viable option for replacing missing teeth. Ongoing research hopes to enhance these techniques and develop more cost-effective procedures involving stem cells.[21]

17. Current Technologies for Implant Design and Placement Analysis

The success of dental implantation depends on accurate imaging. Cone Beam Computed Tomography (CBCT) utilising three-dimensional images is one of the newest technologies in dentistry imaging. This technology offers a continuous flow of data that allows dental surgeons to reconstruct images as needed, while minimizing radiation exposure for patients.[22,23]

18. Current developments in computed tomography technology include

1. (a) *Cone beam Computed Tomography:* This technology utilises a cone shaped beam of radiations. The image is reconstructed with special software. Comprehensive information like a Computed Tomography is obtained, albeit with 1/8th of radiation exposure and at minimal cost.
   (b) *Microtomograph:* This device helps in obtaining serial sections of the interface between implant and bone.
   (c) *Multislice helical CT:* This device has the advantage of providing high quality images when compared to Computed Tomography. It is referred as Dentascan Imaging.
   (d) *Interactive Computed Tomography:* This device develops image files that can be transferred from Radiologist to dentist's computer, who can work upon the case with precision and ease. Both the dentist and the radiologist work together and simulate placement of cylinders of arbitrary sizes in images, replicating root form implants, allowing for virtual surgical planning and an "Electronic Surgery".
   (e) *Magnetic resonance imaging (MRI):* This 3D non-invasive imaging method uses an electronic image acquisition process where image is produced digitally.

Better stability is made possible by the shape and configuration of implants, which is essential for the osseo-integration process. Refinement of drilling machines has led to better control over drilling speed and associated torque, which reduces risk of overheating the surrounding bone.[24] Improved control of water irrigation and the incorporation of internal implant irrigation systems also play a crucial role in minimizing the elevation of bone temperature during implant procedures. Additionally, the use of custom-made surgical splints, guided by CT data, assists in accurately defining the implant location and angulation, ensuring precise and optimal placement.[25]

Dental professionals and specifically prosthodontists have greater concern of the occlusal load on given prosthesis. Achieving precise dental implant alignment and connecting implants in a triangular configuration is crucial for the successful placement of fixed bridges in some cases. This configuration enhances stability and helps to resist lateral displacement forces.[26]

19. Peri implant surgery

It is common for tooth loss to be accompanied by the simultaneous resorption of the alveolar bone. As adequate implant width and length are crucial for long-term success of any implant, cases with insufficient remaining bone often pose a problem. The volume of the bone can be increased by varied techniques. For slight depressions, a simple onlay bone graft can be used while an inlay bone

graft can be employed where a sandwich osteotomy is required. Maxillary sinus floor augmentation can be used to increase bone volume in the upper jaw. Distraction osteogenesis is also a state-of-the-art procedure used for augmenting areas of bone. Now a days, osteo-inductive and osteo-conductive substances can help accelerate the healing process. Vestibuloplasty and palatal graft transplant are getting popular in cases where ablative surgery or tissue atrophy decreases the amount of available soft tissue. Free gingival graft transplant is a simpler procedure that produces less overall patient morbidity. Thus, the issues linked to either the soft tissue or bone deficit around the implant can likely be treated by combining several peri- implant operations.[27,28]

20. Image Guided Implantology

Image-guided implant surgery has experienced remarkable advancements in recent years. It involves two main types that utilize dedicated software for precise implant planning to define implant angulation and position, while avoiding contact with the maxillary sinus or with the inferior alveolar nerve. While one procedure consists of real-time navigational implant surgery, the other inserts implants using a surgical splint created using stereo lithography.[29]

Computer-designed surgical splints significantly expedite the implant placement process. However, any errors in planning or splint fabrication cannot be easily corrected during surgery. In such cases, surgeons may need to forgo the use of the splint altogether, potentially leading to incorrect implant placement.[30]

21. Conclusion

The future of dental implantology holds immense potential through continuous innovation and progress. Areas such as biomaterials, implant design, surface modification, and functionalization are critical for improving patient care and enhancing treatment outcomes. Advancements at every stage, including diagnosis, treatment planning, surgery, grafting, and implant designs, are essential for achieving successful long-term results in restoring missing dentition. By focusing on these areas of improvement, we can strive towards better patient outcomes and advancements in dental implant technology.

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None.

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(57) Abstract :
One of the most common non-commutable types of chronic inflammatory disease is Periodontitis. It is the sixth most common disease affecting nearly 750 million population worldwide every year. It is very important to treat such Intrabony Osseous Defects, as if left untreated, it may lead to increased risk of disease progression sometimes leading to loss of teeth. Research studies suggest that piezoelectric surgical instruments with accurate precision would provide correct prediction of periodontal osseous defects. Any immediate reduction in periodontal dental angulation could be detected by bone swaging. Proposed is a System and Method to Detect the Depth of Intrabony Osseous Defect using Machine Learning. Input Cone Beamed Computed Tomography (CBCT) which provides inter-relational images in three orthogonal planes namely axial, sagittal and coronal and also customized planes are subject to Image Pre-Processing. Images are converted to Gray Scale and Binarization of images is carried out using Social Edge Detection to increase the object recognition rate. Target object recognition is trained using Convolutional Neural Networks. Multiclass Classifier and Bounding Box Regressor employed for each convolutional and pooling layers for accurate detection of depth of intrabony osseous defects.

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Review Article

Changing trends in implant designs: A review

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ABSTRACT

Implantology is an ever-evolving scientific field that undergoes continuous refinement and innovation. Dedicated research and development efforts are focused on consistently improving the success rates of implants through innovative redesign and advancements. The introduction of advanced technologies has revolutionized the evaluation of patients in three dimensions, enabling clinicians to utilize precise and predictable approaches for diagnosis, planning, and treatment. This multidisciplinary patient-centric framework has opened new avenues for providing tailored and effective healthcare solutions. Therefore, it is of utmost importance for clinicians to conduct a comprehensive analysis of each patient's condition, ensuring meticulous selection of the suitable implant design and material, and making informed decisions regarding the most appropriate technique to be employed.

1. Introduction

Dental implants are widely recognized as one of the most promising and effective solutions for replacing missing teeth. With long-term success rates surpassing 90%, they have proven to be highly effective in restoring oral function and aesthetics in both partially and fully edentulous patients.[1] Thanks to the current availability of advanced diagnostic tools that assist in treatment planning, along with the ongoing research leading to improved implant designs, materials, and techniques, a wide range of challenging clinical situations can now be effectively managed with a high level of predictability and success.[2] Implant design features are vital factors that have a significant impact on the initial stability of implants and their ability to endure loading throughout the osseointegration process and beyond. These design elements play a fundamental role in ensuring the long-term stability and durability of dental implants. Furthermore, dental implants are engineered with specific textures and shapes that can promote cellular activity and facilitate direct bone apposition, facilitating successful integration with the surrounding tissues.[3]

Dental implant design has undergone significant advancements in recent years. In the past, primitive dental implants such as blade, staple, and periosteal types were used, but they had inherent biomechanical limitations, leading to high failure rates.[4] Recent advancements have brought about significant improvements in the morphology, structure, and design of dental implants, aimed at enhancing their biomechanical properties, stability, and long-term success. These developments reflect the ongoing commitment to innovation and the continuous pursuit of excellence in the field of dental implantology.

Implant design encompasses the comprehensive three-dimensional structure of the implant, including its various elements and characteristics. It encompasses factors such as form, shape, configuration, as well as the surface macrostructure and macro irregularities, all of which

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contribute to the overall attributes of the implant's three-dimensional structure.

2. Implant Shape

Implant shape directly influences the surface area available for stress transfer, playing a critical role in determining the implant's initial stability. The predominating macro structure for root-form endosseous implants is the screw shape, which consists of parallel-sided screw and the tapered screw.[2] Smooth-sided cylindrical implants offer a convenient advantage when it comes to surgical placement.[4] A tapered implant with smooth sides enables the transfer of a comprehensive load to the interface between the bone and the implant, the extent of which depends on the taper's degree. Implants with threaded design and circular cross sections facilitate easy surgical placement and enable enhanced optimization of the functional surface area to effectively transmit compressive loads to the bone-to-implant interface.[2]

3. Implant Geometry

The primary criterion for developing the treatment plan is still the size of the implant, including its diameter and length, primarily determined by the amount of available alveolar bone. For a given implant length, increasing the implant diameter will increase the implant surface area that is available for force transfer to the bone.[5] Provided there is sufficient bone volume, a larger diameter implant is better able to resist occlusal forces, particularly in the molar region. When designing the treatment plan, it is important to consider the drawbacks associated with bone augmentation, which used to be considered the "gold standard" in severe atrophy cases. These drawbacks include morbidity at the donor site, elevated risks of complications, extended time and increased costs, as well as potential resorption of the bone graft. Additionally, the advancing capabilities of smaller-sized implants should be considered when formulating the treatment approach.[6]

Several new concepts may provide other options for implantation, aiming to reduce treatment duration, minimize complication rates, and simplify the overall treatment procedure, such as:

4. One-piece Implant

In a one-piece implant the endosseous and abutment portions form a single unit. By eliminating the abutment interface, the one-piece implant enhances the strength and stability of the prosthesis. It is a suitable option for patients or surgical sites with insufficient bone to adequately support a prosthesis. In spite of these advantages, one-piece dental implants do have a limitation in terms of flexibility compared to two-piece implants. Their single-unit construction restricts the ability to make precise adjustments once placed.

The design of one-piece implants allows for uninterrupted healing of the soft tissues surrounding the implant and avoids any disruption to the soft tissue seal when placing the final prosthetic restoration.[7]

5. Mini-Implants

Compared to standard dental implants, mini-implants are characterized by their reduced diameter, typically less than 3 mm, and shorter length. Despite their smaller size, they are typically made from the same biocompatible materials as standard implants. These implants are particularly useful when achieving acceptable and satisfactory function with conventional prostheses is challenging. Clinical situations like flabby ridges, atrophic ridges, or inadequate residual bone where denture retention is less, are likely to do well with mini-implants.[8]

6. Short Implants

Placing conventional implants can be challenging in cases of atrophic alveolar ridges due to various anatomical restrictions. These include the presence of the maxillary sinus, nasal floor, nasopalatine canal, and inferior alveolar canal. These structures can limit the available bone volume and affect the feasibility of conventional implant placement. To address these and other vertical bone deficits, additional surgical procedures are often employed to facilitate the placement of standard implants. These may include guided bone regeneration, block bone grafting, maxillary sinus lift, distraction osteogenesis, and nerve repositioning. These techniques aim to augment the available bone volume, create a favorable environment for implant placement, and overcome the challenges presented by the anatomical restrictions.

Short implants are often regarded as a simpler and more effective solution for rehabilitating the atrophic alveolar ridge. By minimizing the likelihood of complications, patient discomfort, procedure costs, and overall treatment time, they offer several advantages. In this context, however, it is worth mentioning that the categorization of a dental implant as "short" is subjective, and there are no universally defined criteria for determining the specific length that qualifies as a short dental implant. Recently, less than 8 mm- long short implants have been offered by implant companies.[9]

7. Tilted and Zygomatic implants

The utilization of a tilted or angulated implant in the posterior maxilla has been suggested as a potential alternative to sinus augmentation procedures. In the All-on-4 concept (a theory that uses four implants to restore total edentulism) for completely edentulous maxilla patients trans-sinus tilted implants are employed.

Zygomatic implants present an alternative to sinus augmentation procedures. They are lengthy implants travelling through the sinus or laterally into the sinus and are almost identical to trans-sinus tilting implants.[10]

8. Pterygoid implants

Pterygoid implants were introduced as another method of increasing the amount of bone that can be used for placement of implants in posterior maxillary region. The typical implant size for this method is between 15 and 20 mm. The implant enters the maxilla in the first or second molar region, following an oblique mesio-cranial direction. From there, the implant trajectory proceeds posteriorly toward the pyramidal process. Thereafter, it ascends between wings of the pterygoid processes and continues its course in the sphenoid bone to find anchorage in pterygoido scaphoid fossa.

The presence of dense cortical bone provides excellent engagement and stability for the pterygoid implants. That and an opportunity to obviate the requirement for maxillary sinus augmentation and other grafting procedures are two benefits of employing these implants.[11]

9. Tuberosity implants

Tuberosity implants are designed to be placed at the most distal aspect of the maxillary alveolar process, specifically targeting the tuberosity region. They are positioned to potentially engage the pyramidal process of the maxilla. Because of the dense bone present in this region, the difference in bony support for a pterygoid implant and a tuberosity implant can be significant.[11]

10. Utilizing three-dimensional printing for customized implants

The initial adoption of three-dimensional printing (3DP) for custom implants took place in the domains of rapid tooling and rapid prototyping. Digital scanning was combined with a CAD/CAM design and using 3DP, dental labs produced dental prostheses and patient models in significantly less time and with a precision that was unmatched by most traditional procedures. The combination of cone beam computed tomography (CBCT) and CAD/CAM was proposed to generate a surgical guide for precise implant placement.[12]

11. Transitional Implant

Their length varies from 7 to 14 mm, and diameter is between 1.8 and 2.8 mm. Transitional implants are manufactured using pure titanium and consist of a single-body design with a treated surface. They play an important role by absorbing the masticatory stress during the healing phase. This stress absorption helps promote a stress-free environment for the maturation of bone around the submerged implants, allowing them to heal smoothly and without complications.

Some commercially available Transitional Implant System include the Immediate Provisional Implant System–IPI by Nobel Biocare; Modular Transitional Implant System -MTI by Dentatus; and TRN/ TRI Implants by Hi Tec implants.[13]

12. Ligaplant

This technology involves the integration of periodontal ligament (PDL) cells with implant biomaterial. Research is currently being done to make this implant honourable. In Ligaplant, the PDL cells serve as a soft, vascular tissue that distributes forces, absorbs shocks, and provides proprioception for the tooth within its socket.[14]

13. Design Variables in Surface Area Optimization Thread Geometry

The market today offers a variety of implant systems with different implant thread configurations (Figure 1). The number of threads, width of the thread, depth of the thread, face angle of the thread and its pitch are among the various geometric combinations that affect final bone-implant contact (BIC) and distribution of load. A greater number of threads and increased thread depth provides greater available surface area for load distribution.[15]

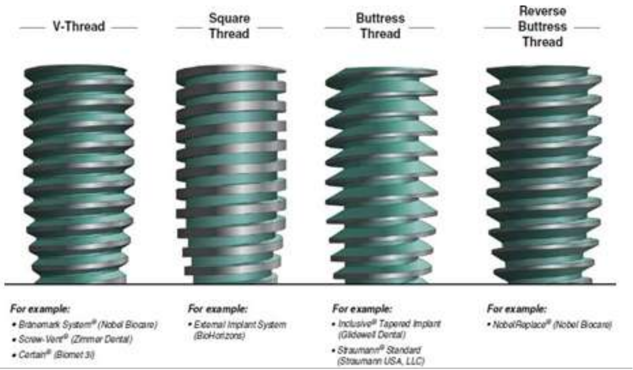

Fig. 1: Thread shapes of dental implants (V-thread, square, buttress, and reverse buttress).

Source: Grant Bullis .Functional Basis for Dental Implant Design. In: Misch,s Contemporary Implant Dentistry .4th ed. St Louis, USA: Mosby.;2021. p.48-68.

Implant threads are crucial for achieving primary stability, particularly in areas where bone quality is not good and for dissipating stresses at the bone-implant interface. This aids in minimizing the risk of complications and supports successful healing and integration of the implant with the bone.

The implant apical region should be tapered to assist insertion into the osteotomy and initial engagement of

threads of the implant. It should be either rounded or flattened to reduce the probability of perforating membranes during placement. It will have flat regions or grooves circumferentially arranged on the implant body to stabilize the implant against rotation after healing and to aid in insertion.[16]

14. Implant Crest Module and Abutment (Figures 2 and 3)

Current knowledge of prosthetic connections suggests that an internal prosthetic connection offers the best functionality. Of the internal prosthetic connection types in use today, the conical prosthetic connection have the best feature set, also conical prosthetic connections provide a stable abutment connection, lower peak bone stresses when positioned level to the marginal bone, and have a high resistance to axial loads. The Morse taper implant abutment connection features a tapered projection on the abutment that fits into a tapered recess in the implant. This creates a friction fit and cold welding to prevent rotation, providing stability during function. Taper angles vary, such as 8° in ITI Straumann or Ankylos, or 11° in Astra. The Bicon implant system has rounded channels with a 1.5 degree taper. When the cross section of the implant permits, platform shifting should be used to redistribute the stress away from the bone-implant interface. Platform shifting or using abutments with a diameter less than the implant collar is thought to be advantageous to maintain marginal bone levels while providing a biomechanical advantage in osseointegrated implants as it redirects the concentration of stress, taking it away from the cervical region of bone-implant interface; with an inverse relationship between the amount of implant-abutment diameter mismatch and cortical bone stress concentration.

Angled abutments, UCLA Abutment, Ceramic abutments, CERADAPT Abutment, and Multi- Unit abutment are recent advancements in implant abutments.[17]

Fig. 2: a): CAD/ CAM custom abutments. Left to right, posterior milled titanium abutment, anterior milled titanium abutment, and hybrid milled zirconia bonded to titanium abutment base. **b):** Multiunit abutments with screws.

Fig. 3: a): Stock/standardized healing abutments **b):** Custom healing abutment with ideal contours.
Source: Park NI, and Kerr M. Terminology in Implant Dentistry. In: Misch,s Contemporary Implant Dentistry .4th ed. St Louis, USA: Mosby.;2021.p.20-4

15. Implant Materials

Dental implants have been tested using various materials, including metals, alloys, ceramics, polymers, glasses, and carbon. Biocompatibility, bio functionality, availability, and the ability to Osseo integrate are specific characteristics needed for their manufacturing.

Materials for dental implants and the prosthetic components they support must adhere to several strict requirements. For dental implants, titanium alloys continue to have the finest mechanical and biocompatibility qualities, and their usage is recommended. Currently, commercially pure titanium, titanium alloys, and zirconia (zirconium dioxide, ZrO2), ceramic implants are the representative biomaterials in wide use for dental implant applications. Additional other advanced material are Zirconia Toughened Alumina (ZTA) and Alumina Toughened Zirconia (AZT), Poly-Ether-Ether-Ketone (PEEK), Powder Injection Molding (PIM), Tantalum Implants, Porous Tantalum Trabecular Metal (PTTM), LASER- LOK Technology.[18]

16. Surface Modification of Implants

Research has shown that microrough surfaces had higher degrees of bone-to-implant contact or BIC. These modifications can be divided into subtractive and additive processes, depending on whether material is removed or deposited on the implant surface in the development of the surface.[19] Plasma arc is an additive process that involves depositing a bioactive hydroxyapatite (HA) material onto the implant surface. Polishing, machining, and acid etching are subtractive procedures used for implant surface treatment. These treatments can be classified into various methods, including mechanical, chemical, electrochemical, electropolishing, vacuum, thermal, and laser techniques (Figure 4). Various modifications have been implemented to enhance the biological surface of dental implants, aiming to achieve optimal bone-to-implant contact.[20]

Surface treatments involving calcium deposition have shown increasing bioactivity over time, with the highest deposition observed in the sandblasted, acid-etched, and thermally oxidized group. This is in lieu of greater surface roughness that promotes cell adhesion, proliferation, and differentiation.[20]

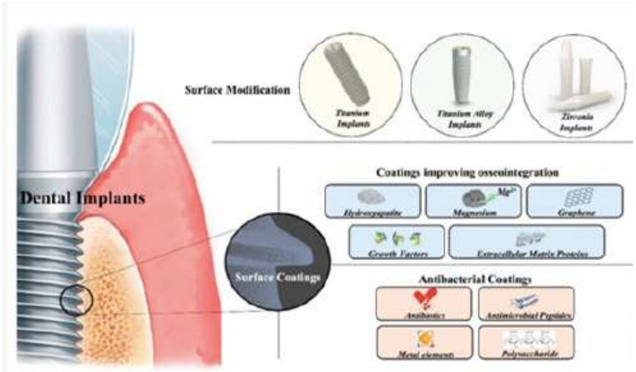

Fig. 4: Schematic illustration depicting surface modification and coatings of dental implants Source: Dong H, Liu H, Zhou N, Li Q, Yang G, Chen L, MouY. Surface Modified techniques & Emerging Functional Coating of Dental Implants. Coatings 2020, 10(11),1012:3-25

Recent studies have explored bioactive surface modifications of dental implants using inorganic materials (e.g., HA, calcium phosphate), growth factors, peptides, and extracellular matrix components. These approaches aim to enhance implant osseointegration and improve biological responses.[20] Research has shown the potential of utilizing stem cell-mediated bone regeneration for the treatment of peri-implant defects. However, stem cell implant technology is still in its early stages and is not currently a viable option for replacing missing teeth. Ongoing research hopes to enhance these techniques and develop more cost-effective procedures involving stem cells.[21]

17. Current Technologies for Implant Design and Placement Analysis

The success of dental implantation depends on accurate imaging. Cone Beam Computed Tomography (CBCT) utilising three-dimensional images is one of the newest technologies in dentistry imaging. This technology offers a continuous flow of data that allows dental surgeons to reconstruct images as needed, while minimizing radiation exposure for patients.[22,23]

18. Current developments in computed tomography technology include

1. (a) *Cone beam Computed Tomography:* This technology utilises a cone shaped beam of radiations. The image is reconstructed with special software. Comprehensive information like a Computed Tomography is obtained, albeit with 1/8th of radiation exposure and at minimal cost.
   (b) *Microtomograph:* This device helps in obtaining serial sections of the interface between implant and bone.
   (c) *Multislice helical CT:* This device has the advantage of providing high quality images when compared to Computed Tomography. It is referred as Dentascan Imaging.
   (d) *Interactive Computed Tomography:* This device develops image files that can be transferred from Radiologist to dentist's computer, who can work upon the case with precision and ease. Both the dentist and the radiologist work together and simulate placement of cylinders of arbitrary sizes in images, replicating root form implants, allowing for virtual surgical planning and an "Electronic Surgery".
   (e) *Magnetic resonance imaging (MRI):* This 3D non-invasive imaging method uses an electronic image acquisition process where image is produced digitally.

Better stability is made possible by the shape and configuration of implants, which is essential for the osseo-integration process. Refinement of drilling machines has led to better control over drilling speed and associated torque, which reduces risk of overheating the surrounding bone.[24] Improved control of water irrigation and the incorporation of internal implant irrigation systems also play a crucial role in minimizing the elevation of bone temperature during implant procedures. Additionally, the use of custom-made surgical splints, guided by CT data, assists in accurately defining the implant location and angulation, ensuring precise and optimal placement.[25]

Dental professionals and specifically prosthodontists have greater concern of the occlusal load on given prosthesis. Achieving precise dental implant alignment and connecting implants in a triangular configuration is crucial for the successful placement of fixed bridges in some cases. This configuration enhances stability and helps to resist lateral displacement forces.[26]

19. Peri implant surgery

It is common for tooth loss to be accompanied by the simultaneous resorption of the alveolar bone. As adequate implant width and length are crucial for long-term success of any implant, cases with insufficient remaining bone often pose a problem. The volume of the bone can be increased by varied techniques. For slight depressions, a simple onlay bone graft can be used while an inlay bone

graft can be employed where a sandwich osteotomy is required. Maxillary sinus floor augmentation can be used to increase bone volume in the upper jaw. Distraction osteogenesis is also a state-of-the-art procedure used for augmenting areas of bone. Now a days, osteo-inductive and osteo-conductive substances can help accelerate the healing process. Vestibuloplasty and palatal graft transplant are getting popular in cases where ablative surgery or tissue atrophy decreases the amount of available soft tissue. Free gingival graft transplant is a simpler procedure that produces less overall patient morbidity. Thus, the issues linked to either the soft tissue or bone deficit around the implant can likely be treated by combining several peri- implant operations.[27,28]

20. Image Guided Implantology

Image-guided implant surgery has experienced remarkable advancements in recent years. It involves two main types that utilize dedicated software for precise implant planning to define implant angulation and position, while avoiding contact with the maxillary sinus or with the inferior alveolar nerve. While one procedure consists of real-time navigational implant surgery, the other inserts implants using a surgical splint created using stereo lithography.[29]

Computer-designed surgical splints significantly expedite the implant placement process. However, any errors in planning or splint fabrication cannot be easily corrected during surgery. In such cases, surgeons may need to forgo the use of the splint altogether, potentially leading to incorrect implant placement.[30]

21. Conclusion

The future of dental implantology holds immense potential through continuous innovation and progress. Areas such as biomaterials, implant design, surface modification, and functionalization are critical for improving patient care and enhancing treatment outcomes. Advancements at every stage, including diagnosis, treatment planning, surgery, grafting, and implant designs, are essential for achieving successful long-term results in restoring missing dentition. By focusing on these areas of improvement, we can strive towards better patient outcomes and advancements in dental implant technology.

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23. Conflict of Interest

None.

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A Comparative Study of Serum Glycosylated Hemoglobin Levels and Periodontal Therapy in Smokers and Non-Smokers with Chronic Periodontitis Patient

Running Title: Effect of Non-Surgical Periodontal Therapy in Non-Diabetic Patients.

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Abstract.

Background and aim: Smoking is the major risk factor for periodontitis, and affects the extent and severity of disease. Glucose can bind irreversibly to hemoglobin, through a non-enzymatic reaction to form glycosylated hemoglobin. Because it is based on the average life span of an erythrocyte, serum glycosylated hemoglobin levels reflect glycemic control over the previous one to three months. The aim of this study assess the serum glycosylated hemoglobin levels and clinical outcome in smokers and non–smokers with chronic periodontitis following periodontal therapy.

Methods: A total of 40 subjects (Group I- 20 Non-Smokers, Group II- 20 Smokers) in the age group of 20-40 years participated in this study. Both groups received initial periodontal therapy. Clinical parameters such as plaque index, gingival index, extent and severity index were evaluated at baseline and 3 months after initial periodontal therapy. Serum glycosylated hemoglobin was investigated at baseline and 3 months in both groups. The statistical tests used were paired t-test.

Results: After 3 months initial periodontal therapy both the groups exhibited improvement in clinical periodontal parameters. However, statistically significant results were observed in all the clinical periodontal parameters. When the post treatment clinical periodontal parameters and serum glycosylated hemoglobin levels were evaluated, statistically non-significant differences were obtained in both the groups.

Conclusions: Initial periodontal therapy is effective tool in periodontal diseases. This study demonstrated that Group-I and Group II showed significant improvement in all clinical periodontal parameters and serum glycosylated hemoglobin levels after 12 weeks.(www.actabiomedica.it)

Key words: Diabetes Mellitus, Glycosylated Hemoglobin, Periodontal Therapy, Smoking

Introduction – According to the World Health Organization (WHO), non-communicable diseases (NCDs) accounted for 74% of deaths globally in 2019, of which, diabetes resulted in 1.6 million deaths, thus becoming the ninth leading cause of death globally. The major factors for the global increase in the diabetes epidemic is due to socioeconomic changes, with other associated risk factors such as population growth, unhealthy eating habits, and a sedentary lifestyle modification.(1) In India, 62.4 million people are suffering from Type 2 Diabetes Mellitus and 77 million are suffering from prediabetes.(2) More than 50% of Indian population are suffering from periodontal diseases.(3)

Periodontal disease is an entity of localized infections that involves tooth supporting tissues, the structure that make up the periodontium. The designation periodontal disease includes both reversible (gingivitis) and irreversible (periodontitis) process.(4) The pathological nature of periodontal disease is certainly based on inflammatory responses to pathogens and destructive materials. In 1993, Loe et al. stated that periodontal disease as the sixth complication of diabetes, after neuropathy, diabetic nephropathy, retinopathy, vascular diseases and delayed healing.(5)

Smoking causes periodontal diseases. Periodontal disease is an entity of localized infections that involves tooth supporting tissues, the structure that make up the periodontium.(6,7) Many authors stated that nicotine which is present in cigarette, has been demonstrated to increase the blood glucose levels.(8) It is the most active substance in tobacco which is absorbed through lung alveoli.(9) Nicotine not only has a direct toxic effect on pancreatic beta cells but also is associated with increased insulin resistance leading to impaired glucose tolerance. Furthermore, the antiestrogenic effect of nicotine could contribute to an increase in visceral adipose tissue accumulation and via this mechanism, insulin resistance. Finally nicotine increases cortisol level and inflammation and has influence on adiponectin a peptide that regulates food intake and body weight, all of which could contribute to higher HbA1c.(5) Nicotine is highly addictive. It may cause rise in blood pressure, increased heart, respiratory rates, and peripheral vasoconstriction which leads to contraction of oral capillaries affecting periodontal tissue and gingival blood flow.(7)

Glycated hemoglobin (HbA1c) is a marker of long-term glucose homeostasis reflecting average blood glucose concentration in the past two to three months.(5) The process of non-enzymatic addition of carbohydrate to polypeptides and proteins is called glycosylation/ glycation and the products that are formed are called as advanced glycated end products (AGE's).(10)

Thus, the aim of this study was to compare the efficacy of serum glycosylated hemoglobin levels and periodontal therapy in smokers and non-smokers with chronic periodontitis patients without Type 2 Diabetes Mellitus.

Materials And Methods - This study was carried out in Department of Periodontology, Seema Dental College & Hospital, Rishikesh, Uttarakhand, India with the approval of institutional ethical committee. The reference number of the ethical clearance was SDC/2018/A-115. The study was conducted over a duration of 3 months starting from March 2018 and extending to June 2018 at Dehradun, Uttarakhand, India.

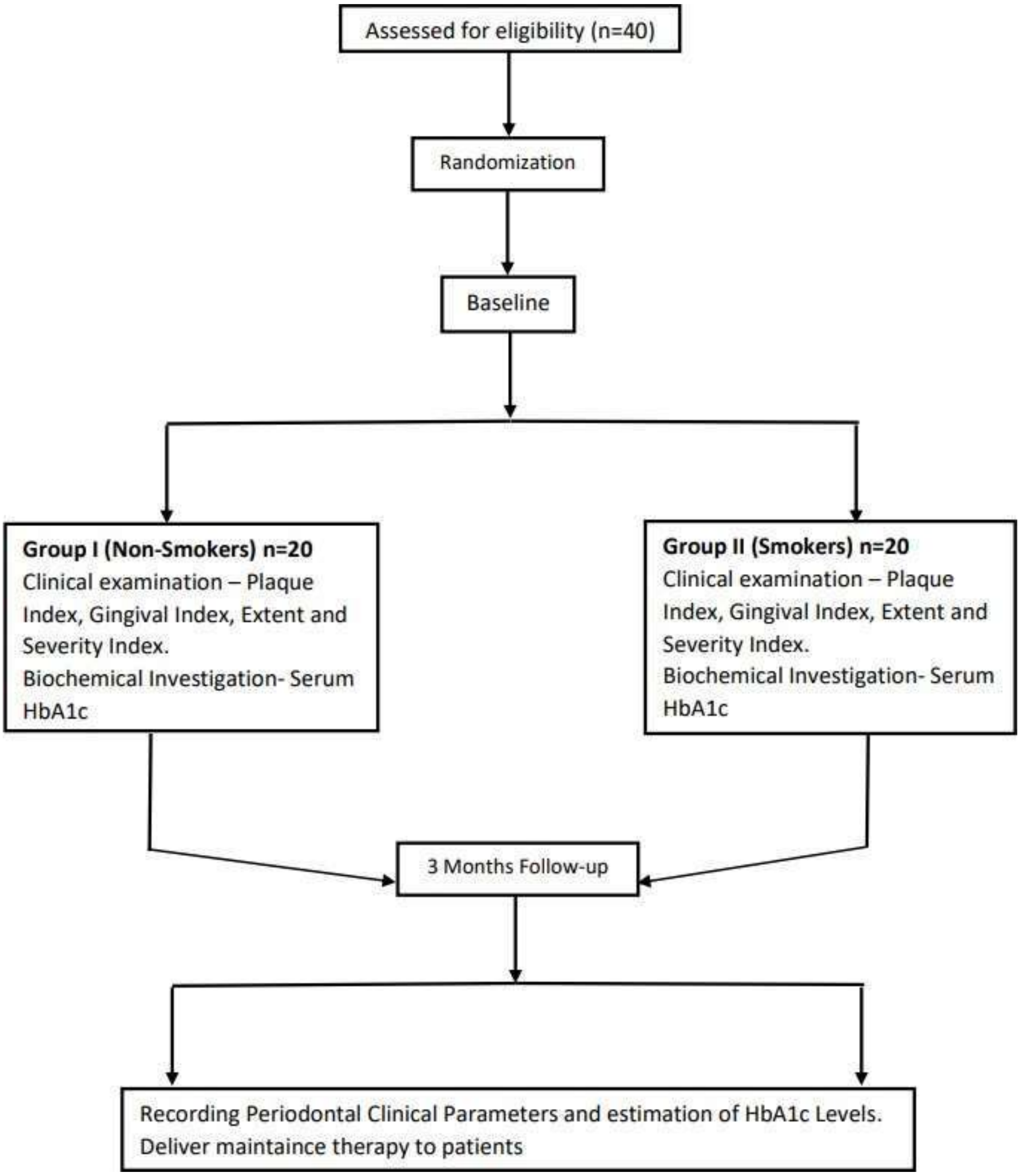
Sample Size: A sample size of 40 were required to achieve 80% power and 5% significance. During this study, 40 patients reporting to the outpatient department were selected who were found to have who were smokers/ non-smokers with chronic periodontitis. The study subjects were categorized into two groups consisting of twenty subjects each.

Selection Criteria:

A total of 40 subjects (Group I- 20 Non-Smokers, Group II- 20 Smokers) in the age group of 20-50 years participated in this study. Clinical parameters such as Plaque Index, Gingival Index, Extent and Severity Index were evaluated at baseline and 3 months after initial periodontal therapy. Serum glycosylated hemoglobin was investigated at baseline and 3 months in both groups. Each patient was given detailed verbal and written description of the treatment.

Inclusion Criteria: Patients who were smokers and non-smokers with chronic periodontitis. Patients who were systemically healthy with no history of periodontal therapy in last six months.

Exclusion Criteria: Medically compromised patients with underlying systemic disease and those patients who were not willing to report for follow-up were excluded from this study.
The selected patients were randomly allocated to two groups (Flowchart 1)
Group I (20 patients): Patients who were non-smoker with chronic periodontitis
Group II (20 patients): Patients who were smoker with chronic periodontitis
The patients were scheduled for laboratory and periodontal examinations before treatment (baseline), and after nonsurgical treatment (3-month recall visits).



Flowchart 1: Schematic diagram of the study design

Clinical Procedure

In Group I (non-smoker) patients who received a full-mouth scaling and root planing at baseline by performing the supra and subgingival scaling using an ultrasonic scaler and root planning using Gracey curettes. Oral hygiene instructions were given to all patients. Patients were instructed to brush

their teeth twice daily and rinse with 0.2% chlorhexdine gluconate solution twice daily. Oral hygiene control and reinstruction were reviewed each recall visit. Venous blood samples were taken for each patient to measure HbA1c (glycosylated hemoglobin) value at baseline, 3 months, after treatment.
In Group II (smoker) patients who received a full-mouth scaling and root planing at baseline by performing the supra and subgingival scaling using an ultrasonic scaler and root planning using Gracey curettes. Oral hygiene instructions were given to all patients. Patients were given instructions to maintain oral hygiene and motivated to stop smoking. Patients were instructed to brush their teeth twice daily and rinse with 0.2% chlorhexdine gluconate solution twice daily. Oral hygiene control and reinstruction were reviewed each recall visit. Venous blood samples were taken for each patient to measure HbA1c (glycosylated hemoglobin) value at baseline, 3 months, after treatment.
Parameters Assessed- The following clinical parameters were assessed at baseline before the periodontal therapy and at 3 months. Clinical periodontal parameters such as Plaque Index, Gingival Index, Extent and Severity Index were taken in the both groups. Serum Glycosylated Hemoglobin Levels were taken in both groups. Clinical parameters were carried out by a precalibrated examiner with the appropriate armamentarium.

Results – Demographic details are given in Table 1. There was no statistically significant difference between the two groups in terms of age, gender (*p* >0.05). The statistical tests used were paired t-test and chi square test.

Table 1: Age, Gender distribution of the Group I and Group II.

Variable	**Group-I (Non-smokers) N=20**	**Group-II (Smokers) N=20**	**df**	***P* value**
Age (Mean ± SD)	38.05 ± 8.00	39.95 ± 8.86	39.01 ± 8.86	>0.05*
Gender (Male:female)	16:14	16:14	32:28	>0.05*

SD-Standard deviation
df- difference
**P* value obtained is non significant

Change of Clinical Parameters after Nonsurgical Periodontal Treatment (Table 2)

At baseline, there was statistically significant difference in clinical periodontal parameters between the two groups (p >0.05). After nonsurgical treatment, the periodontal clinical parameters of Group I and Group II showed statistically significant changes. At third month follow-up, the results showed that there was a reduction in clinical periodontal parameters. (Table 2)

Table 2: Statistical comparison of mean values of Clinical Periodontal parameters at different intervals for Group-I (Non-Smokers) and Group-II (Smokers).

	Group-I (Non-smokers)					Group-II (Smokers)			
Parameter	**Different Interval**	**Mean ± SD**	**Mean Difference**	**t**	***P* value**	**Mean ±SD**	**Mean Difference**	**t**	***P* value**
Plaque index	Baseline	1.87 ±0.49	0.33 ±0.30	4.939	**<0.001***	2.25±0.363	0.52 ± 0.32	7.12	**<0.001***
	3 months	1.54 ±0.31				1.72 ±0.28			
Gingival index	Baseline	2.23 ±0.29	0.34 ± 0.19	7.85	**<0.001***	1.94 ±0.407	0.36 ± 0.303	5.327	**<0.001***
	12 weeks	1.88 ±0.36				1.58 ±0.27			
Extent	Baseline	84.20±11.62	5.33 ± 1.59	14.9	**<0.001***	90.64 ±6.61	5.52 ± 2.43	10.16	**<0.001***
	12 weeks	78.87±11.69				85.12 ±7.22			
Severity	Baseline	3.52 ± 0.53	0.18 ± 0.17	4.949	**<0.001***	4.01 ±0.61	0.31 ± 0.25	5.53	**<0.001***
	12 weeks	3.33 ± 0.54				3.70 ±0.57			

SD - Standard Deviation
**p* value obtained is significant

Change of Hba1c Level after Nonsurgical Periodontal Treatment (Table 3)

At baseline, there was statistically significant difference in glycosylated hemoglobin at baseline and 3 months of both groups.

Table 3: Statistical comparison of mean values of glycosylated hemoglobin at different intervals for Group-I (non-smokers) and Group-II (smokers).

	Group-I (Non-smokers)					Group-II (Smokers)			
Parameter	**Different Interval**	**Mean ± SD**	**Mean Difference**	**t**	***P* value**	**Mean ± SD**	**Mean Difference**	**t**	***P* value**
Glycosylated Hemoglobin	Baseline	5.43 ±0.39	0.43 ± 0.27	6.93	**<0.001***	5.95 ± 0.604	0.41 ± 0.23	8.068	**<0.001***
	12 weeks	5.005 ±0.27				5.53 ± 0.457			

SD- Standard Deviation,
*P value obtained is significant

Comparison of mean difference for clinical periodontal parameters and HbA1c at different time intervals for non-smokers and smokers group.

The intragroup comparison of the clinical periodontal parameters (Plaque index, gingival index, extent and severity index) of group I (non-smokers) and group II (smokers) the mean values were not statistically significant (Table 4). Regarding glycemic control, In intergroup comparison Group I (non-smokers) and group II (smokers) glycosylated hemoglobin at baseline and 3 months of both groups the mean values were not statistically significant showed an insignificantly difference (Table 4).

Table 4: Statistical Comparison of mean difference for plaque index, gingival index, extent, severity and HbA1c at different time intervals for non-smokers and smokers group.

	Group-I (Non-smokers)	Group-II (Smokers)		
Parameter	**Mean ± SD**	**Mean ± SD**	**t**	**P value**
Difference in plaque index	0.332 ± 0.3006	0.52 ±0.32	-1.919	0.063*
Difference in gingival index	0.348 ± 0.198	0.36 ± 0.303	-0.167	0.869*
Difference in extent	5.33 ± 1.59	5.527 ± 2.43	-0.303	0.764*
Difference in severity	0.188 ± 0.170	0.313 ± 0.253	-1.831	0.075*
Difference in HbA1c	0.43 ± 0.277	0.415 ± 0.230	0.186	0.853*

SD- Standard Deviation,
*P value obtained is non significant

Discussion – Glycohemoglobin is formed by a non-enzymatic interaction between glucose and the amino groups of the valine and lysine residues in hemoglobin. Formation of glycohemoglobin is irreversible and the level in the red blood cell depends on the blood glucose concentration.(11) In this study glycemic status was evaluated in smokers and non-smokers at baseline and 3 months with higher mean values in smokers. In this study total of 40 patients (Group I- 20 Non-Smokers, Group II- 20 Smokers) in the age group of 20-50 years were distributed to two groups, each patient received nonsurgical periodontal treatment. Clinical parameters related to chronic periodontitis include plaque index, gingival index, extent and severity index were evaluated at baseline and 3 months after initial periodontal therapy. By recording these parameters, previous periodontal destruction, ongoing disease and prediction of disease progression may be monitored and are essential for treatment planning and to evaluate treatment outcomes. Serum glycosylated hemoglobin levels was investigated at baseline and 3 months after initial periodontal therapy in both groups. Smoking affects active periodontal therapy and responds less favorably to treatment outcomes. Smokers have less gingival scores as nicotine causes vasoconstriction in peripheral blood vessels and reduces the clinical signs of gingival inflammation. In the current study, it was observed that there was significant reduction in plaque and gingival index at 3 months after non-surgical periodontal therapy in Group I (non-smokers) which is in accordance with the study of Indurkar (12) who reported the clinical effects of mechanical non-surgical periodontal therapy in subjects with chronic periodontitis over a period of six weeks and concluded that decrease in scores of plaque and gingival index. On comparison of mean difference between the groups, there was no statistically significant difference observed in PI and GI with reduction in scores of non-smokers. This observation indicates that non-smokers maintained optimum level of hygiene throughout the course of study which was in accordance with the study of Aziz AS et al.(13) who assessed the short-term effectiveness of scaling and root planing on clinical parameters, systemic inflammatory and oxidative stress markers between smokers and non-smokers and concluded that smokers exhibited more periodontal damage and higher systemic inflammatory and oxidative stress burden than non-smokers. In the current study Extent and Severity Index was evaluated to assess the periodontal destruction in smokers and non-smokers. Since there is lack of literature regarding extent and severity index the results have been compared with other similar studies Thomson KFR et al,(14) Carlos JP et al.(15) Thomson KFR et al.(14) assessed clinical attachment loss to determine prevalence, extent and severity of severe periodontitis and concluded that current smokers had significantly higher extent of periodontal destruction. Another study by Carlos JP et al(15) evaluated extent and severity index in 369 aged 17-32yrs old. 22% of sites examined showed evidence of disease, with an average severity of 1.48 mm attachment loss per diseased site. When re-examined approximately three years later, both extent and severity had increased significantly during the three-year period. In this study glycemic status was evaluated in smokers and non-smokers at baseline and 3 months with higher mean values in smokers. Ohkuma T et al.(16) reported that glycosylated hemoglobin increased significantly with increase in number of cigarettes per day compared with non-smokers, indicating a dose-response relationship.(11) There was statistically significant reduction in glycated hemoglobin at three months after non-surgical periodontal therapy in group I (non-smokers) and Group II (smokers) which was in accordance with the Study of Vaghani H et al.(17) Muthu J et al.(18) Vaghani H et al.(17) evaluated the glycated hemoglobin levels in healthy patients and patients with periodontitis, before and after non-surgical periodontal therapy and concluded that glycated hemoglobin of patients with periodontitis were significantly reduced after three months of non-surgical periodontal therapy. Muthu J et al.(18) compared HbA1c in subjects with periodontitis and healthy controls and evaluate the effect of non-surgical periodontal therapy on the glycemic control in periodontitis and concluded that HbA1c was higher in periodontitis. 3 months following periodontal therapy there was improvement in periodontal parameters and decreased in HbA1c levels. There was statistically significant reduction in HbA1c at 3 months after non-surgical periodontal therapy in Group II (smokers) which is contraindicatory to study by Verma N(19) who found no significant difference in mean values of HbA1c in cigarette smokers and Bidi smokers and no correlation between smoking index and HbA1c.

Study by Jyothirmayi B et al.(10) evaluated the association between cigarette smoking and glycated hemoglobin levels and found a significant association between smoking and glycated hemoglobin levels. This was similar to Torrungruang K et al.(20) determine the effect of cigarette smoking on the severity of periodontitis in older Thai adults and concluded that former smokers were more likely to have severe periodontitis than non-smokers. Ali OH et al.(21) evaluated the clinical parameters plaque index, gingival index, probing depth, clinical attachment level in smokers and non-smokers and concluded that smokers exhibited more amount of plaque and lesser amount of gingival index. Study by Urberg M et al.(22) is contradictory to present study who reported the effects of smoking on plasma glucose by comparing the glycosylated hemoglobin levels of subjects who smoked one pack per day or more with those of non-smokers and concluded that smokers have average blood glucose that is higher than that of non-smokers. On comparison of mean difference between the groups, there was no statistically significant difference observed in PI and GI with reduction in scores of non-smokers. This observation indicates that non-smokers maintained optimum level of hygiene throughout the course of study. Thus, Bacteria can survive and grow in the complex ecosystem of biofilm as they produce of various virulence factors to evade the host immune defense system and destroy host periodontal tissues. (23) Thus, diagnosis and management of periodontal disease is essential for treatment and maintenance of periodontitis-susceptible patients. (24,25) Further long term study with large sample size and follow up areneeded to confirm the findings of this study.

Conclusion - This study demonstrated that both groups showed significant improvement in clinical periodontal parameters and serum glycosylated hemoglobin after non-surgical periodontal therapy. On comparison Group-I (non-smoker) showed better treatment outcome as compared to Group-II (smokers).

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Conflict of Interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

Authors Contribution: all authors contributed to conceptualization, methodology, software, validation, formal analysis, investigation, data curation, as well as writing of original research.

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Caries Risk Assessment: Where Do We Stand Today?

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Caries Risk Assessment: Where Do We Stand Today?

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Abstract

Caries Risk" is defined as the probability that an individual will develop at least a certain number of carious lesions reacting a giver stage of disease progression during a specified time conditional on his/her exposure status remaining stable during the period in question. This is generally considered "high" or "low". "Caries risk assessment" is the identification of individuals at high risk for future caries. Assessment of caries risk is an important part of contemporary dental practice. Dental practitioners perform such assessments every day of their practicing lives. The patient should be made aware of their risk status so that they become involved in their preventive care. For dentists to practice preventive dental medicine, they need information about the caries-risk status of their patients. The validity of a caries-risk assessment can be evaluated as regards specificity, sensitivity, positive and negative predictive values. Thus, this review article will the risk assessment can be tested for how well it correlates with the future disease.

Keywords: caries; risk assessment; dental; Practitioners; preventive care

Introduction

The most common disease that has affected the dentition of a child patient since a long time is dental caries. Dental caries has a multi-factorial etiology in which there is an interplay of four principal factors [1]:

1. the host (saliva and teeth).
2. The microflora (plaque).
3. the substrate (diet).
4. Time.

The American Academy of Pediatric Dentistry (AAPD) recognizes that caries-risk assessment and management protocols can assist clinicians with decisions regarding treatment based upon caries risk and patient compliance and are essential elements of contemporary clinical care for infants, children, and adolescents and it aids in clinical decision making regarding diagnostic, fluoride, dietary, and restorative protocols [2].

Caries-risk assessment [3]

- ✓ Risk assessment procedures used in medical practice normally have sufficient data to accurately quantitate a person's disease susceptibility and allow for preventive measures.
- ✓ Even though caries-risk data in dentistry still are not sufficient to quantitate the models, the process of determining risk should be a component in the clinical decision making process.

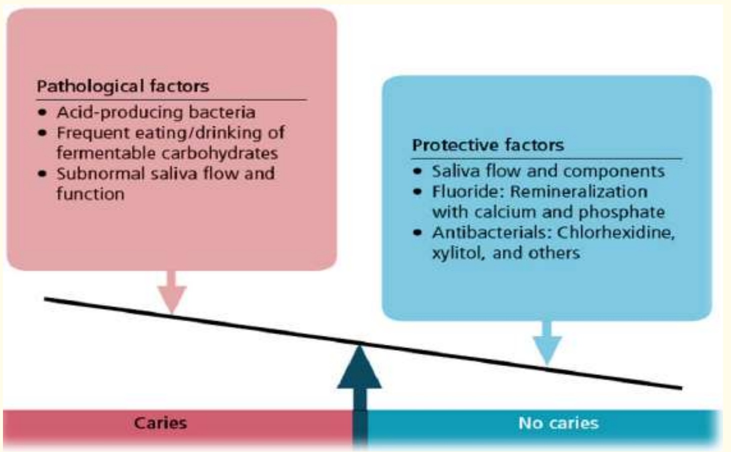

Figure 1: Caries balance concept- basis for caries risk assessment (Featherstone JD).

Caries risk assessment occurs in two phases

A) The first is to determine specific disease indicators, risk factors and protective factors.
B) The second step is to determine the level of risk that the sum of these factors indicates.

Caries risk factors [4]

- ➢ Caries risk factors are defined as biological reasons that cause or promote current or future caries disease.

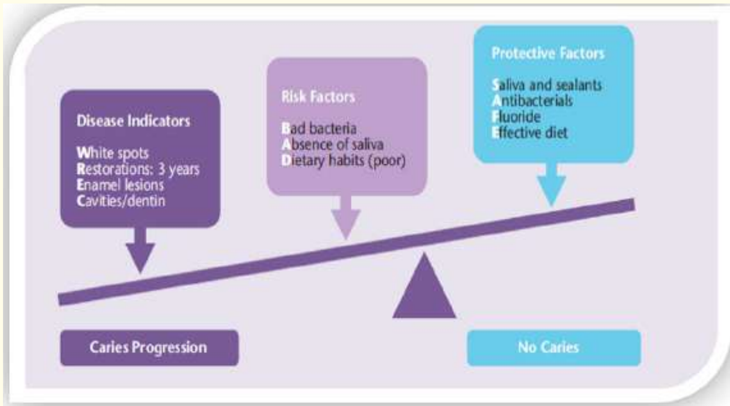

Figure 2: Caries Imbalance model (Featherstone JD).

The Caries Imbalance model uses the acronym "BAD" to describe three risk factors that are supported in the literature as causative for dental caries:

- ✓ Bad bacteria, meaning Acidogenic, Aciduric or Cariogenic bacteria.
- ✓ Absence of saliva, meaning hyposalivation or salivary hypofunction.

  Destructive lifestyle habits that contribute to caries disease, such as frequent ingestion of fermentable carbohydrates, and poor oral hygiene (self care).

Caries disease indicators

Caries disease indicators are described as physical signs of the presence of current dental caries disease or past dental caries disease history and activity.

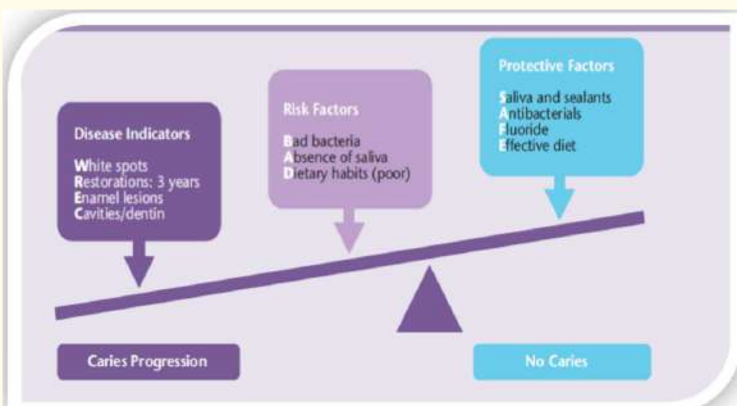

Figure 3: Caries disease indicators (Featherstone JD).

The Caries Imbalance model uses the acronym "WREC" (pronounced "wreck") to describe the following four disease indicators:

- ✓ White spots visible on smooth surfaces.
- ✓ Restorations placed in the last three years as a result of caries activity.
- ✓ Enamel approximal lesions (confined to enamel only) visible on dental radiographs.
- ✓ Cavitation of carious lesions showing radiographic penetration into the dentin.

Discussion

Caries risk assessment is an important process used by dental professionals to evaluate an individual's susceptibility to tooth decay (caries) [4]. It helps dentists identify patients who are at higher risk of developing cavities and enables them to develop personalized preventive strategies and treatment plans. The process of caries risk assessment typically involves the following components:

1. *Medical and dental history*: Dentists collect information on the patient's medical conditions, medications, previous dental treatments, oral hygiene habits, and dietary patterns. These factors can influence the risk of caries development.
2. *Clinical examination*: Dentists visually inspect the teeth, gums, and oral tissues. They may also use dental instruments or diagnostic tools like X-rays to assess the presence of current cavities, areas of enamel demineralization, and other signs of dental decay.
3. *Evaluation of risk factors*: Dentists consider specific risk factors that contribute to tooth decay, such as inadequate oral hygiene, frequent consumption of sugars or acidic foods and beverages, reduced salivary flow, previous history of cavities, orthodontic appliances, and certain medical conditions.
4. *Scoring or grading system*: Various caries risk assessment tools employ scoring or grading systems to categorize patients into different risk levels, such as low risk, moderate risk, or high risk. These assessments can be based on a combination of factors, including the presence of risk indicators and historical data.
5. *Determining preventive strategies*: Based on the individual's risk level, dentists can recommend appropriate preventive strategies. These may include regular dental check-ups, professional cleanings, fluoride treatments, sealants, dietary modifications, oral hygiene instructions, and the use of antimicrobial products.

It's essential to note that caries risk assessment is an ongoing process, and risk levels can change over time. Regular dental visits and re-evaluation help monitor changes in risk status and allow for adjustments in preventive strategies to best manage oral health effectively. Indeed, aesthetic considerations play a role in dentistry, with patients increasingly valuing the appearance of their smiles. Advancements in cosmetic dentistry contribute to this trend, offering a range of options to enhance both oral health and the visual appeal of teeth [6].

Caries, commonly known as tooth decay, is a prevalent oral health issue that affects a large portion of the global population. Over the years, scientists and dental professionals have been striving to develop methods for caries risk assessment, aiming to identify individuals with a higher risk of developing tooth decay [7]. Permanent posterior teeth with deep pit and fissure are more prone to dental caries [8].

Conclusion

Caries risk assessment is still in the developmental stage. In conclusion, caries risk assessment has come a long way in the field of dentistry. The development of comprehensive protocols such as CAMBRA, the incorporation of fluorescence-based technologies, and the evolving understanding of genetic influences have significantly enhanced our ability to assess caries risk accurately. By identifying high-risk individuals and implementing appropriate preventive strategies, dental professionals can effectively combat tooth decay and promote optimal oral health. Caries risk assessment serves as a vital tool in preventive dentistry, helping to reduce the impact of caries on individuals and society as a whole.

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ORIGINAL ARTICLE PERIODONTITIS

Evaluation of Glycosylated Hemoglobin Levels and Effect of Tobacco Smoking in Periodontally Diseased Non-Diabetic Patients

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ABSTRACT

Background and Objective: Chronic diseases have progressively increased worldwide, impacting all areas and socioeconomic groups. Periodontal disease is an increasing global concern and contains risk factors similar to other chronic illnesses. The main risk factor for periodontitis is smoking. Smoking not only hastens periodontal disease but also complicates periodontal therapy. Serum glycosylated hemoglobin levels, which are derived from the average life span of an erythrocyte, are a good indicator of glycemic management during the preceding one to three months. This study was undertaken to assess the association between tobacco smoking and periodontal disease by evaluating plaque score, gingival score, extent and severity index (ESI), and glycemic status by estimating serum HbA1c in cigarette smoker patients compared to non-smokers.

Methods: The study was conducted with 40 patients in the age range of 20–40 years. Patients were divided into two groups: non-smokers (Group I) and cigarette smokers (Group II). Periodontal clinical parameters such as the plaque index (PI), gingival index (GI), and ESI were recorded during the oral cavity examination. The biochemical marker, serum glycosylated hemoglobin, was measured in both groups. All parameters were measured at baseline and three months after periodontal therapy. The statistical tests used were the paired *t-test*, and *Chi-square* test for comparison between both groups.

Results: The mean difference of PI of non-smokers was 0.33 ± 0.30, and smokers were 0.52 ± 0.32, which was statistically significant. The mean difference of GI of non-smokers was 0.34 ± 0.19 and smokers 0.36 ± 0.303, which was statistically significant. The mean difference of extent in non-smokers was 5.33 ± 1.59, 5.52 ± 2.43, and smokers were 0.18 ± 0.17. The mean difference in severity in non-smokers was 0.18 ± 0.17, and smokers were 0.31 ± 0.25, which was statistically significant. The mean difference of HbA1c in non-smokers and smokers was 0.43 ± 0.277 and 0.415 ± 0.230, which shows a higher mean difference in non-smokers, which was statistically non-significant.

Conclusion and Global Health Implications: This study concluded that each of Group I and Group II showed substantial improvements in all clinical periodontal variables, which include plaque index (PI), gingival index (GI), extent and severity index (ESI), and biochemical marker serum glycosylated hemoglobin. Controlling inflammation with SRP can improve insulin resistance, lower glucose levels, and prevent non-enzymatic glycation of hemoglobin.

Keywords: Diabetes Mellitus, Glycosylated Hemoglobin, Periodontitis, Tobacco Smoking, Non-Smokers

INTRODUCTION

Background of the Study

As one of the most common non-communicable diseases, periodontal disease is caused by poor dental hygiene, smoking, stress, alcohol use, and systemic disorders.[1] According to the World

Health Organization (WHO), Non-communicable diseases (NCDs) accounted for 74% of the fatalities globally in 2019. Socioeconomic shifts are the primary cause of the global diabetes epidemic, with population expansion, bad eating habits, and a shift to a sedentary lifestyle also contributing risk factors.[2] Of the population of India, 77 million have prediabetes, and 62.4 million have type 2 diabetes mellitus.[3] The overall frequency of periodontal disease was 51%, and gingivitis was 46.6%. The average incidence of mild-to-moderate periodontitis was 26.2%, whereas severe periodontitis was 19%.[4]

The group of localized infections known as periodontal disease affects the tissues that support teeth and form the periodontium. Periodontal disease is a term that encompasses both irreversible (periodontitis) and reversible (gingivitis) processes. Inflammatory reactions to infections and damaging substances are undoubtedly the pathogenic basis of periodontal disease. It has been suggested that periodontal disease is the sixth complication of diabetes, and smoking has a negative impact on the clinical result of both nonsurgical and surgical therapy.[5,6] Glycated hemoglobin, or HbA1c, is a measure of the average blood glucose level over the two to three months prior and is used as an indicator of long-term glucose homeostasis.[7] Glycosylation, also referred to as glycation, is the non-enzymatic addition of carbohydrates to polypeptides and proteins that results in the creation of advanced glycated end products (AGEs).[8] It has been demonstrated, according to a number of researchers, that nicotine, which is present in cigarettes, increases blood sugar.[9] Through the alveoli, tobacco's most potent ingredient enters the lungs.[10] Nicotine is linked to increased insulin resistance, which impairs glucose tolerance, in addition to its direct toxic effect on pancreatic beta cells. In addition, nicotine's anti-estrogenic properties could increase the build-up of visceral adipose tissue, and consequently, insulin resistance. Finally, nicotine affects adiponectin, a peptide that controls body weight and food intake, as well as raising cortisol and inflammatory levels, all of which may lead to an elevated HbA1c. Nicotine has a strong addictive potential. Increased heart rate, blood pressure, respiration, and peripheral vasoconstriction can all result from it. This can then contract mouth capillaries, impacting gingival and periodontal tissue blood flow.[6] Studies have shown that smoking can exacerbate the negative effects of elevated HbA1c levels on periodontal health. Smoking combined with poorly controlled diabetes can create a more hostile oral environment, leading to more severe periodontal disease progression. Overall, there is a complex interplay between smoking, HbA1c levels, and periodontitis, with each factor influencing the others and contributing to the overall risk of developing periodontal disease. It is important for healthcare providers to consider these relationships when assessing and managing the oral health of individuals, especially those with diabetes who smoke.[11]

Objectives of the Study

The relationship between smoking and periodontal disease was explained in this study. Furthermore, it was aimed at assessing the degree of periodontal disease in patients, who did not smoke compared to smokers, by looking at their gingival index (GI) and plaque index (PI) scores, extent and severity index (ESI), and glycemic status by estimating serum HbA1c in non-smokers compared to cigarette-smoking patients.

METHODS

A total of 40 patients with an age range of 20–40 years were included in the study. Patients were divided into two groups: Group I included patients with chronic periodontitis who did not smoke, and Group II included patients with chronic periodontitis who smoked. A thorough explanation of the treatment approach was given to each patient, and both, verbal and informed written consent were obtained.

The inclusion criteria were: Patients with chronic periodontitis, who did not smoke and who smoked, who had not undergone any periodontal therapy in the six months prior to the study, in the age range of 20–40 years. The exclusion criteria were: The patients who had underlying systemic disease and were medically compromised.

***Clinical Procedure*:** Twenty patients were included in both groups. Root planning and scaling were administered to every patient in both groups at baseline. An ultrasonic scaler was used for supra- and subgingival scaling, and Gracey curettes were used for root planning. Oral hygiene instructions were given to patients in both groups. Patients were instructed to use a 0.2% chlorhexidine gluconate solution to rinse and brush their teeth twice a day. Every recall visit involved an evaluation of oral hygiene reinforcement. Each patient had a venous blood sample drawn from the antecubital fossa in order to test the baseline and three-month post-treatment HbA1c values. Patients in the smoking group were urged to stop smoking, and instructions were given to maintain oral hygiene. Before and after non-surgical periodontal treatment, patients were scheduled for periodontal examinations and laboratory.

Ethical Approval

The study was conducted in the Department of Periodontology at Seema Dental College & Hospital in Rishikesh, Uttarakhand, India, with approval from the institutional ethical committee

2016/A-115 dated December 12, 2016. The duration of the study was three months.

Statistical Analysis

The obtained data was recorded in Microsoft Excel 2019, and statistical analysis was conducted with the Statistical Package for the Social Sciences (SPSS) version 25 (SPSS, Inc., Chicago, IL, USA) software. Descriptive analyses, i.e., the mean and standard deviations (SDs), were calculated for GI, PI, ESI, and serum glycosylated hemoglobin. The statistical tests used were paired *t-test, and Chi-square* test for comparison of both groups.

The sample size was calculated, and the study took into account the 95% confidence interval (CI) and 95% power. In order to obtain 80% power and 5% significance, a sample size of 40 was determined.

Study Variables

Clinical and Biochemical Parameters Assessed: The following parameters were evaluated at baseline and three months after starting periodontal therapy: PI described by Silness and Loe in 1964,[12] GI, described by Loe and Sillness in 1963,[13] ESI, described by Carlos in 1986[14] were assessed for both groups. Serum levels of glycosylated hemoglobin were assessed in both groups. All the parameters were assessed at baseline and at three months.

RESULTS

Demographic Details

The mean age with a standard deviation of non-smokers was 37 ± 2, and for smokers, it was 40 ± 2 with a *P*-value ≥0.05, which was statistically non-significant. There was no statistically significant difference in gender between the two groups, as shown in Table 1.

Clinical Parameters Results

Plaque Index: The mean values of PI in non-smokers at baseline was 1.87 ± 0.49 and at three months, 1.54 ± 0.31 with a mean difference of 0.33 ± 0.30, which was statistically significant with a *t* value of 4.939 as shown in Table 2. The mean values of PI in smokers at baseline was 2.25 ± 0.363 and at three months, 1.72 ± 0.28 with a mean difference of 0.52 ± 0.32, which was statistically significant with a t value of 7.12, as shown in Table 2. The mean difference of PI in non-smokers and smokers was 0.332 ± 0.3006 and 0.52 ± 0.32, respectively, which shows a higher mean difference in smokers with a *t* value of -1.919, which was statistically non-significant.

Table 1: Demographic details in Group I and Group II.

Variable	Non-smokers	Smokers	Mean	*p*-value
Age (Mean ± SD)	37 ± 2	40 ± 2	38.5 ± 2	≥0.05*
Gender (Male: Female)	15:13	17:14	16:13	≥0.05*

SD-Standard deviation.
**p*-value - non-significant.

Gingival Index: The mean values of GI in non-smokers at baseline was 2.23 ± 0.29 and at three months, 1.88 ± 0.36 with a mean difference of 0.34 ± 0.19, which was statistically significant with a *t* value of 7.85 as shown in Table 2. The mean values of GI in smokers at baseline was 1.94 ± 0.407 and at three months, 1.58 ± 0.27 with a mean difference of 0.36 ± 0.303, which was statistically significant with a t value of 5.327, as shown in Table 2. The mean difference of GI in non-smokers and smokers was 0.348 ± 0.198 and 0.36 ± 0.303, respectively, which shows a higher mean difference in smokers with a *t* value of -0.167, which was statistically non-significant.

Extent: The mean values of extent in non-smokers at baseline was 84.20 ± 11.62, and at three months, 78.87 ± 11.69 with a mean difference of 5.33 ± 1.59, which was statistically significant with a *t* value of 14.9 as shown in Table 2. The mean values of extent in smokers at baseline was 90.64 ± 6.61 and at three months 85.12 ± 7.22 with a mean difference of 5.52 ± 2.43, which was statistically significant with a *t* value of 10.16 as shown in Table 2. The mean difference of extent in non-smokers and smokers was 5.33 ± 1.59 and 5.527 ± 2.43, respectively, which shows a higher mean difference in smokers with a *t* value of -0.303, which was statistically non-significant.

Severity: The mean values of severity in non-smokers at baseline was 3.52 ± 0.53, and at three months, 3.33 ± 0.54 with a mean difference of 0.18 ± 0.17, which was statistically significant with a *t* value of 4.949 as shown in Table 2. The mean values of severity in smokers at baseline were 4.01 ± 0.61 and at three months, 3.70 ± 0.57 with a mean difference of 0.31± 0.25, which was statistically highly significant with a t value of 5.53, as shown in Table 2. The mean difference of severity in non-smokers and smokers was 0.188 ± 0.170 and 0.313 ± 0.253, respectively, which shows a higher mean difference in smokers with a *t* value of -1.831, which was statistically non-significant.

Biochemical Parameter Result

Serum Glycosylated Serum: The mean values of HbA1c in non-smokers at baseline was 5.43 ± 0.39 and at three months, 5.005 ± 0.27 with a mean difference of 0.43 ± 0.27, which was

Table 2: A statistical comparison of the mean values of clinical periodontal parameters at different intervals between Group-I (non-smokers) and Group-II (smokers).

Parameter	Non-smokers					Smokers			
	Different interval	Mean ± SD	Mean difference	t	*p*-value	Mean ± SD	Mean difference	t	*p*-value
Plaque index	Baseline	1.87 ±0.50	0.33 ±0.30	4.939	**≤0.001***	2.25±0.363	0.52 ± 0.32	7.12	**≤0.001***
	3 months	1.54 ±0.31				1.72 ±0.28			
Gingival index	Baseline	2.23 ±0.29	0.34 ± 0.20	7.85	**≤0.001***	1.94 ±0.407	0.36 ± 0.303	5.327	**≤0.001***
	3 months	1.88 ±0.37				1.58 ±0.27			
Extent	Baseline	84.20±11.63	5.33 ± 1.59	14.9	**≤0.001***	90.64 ±6.61	5.52 ± 2.43	10.16	**≤0.001***
	3 months	78.87±11.69				85.12 ±7.22			
Severity	Baseline	3.52 ± 0.53	0.18 ± 0.17	4.949	**≤0.001***	4.01 ±0.61	0.31 ± 0.25	5.53	**≤0.001***
	3 months	3.33 ± 0.55				3.70 ±0.57			

SD - Standard deviation.
*p-value – significant.

Table 3: Comparing the means of clinical periodontal markers and HbA1c at different time points between the smokers and non-smoker groups.

Parameter	Non-smokers					Smokers			
	Different interval	Mean ± SD	Mean difference	t	*p*-value	Mean ± SD	Mean difference	t	*p*-value
Glycosylated hemoglobin	Baseline	5.43 ± 0.40	0.43 ± 0.27	6.89	<0.001*	5.95 ± 0.604	0.40 ± 0.23	8.069	<0.001*
	3 months	5.005 ± 0.27				5.53 ± 0.457			

SD - Standard deviation,
*p-value – significant.

statistically highly significant with t value of 6.93 as shown in Table 3. The mean values of HbA1c in smokers at baseline was 5.95 ± 0.604, and at three months, 5.53 ± 0.457 with a mean difference of 0.41 ± 0.23, which was statistically highly significant with a t value of 8.068 as shown in Table 3. The mean difference of HbA1c in non-smokers and smokers was 0.43 ± 0.277 and 0.415 ± 0.230, respectively, which shows a higher mean difference in non-smokers with a t value of 0.186, which was statistically non-significant.

DISCUSSION

Glycohemoglobin is created when the amino groups of the lysine and valine residues of hemoglobin combine with glucose through a non-enzymatic process. The amount of the protein glycohemoglobin in red blood cells is determined by blood glucose levels because it is an irreversibly generated protein.[15] In this study, baseline and three-month glycemic status were measured for non-smokers and smokers, with smokers having higher mean values. Forty patients in the age range from 20 to 40 years were divided into two groups: non-smokers and smokers. Non-surgical periodontal therapy was administered to each patient in both groups. The clinical indicators were measured at baseline and three months after the initiation of periodontal therapy. These indicators allow for the monitoring of past periodontal destruction, ongoing illness, and the prognosis of disease development, which makes them essential for treatment planning and outcome evaluation. In both groups, serum levels of glycosylated hemoglobin were measured at baseline and three months after periodontal therapy. Smoking affects the efficacy of active periodontal therapy and has a detrimental effect on treatment outcomes. Smokers had lower gingival scores because nicotine increases vasoconstriction of peripheral blood vessels and reduces the clinical indications of gingival inflammation.

Indurkar recorded the clinical results of non-surgical periodontal therapy in patients with chronic periodontitis and concluded a decline in PI and GI scores over a six-week period.[16] Three months following non-surgical periodontal therapy, this study demonstrated a significant reduction in both PI and GI in non-smokers. A decrease in the non-smokers' scores did not seem to have any statistically significant impact on PI or GI when the mean difference between the groups was evaluated. Aziz *et al.* evaluated the effects of scaling and root planing in the short term on clinical parameters and systemic inflammatory and oxidative stress markers in smokers and non-smokers.[17] The findings demonstrated that compared to non-smokers, smokers had greater rates of systemic inflammation and oxidative stress, as well as periodontal damage. This finding suggests that non-smokers maintained optimal hygiene throughout the course of the study. The ESI was used in the study to evaluate the degree and severity of periodontal disease in smokers and non-smokers. Since the ESI had not been thoroughly investigated, the findings have been contrasted with those of similar studies. Carlos *et al.* and Thomson *et al.* discovered that the level of periodontal damage was significantly higher in smokers.[14,18] Carlos *et al.* assessed the extent and severity indexes of 369 persons, aged 17–32 years. For each damaged site, 22% of the research locations had attachment loss with a mean severity of 1.48 mm. The severity and scope of the illness had considerably worsened, both over the preceding three years and when the condition was re-examined about three years later.[14]

In this study, the glycemic status of smokers and non-smokers was measured at baseline and three months later, with smokers showing higher mean values. According to Ohkuma *et al.,* the amount of cigarettes smoked each day and the rise in glycosylated hemoglobin were correlated in a dose-response manner.[15,19] Glycated hemoglobin in both groups decreased statistically significantly three months after non-surgical periodontal therapy, according to a study by Vaghani *et al.*[20] Before and after non-surgical periodontal therapy, the levels of glycosylated hemoglobin in healthy individuals and those with periodontitis were compared by Muthu *et al.*[21] and Vaghani *et al.*[20] After three months of non-surgical periodontal therapy, patients with periodontitis showed significantly lower levels of glycosylated hemoglobin. When Muthu *et al.* examined the impact of non-surgical periodontal therapy on glycemic control in patients with periodontitis, they found that their HbA1c was higher than that of healthy controls.[21] Three months after the initiation of periodontal therapy, HbA1c levels dropped, and periodontal parameters improved. According to a Verma study, there was no statistically significant difference in the mean HbA1c values between cigarette and bidi smokers and no correlation between the smoking index and HbA1c.[22] Nevertheless, Group II (smokers) reported a statistically significant decrease in HbA1c three months following non-surgical periodontal therapy.

In a 2013 study, Jyothirmayi *et al.* examined the relationship between glycated hemoglobin levels and cigarette smoking and concluded a correlation between the two.[10] When evaluating the impact of cigarette smoking on the severity of periodontitis in older Thai individuals, Torrungruang *et al.* found a similar conclusion; those who had smoked in the past were more likely to have severe periodontitis than non-smokers.[23] Ali *et al.* evaluated the clinical parameters PI, GI, probing depth, and clinical attachment level in order to compare smokers and non-smokers. The author concluded that smokers had lower GI index scores and more plaque.[24] A study by Urberg *et al.* found that smoking negatively affects plasma glucose levels. The author concluded that smokers had higher average blood glucose than non-smokers when they compared the levels of glycosylated hemoglobin in patients who smoked one pack or more per day with those of non-smokers.[25]

The decline in the non-smokers' assessments on PI or GI did not seem to have any statistically significant impact based on the mean difference between the groups. This implies that non-smokers maintained optimal levels of hygiene throughout the study. Because of this, bacteria were able to multiply and survive in the intricate biofilm ecology while generating a range of virulence factors that allow them to evade the host immune system and cause the destruction of human periodontal tissues.[26] Consequently, periodontal disease diagnosis and therapy were necessary for the management of patients who were susceptible to periodontitis.[27,28] In order to validate the findings of this investigation, further comprehensive research utilizing a larger sample size and follow-up was necessary. Christine Patramurti proposed that the interaction between the number of cigarettes smoked and smoking duration was strongly and independently connected with the risk of T2DM in smokers, as demonstrated by HbA1c.[29] Smoking affects the periodontium in healthy people, but it exacerbates the damage in smokers with diabetes, despite the minimal influence of diabetes on periodontium health.[30]

CONCLUSION AND GLOBAL HEALTH IMPLICATIONS

The outcomes of this study showed that both groups' clinical periodontal parameters and blood glycosylated hemoglobin levels improved following non-invasive periodontal therapy. Compared to the smoking group, the non-smoking group had better treatment outcomes. Controlling inflammation with SRP can improve insulin resistance, lower glucose levels, and prevent non-enzymatic glycation of hemoglobin.

Key Messages

- The interplay between tobacco smoking, glycosylated hemoglobin, and periodontal health underscores the importance of addressing smoking cessation to mitigate the risk of periodontal diseases, particularly in individuals with diabetes.
- The periodontal therapy outcomes are affected in both non-smokers and smokers with chronic periodontitis
- Tobacco smoking has a detrimental effect on periodontal health, as evidenced by a significant correlation with an increase in serum glycosylated hemoglobin levels.

- The elevated levels of glycosylated hemoglobin indicate compromised glycemic control, exacerbating the inflammatory response in periodontal tissues.

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COMPLIANCE WITH ETHICAL STANDARDS

Conflicts of Interest

There are no conflicts of interest.

Financial Disclosure

Nothing to declare.

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Ethics Approval

The research/study was approved by the Institutional Review Board at Seema Dental College, number 2016/A-115, dated December 12, 2016.

Declaration of Patient Consent

The authors certify that they have obtained all appropriate patient consent.

Use of Artificial Intelligence (AI)-Assisted Technology for Manuscript Preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

Disclaimer

None.

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(57) Abstract :
One of the most common non-commutable types of chronic inflammatory disease is Periodontitis. It is the sixth most common disease affecting nearly 750 million population worldwide every year. It is very important to treat such Intrabony Osseous Defects, as if left untreated, it may lead to increased risk of disease progression sometimes leading to loss of teeth. Research studies suggest that piezoelectric surgical instruments with accurate precision would provide correct prediction of periodontal osseous defects. Any immediate reduction in periodontal dental angulation could be detected by bone swaging. Proposed is a System and Method to Detect the Depth of Intrabony Osseous Defect using Machine Learning. Input Cone Beamed Computed Tomography (CBCT) which provides inter-relational images in three orthogonal planes namely axial, sagittal and coronal and also customized planes are subject to Image Pre-Processing. Images are converted to Gray Scale and Binarization of images is carried out using Social Edge Detection to increase the object recognition rate. Target object recognition is trained using Convolutional Neural Networks. Multiclass Classifier and Bounding Box Regressor employed for each convolutional and pooling layers for accurate detection of depth of intrabony osseous defects.

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Review Article

Piezosurgery in periodontology

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ABSTRACT

Piezosurgery is a relatively new method derived from the Greek term "piezein" which means "to press tight or to squeeze". Tomaso Vercellotti an italian physician invented it. He teamed up with Mectron Medical Technology, a medical device company was founded by Italian engineers Fernando Bianchetti and Domenico Vercellotti. It is a technique conceived to overcome the limitations of traditional bone cutting instruments in order achieve the most effective treatment with minimal amount of morbidity. It is used for bone removal and bone recontouring procedure on the principle of ultrasonic vibration. Piezoelectric effect generates an electrical charge when subjected to mechanical stress.

1. Introduction

Over the past years dentistry has underwent lots of advancement in day to day life. Various diagnostic imagining technique such as Ultrasonography, Cone Beam Computed Tomography, LASERS, Implants, Microsurgery and Nanotechnology had made the dentistry front runners in the medical field. Traditionally, osseous surgery has been performed with hand instruments (chisel, osteotome or mallet) or various motorized equipment that can be powered by air pressure or electrical energy. Manual hand cutting instruments take much longer time to yield desired results and often difficult to apply in many osseous surgical procedures. Motorized devices have rotary, reciprocal or oscillatory movements that have certain disadvantages such as: necrosis occurs due to overheating of bone tissue; loss of perceptivity to a gentle touch due to pressure on the handpiece; cutting depth is difficult to determine; iatrogenic impairment in undesirable areas due to a failure in the accurate adjustment of the speed of a rotating head or saw; and the risk of soft tissue injury to important anatomical structures such as the inferior alveolar nerve or the maxillary sinus.[1]

2. Objectives

To overcome the limitation of traditional instruments, researchers have surpassed advanced therapeutic devices that function on the idea of ultrasonic microvibrations to cut bone precisely in harmony with the surrounding tissue.[2]

Rationale of the study is to delinate the piezosurgery invention, its indication and contraindication, armamentarium, application of piezosurgery in periodontology and its limitation.

3. Piezosurgery

Piezosurgery is a method used for bone removal and bone recontouring that uses the principle of ultrasonic vibration. The word "piezo" derived from the Greek word piezein which means "to press tight or to squeeze."[3] The Piezoelectric effect is the property of certain materials to

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produce an electrical charge in response to an applied mechanical stress. It was innovated in 1988 by Professor Tomaso Vercellotti and was developed by Mectron Medical Technology.[4] He proposed the idea of using sharpened instruments fitted on ultrasonic device for ablation to perform peri radicular osteotomy to extract an ankylosed tooth. Vercellotti et al. (2000) have revised this method for nerve and soft tissue protecting surgery that has overcame the limitations of traditional instruments in oral bone surgery. Mectron (2000) developed the first generation piezosurgery device.[5,6]

4. Historical Background

Piezoelectrical device was first discovered in 1880 by Jacques and Pierre Curie. They found that applying pressure to different crystals, ceramics, and bone produces electricity. In 1881, Gabriel Lippmann found the converse piezoelectric effect.[7] In 1927, Wood and Loomis explained the physical and biological impacts of high frequency soundwaves.[8] Pohlman used ultrasound on human tissues to treat myalgias and neuropathic pain in 1950.[9,10] In the same year, Maintz demonstrated a beneficial effect on bone regeneration and healing.[11] In 1952, Blamuth introduced an ultrasonic device which was used in dentistry for cavity preparation.[12] Catuna was the first person to use ultrasound in the field of dentistry specifically for preparing dental cavities. This resulted in the introduction of high-speed rotary instruments. In 1955, Zinner introduced the first ultrasonic scalers in periodontal procedures. Richman MJ was the first to disclose the surgical use of an ultrasonic chisel without slurry to remove bone and resect roots in apicoectomies in 1957.[13] Mcfall TA et al in 1961 evaluate distinction of healing by comparing of rotating instruments and oscillating scalpel blades and found a slow healing with no severe complications by use of these scalpel blades.[14] Horton JE et al in 1980 ultrasonic devices improves bone regeneration.[15]

In 1997, Vercellotti was the first who introduced the use of an ultrasonic device for ablation fitted with a sharpened insert, such as a scalpel blade, to perform periradicular osteotomy to extract an ankylosed root of a maxillary canine. Piezosurgery an ultrasound device in 1998 was introduced in medical field by Vercellotti for different procedures such as for hard tissue surgery. In 1999, Tomaso Vercellotti invented Piezoelectric bone surgery in collaboration with Mectron Spa and published about this topic in year 2000.[16]

In 2000, Vercellotti et al. renewed the approach for nerve and soft tissue protecting surgery to overcome the limitations of traditional instruments in oral bone surgery. It was first reported for pre-prosthetic surgery, alveolar crest expansion, and sinus grafting. Mectron developed first generation piezosurgery device in 2000. Vercellotti et al developed a suitable device for routine work in oral surgery that replaced conventional osteotomy instruments in 2001. The first sinus lift and bone block grafting surgeries employing piezosurgery was performed in 2001 and 2002. In 2003, Vercellotti used piezosurgery in animal studies to compare its traumatic impact with that of traditional orthopaedic surgery and reported that it allows for more accurate cuts and a clearer view of the operative field.

In 2004, Mectron introduced Second generation of piezosurgery device. Ultrasonic osteotomy was utilised to relocate the inferior alveolar nerve (IAN) by Bovi in 2005.

The same year first implant site preparation was performed by using piezosurgical device. In the same year, the US Food and Drug Administration extended the use of ultrasonics in dentistry to encompass bone surgeries.[17] In 2006, first ultrasound osteotomy in hand surgery was performed by Hoigne et al.[18] Third generation piezosurgery device was introduced in 2009, and a clean, precise technique of harvesting bone grafts from mandibular ramus was given by Happe A.

5. The Piezosurgical Armamentarium

Piezoelectric devices consists of:

5.1. *Main body*

Display screen, electronic touchpad, peristaltic pump, stand for handle, and stand for irrigation fluid bag are the constituents of the main body. For selecting the operating mode, particular programme, and coolant flow, the interactive touchpad comprises four keys. Every command is displayed on the screen.[18]

The main unit has three different power levels:[19]

1. Low Mode: It is utilised for orthodontic treatment and apico-endo-canal cleaning procedures
2. High Mode: It is used to clean and smooth the radicular surfaces
3. Boosted Mode: Is used in bone surgeries, osteotomy and osteoplasty procedures.

5.2. *Peristaltic pump*

Peristaltic pump contains an irrigation solution that flows at an adjustable rate of 0–60 ml/min to cool the cutting area and remove debris. The solution is refrigerated at 4°C to provide a cooling effect, and the volume of liquid can be adjusted with the + and - buttons.

5.3. *Hand piece*

Piezosurgical device consist of two hand pieces. The handpiece is firmly connected to the cord, which may be sterilised together.[20]

5.4. Handle

The cutting action is based on ultrasonic waves that travelling via piezoelectric ceramic within. These ceramic plates are created by an external generator and alter in volume to produce ultrasonic vibrations. They are channelled into the amplifier, which transmits them to the handle pointed end. A specific key is used to clamp the insert for this function.In this manner, the optimum efficiency for cutting and insert duration is accomplished.[21]

5.5. Foot pedal

Handpiece is controlled by an adjustable pedal on the base.

5.6. Base unit

The power is supplied by the base unit which also have the holder for handpiece and irrigation fluids. The device has display that allows the operator to select between the BONE cutting mode and ROOT operating modes. Using a specific selection for the type or density of the bone, the BONE cutting mode is utilised to cut bone. For endodontic and periodontal root treatments, the ROOT mode is utilised to shape, clean and smooth the root surfaces.

5.6.1. Bone mode

Bone mode are characterized as extremely high ultrasonic power compared to root mode.[22] Its performance is monitored by several advanced software and hardware controls. Due to excessive frequency modulation, mechanical ultrasonic vibration are unique for cutting different kinds of bone.

The selection recommended are:[23]

1. Quality 1: Cutting cortical bone or high density cancellous bone.
2. Quality 3: Cutting low density cancellous bone.

5.6.2. Root mode

The vibrations generated by selecting root mode have an average ultrasonic power without frequency over modulation.[22]

Root operating mode consists of two different programs:[23]

1. Endo program: A limited level of power provided by applying a reduced electrical tension to the transducer, which generates insert oscillation by a few microns. These mechanical micro-vibrations are ideal for irrigating the apical part of the root canal in endodontic surgery.
2. Perio program: An intermediate power level between the endo program and the bone program. The ultrasonic wave is continuosly transmitted through the transducer in a continuous sinusoidal manner, characterized by a frequency equal to the resonance frequency of the insert used.

A special program is designed with a slightly lower standard power than the bone programs has the same frequency over modulation. A special program is dedicated to a limited series of particularly thin and delicate surgical insertstips. These are only recommended for surgeons experienced in piezosurgery and who want an extremely thin and efficient incision.

5.6.3. Inserts tips

The Mectron Medical Technology has developed the design and function of all insert tips used in Piezoelectric bone surgery. Taking into account morphological-functional and clinical factors, the inserts tips have been defined and organized according to a dual classification system.

Various insert tips are classified as:

5.7. According to insert tip coating:[20]

1. Titanium Nitride coated tips are effective in osteoplasty procedure and for harvesting of bone chips as they provide maximum cutting efficiency, resist corrosion and last longer.
2. Diamond coated tips are used for osteotomy of thin bone and/or proximity to anatomic structures.

   They are classified as follows:

   (a) Sharp Insert tips are designed for maximum cutting efficiency and are used for osteoplasty procedures and to harvest bone chips.
   (b) Smooth Insert tips have diamond coated surfaces that enables precise and controlled work on the bone structures. They are used in osteotomy procedures to prepare difficult and delicate structures such as preparation of the sinus window and/or nerve access.
   (c) Blunt Insert tips are used for preparing soft tissues, e.g., elevation Schneider's membrane and/or, lateralization of the inferior alveolar nerve. In periodontics, these tips are used for root planing.

5.8. According to insert tip color

1. Gold Insert tips are utilised specifically for bone surgery. The gold color of the insert tips is obtained from the titanium nitride which improves the hardness of the surface for longer working life.[24]
2. Steel Insert tips are used specifically for treating soft tissue and/or delicate tooth structures (roots of teeth).[25]

5.9. Clinical classification

Clinical classification comprises insert tips (sharp, smooth, blunt) based on surgical techniques such as osteotomy,

osteoplasty, extraction.[26]

1. Osteotomy OT - OT1, OT2, OT3, OT4, OT5, OT6, OT7, OT7S4, OT7S3, OT8R/L
2. Osteoplasty OP - OP1, OP2, OP3, OP4, OP5, OP6, OP7
3. Extraction EX - EX1, EX2, EX3
4. Implant site preparation IM - IM1(OP5 -IM2A-IM2P OT4-IM3A-IM3P
5. Periodontal Surgery PS - PS2-OP5-OP3-OP3A- Pp1
6. Endodontic Surgery EN - OP3-PS2-EN1-EN2-OP7
7. Sinus Lift- OP3-OT1-OP5 - EL1-EL2-EL3
8. Ridge Expansion- OT7-OT7S4-OP5- IM1 -IM2-OT4 -Im3
9. Bone Grafting- OT7, OT7S4, OP1, OP5
10. Orthodontic Microsurgery- OT7S4-OT7S3

5.9.1. Indications

1. Implantology:[26]
   (a) Implant site development (socket preparation)
   (b) Splintting and expansion of the alveolar ridge
   (c) Alveolar crest recontouring
   (d) Mental nerve repositioning
   (e) Distraction osteogenesis with subsequent implant placement
   (f) Retrieval of blade implants
   (g) Placement of implants
   (h) Harvesting block grafts
2. Maxillary sinus bone grafting surgery:[26]
   (a) Creating lateral bone window
   (b) Sinus mucosa atraumatic dissection
   (c) Elevation of internal sinus floor elevation
3. Periodontal treatment procedures:[26]
   (a) Supragingival and subgingival scaling
   (b) Irrigation of periodontal pockets
   (c) Crown lengthening
   (d) Soft tissue debribement
   (e) Resective and regenerative surgerical procedure
4. Others:[27]
   (a) Retrograde root canal preparation
   (b) Apicectomy
   (c) Cystectomy
   (d) Extraction
   (e) Tooth extraction with osteogenic distraction Ankylosed tooth
   (f) Extraction
   (g) Orthodontic surgery
   (h) Removal of cyst

5.10. Contraindications[28]

No absolute contraindications

1. Patients or the clinician with electrical implants such as pacemakers.
2. Certain systemic diseases such as cardiovascular diseases, diabetes and bone disease or in patients undergoing radiotherapy, all of which can hinder the dental implant surgery.
3. Alterations that may or may not be related to systemic diseases, bone structure and vascularization.
4. Behaviours such as smoking and excessive drinking.

6. Application of Piezosurgery in Periodontology

6.1. Scaling and root planing

The piezosurgery device is used to remove supragingival and subgingival calculus as well as stains from teeth. It has been discovered that employing cavitation alone without the touch of the vibrating tip is insufficient for removing the calculus; direct contact between the vibrating tip and the calculus is required. The piezosurgery ultrasonic scaler, set to function On/Mode Periodontics (ROOT), with the insert PS1 and PP1, is used for deposit removal on all tooth surfaces for 15 seconds at a medium power of two. Parallel movements were used, with working strokes perpendicular to the tooth axis.[29]

Busslinger et al.[30] conducted a study to compare magnetostrictive and piezoelectric devices and found a substantial difference in time required. The SEM pictures after instrumentation were utilised to compare the four groups. SEM examination of tooth surface roughness revealed that the C100 group had a smoother surface than the C200 group and that the P100 group had a smoother surface than the P200 group, although the difference was not significant. The difference between the C200 and P200 groups was statistically significant. According to Santos et al[31] there were no changes in the results of magnetostrictive and piezoelectric devices uder SEM.

6.2. Curettage

When compared to manual tools, a piezosurgery device is employed for debridement of the epithelial lining of the pocket wall, resulting in microcauterization and removal of root calculus by employing thin tapered tips with an adjusted power setting.[32]

6.3. Clinical crown lengthening

Raising a full-thickness flap, conducting an ostectomy with manual instruments, osteoplasty with a bur for crest bone architecture recontouring, periradicular bone removal, root planing, and ultimately restoring the flap in an apical position are all part of the conventional surgical approach. The crown lengthening procedure done with piezosurgery for successful bone reduction while maintaining root surface integrity.[33,34]

A controlled clinical split mouth study was conducted by Dayoub ST et al[35] to evaluate the clinical results of a minimally invasive flapless method versus an open-flap approach in aesthetic crown lengthening for the treatment of gingival smile up to three months following piezoelectric bone surgery. The study demonstrated that utilising piezosurgery in bone resection is successful with both surgical techniques and resulted in a considerable increase in clinical crown length as compared to baseline. They concluded that the minimally invasive flapless approach and piezosurgery provide alternatives to traditional procedures of aesthetic crown lengthening.

6.4. Resective surgery

In comparision to other instruments, the piezosurgery device is beneficial in periodontal surgery. After the primary flap is raised during resective surgery the device makes it simpler to accompany with the secondary flap and remove the inflammatory granulation tissue. This process results in minor bleeding but by applying the proper ultrasonic vibration, bleeding is prevented.

6.5. Periodontally accelerated orthodontics

Small vertical bone incisions between the teeth were done as part of the periodontally accelerated orthodontics procedure that allows more expedient orthodontic movement. With acceptable levels of pain and discomfort, the corticotomy procedure conducted with a piezosurgical equipment reduce the treatment duration by 60 to 70%. For selective alveolar corticotomies using the Peizosurgical device, surgical control was reported to be simpler than with traditional surgical burs.[36]

6.6. Block harvesting technique

Traditional rotary cutting instruments for bone block harvesting reduce the width of the cortical bone by at least 1 mm circumferentially and are unable to cut the internal cancellous bone effectively. Piezosurgery provides high accuracy and operational sensitivity, as well as simple distinction between cortical and cancellous bone while removing blocks of monocortical cancellous bone.[37]

6.7. Autogenous bone grafting

Due to absence of osteocytes and prevalence of non-vital bone, utilising manual or motor-driven devices for bone surgery may not be suited for grafting. The Piezosurgery inserts tips that are used for bone harvesting process creates a vibration with a width of 60 to 210 in an oscillation controlled module. In contrast to rotary burs or reciprocating saws, the utilisation of ultrasonic vibration creates controlled osteotomies by micrometric bone slices.

6.8. Osteoplasty and bone grafting

Piezosurgical device enables gentle scrubbing of the bone surface in order to obtain appropriate amount of graft material and can be used for gafting infrabony defects.

The function of the bony chips that are obtained vary with size

1. Small size chips aids in early remodelling
2. Larger size chips particles provide mechanical support and act as scaffold for bone growth.

7. Limitations

1. Difficulty to perform the deeper osteotomies.
2. Requires longer time for bone cutting or preparing osteotomy site than traditional cutting instruments.
3. Have longer and different learning curve.
4. Technique sensitive.

8. Conclusion

When compared to traditional rotational devices, ultrasound application to hard tissue is considered a slow procedure. Because it necessitats specialised surgical abilities associated with a certain learning curve. When compared to conventional procedures and soft tissues, piezosurgery is an advanced and conservative approach. Because, device precisely cuts bone, significant nerve damage may be avoided, and minimally invasive operations are conceivable. Using the fine tip enables curved cutting and provides an opportunity for new osteotomy technique. Predictability, Less Postoperative Pain, And Increased Patients Compliance are three P's of piezosurgery.

9. Source of Funding

None.

10. Conflict of Interest

None.

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Review Article

Current Concepts in Alveolar Ridge Augmentation

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Abstract

Ridge augmentation is a predictable procedure that can correct the defects caused by bone loss in areas with missing teeth. More importantly, this procedure allows the chance to return the natural contours of the soft tissues that existed before the loss of the tooth. It is done in patients with insufficient bone height and width by using various bone substitute materials and bone graft procedures where the successful placement of dental implants is difficult with regards to maintaining an ideal pathway and avoiding important anatomical structures. This review article will be carried out to describe the various techniques of ridge augmentation.

Keywords: Ridge Augmentation; Deficient Ridge; Hard and Soft Tissue Ridge Augmentation

Introduction

Periodontium is an important structure that provides support to the tooth necessary to maintain its function and is affected by any changes that the tooth may undergo, including eruption and extraction [1]. It consists of four principal components which includes gingiva, periodontal ligament, cementum and alveolar bone. Healing process occurring post extraction follows uneventful changes in the alveolar bone causing structural and dimensional changes in the overlying soft tissue [2]. These changes can occur in horizontal and vertical dimensions or both and may hamper with the functional and aesthetic success of prosthetic replacements including implants [3].

The predictability and technical difficulty of surgically reconstructing the ridge can be guided by classifications of ridge defects which are helpful to appreciate treatment modality chosen. According to Glossary of Prosthodontic Terms (GPT) 2009, Ridge augmentation is defined as a procedure designed to enlarge or increase the size, extent or quality of a deformed residual ridge [4]. Ridge augmentation is intended to augment the alveolar ridge volume beyond the existing skeletal envelop on the edentulous site of a deficient alveolar ridge with the variety of materials and techniques to optimize the ridge profile, to re-establish inter maxillary ridge correlation, confirm esthetic outcomes, achieve the biomechanical requisite of the prosthesis and to confirm osseointegration and persistence of Implant. The purpose of soft tissue preservation and bone formation is to provide stability and support for the future dental prosthesis. The sufficient horizontal as well as vertical bone dimensions are a prerequisite to warranty the success of implants.

Techniques For Ridge Augmentation

Ridge augmentation procedures are divided into vertical or horizontal ridge augmentation, which are performed simultaneously and are broadly classified into surgical procedures which undertakes hard tissue procedures, soft tissue procedures and both. Particulate or block autogenous bone grafts with ridge splitting or ridge expansion combined with Guided Bone Regeneration (GBR) are widely used in horizontal ridge augmentations. The outcomes and success rates are more predictable and higher when compared to vertical ridge augmentation. The reconstruction amount has an average 3 to 4 mm target in horizontal ridge

augmentations [5]. Historically, onlay grafts are performed as GBR with particulate or block type autogenous bone grafts in vertical augmentation which involves reconstruction of one wall defects.

1. Socket Preservation

Socket grafting is a preventive procedure for socket preservation at the time of extraction, which does not inhibit the resorption but limits it [6]. The minimal amount of resorption happens after socket grafting but in a predictable manner and the magnitude of volume loss is less in the grafted socket versus the naive socket. The rationale is that it should be performed in aesthetic areas in case of buccal bone thickness ≤2 mm or when there is a proximity to anatomic structures, i.e., maxillary sinus or mandibular canal [7].

2. Hard Tissue Augmentation Procedures

a. Guided Bone Regeneration

The application of GBR was described in 1988 by Dahlin, et al., in an experimental study on animals to see the results of healing of bone defects in which the defect on one side of the jaw was covered with a porous Polytetrafluoroethylene (PTFE) membrane and the other side served as the control, without a membrane covering [8]. The results showed that there was increase in bone regeneration on the membrane side as compared to the control after 3, 6 and 9 weeks of healing. GBR, also known as guided bone regeneration, is an evidence based predictable approach for separating the bone graft material (usually particulate) from neighboring soft tissues to allow unimpeded bone formation. The graft material is covered by securing a membrane to stabilize the material, parting it from adjacent connective tissues and limiting resorption. The volume stability of the graft in defect is the main factor on which the choice of membrane depends. Osseous regeneration by GBR depends on the migration of pluripotent and osteogenic cells (e.g. osteoblasts derived from the periosteum and/or adjacent bone and/or bone marrow) to the bone defect site and exclusion of cells impeding bone formation (e.g. epithelial cells and fibroblasts) [8-11]. There are few principles which need to be met to ensure successful GBR: Cell exclusion in which the barrier membrane is used to prevent gingival fibroblasts and/or epithelial cells from gaining access to the wound site and forming fibrous connective tissue; Space maintenance (Tenting) in which the membrane is carefully fitted and applied in such a manner that a space is created beneath the membrane which completely isolates the defect to be regenerated from the overlying soft tissue and also the membrane should be trimmed so that it extends 2 to 3 mm beyond the margins of the defect in all directions. The corners of the membrane should also be rounded to prevent inadvertent flap perforation; Scaffolding is one of the principles of GBR in which tented space initially becomes occupied by a fibrin clot, which serves as a scaffold for the in-growth of progenitor cells; Stabilization in which the membrane must protect the clot from being disturbed by movement of the overlying flap during healing and then fixed into position with sutures, mini bone screws or bone tacks. The edges of the membrane are simply tucked beneath the margins of the flaps at the time of closure, providing stabilization; Framework is necessary in cases of dehiscences or fenestrations where the membrane must be supported to prevent collapse [12]. Bone regeneration follows a specific sequence of events after GBR procedures. After the bone graft, the graft material/barrier created space is filled with the blood clot within the first 24 hours, which releases growth factors (e.g., platelet derived growth factor) and cytokines (e.g., IL-8) to attract neutrophils and macrophages. The clot is absorbed and replaced with granulation tissue which is rich in newly formed blood vessels. Through these blood vessels, nutrients and mesenchymal stem cells capable of osteogenic differentiation are transported and contribute to osteoid formation [13,14].

b. Onlay Grafting

Onlay grafting is indicated in cases of inadequate palatal vault morphology which is caused by excessive bone resorption. It can either be block onlay grafting or particulate onlay grafting. The latter can further be categorized as subperiosteal tunnel grafting or direct particulate onlay grafting

i. Block Onlay Grafting

Indication

It is done for horizontal or vertical deficiency or combined horizontal and vertical deficiency.

Technique

This is one of the most commonly employed technique. The block graft can be autogenous graft harvested from neighbouring intraoral donor sites, distant extraoral donor sites or commercially available xenografts or alloplastic grafts [15]. The recipient bed is prepared by drilling multiple holes after raising the mucoperiosteal flap till the underlying spongiosa is reached (Fig. 1).

Depending on the type of defect, the graft is contoured to adapt in proximity to the recipient site as veneer, block or inverted J Block graft which is placed for the vertical defects while veneer graft is used in the case of horizontal defects. For combined defects, the graft is modified to the shape of the inverted letter J [16-18]. Defects augmented using autogenous onlay grafts provide a labial cortex of bone capable of resisting occlusal loads, especially in the anterior dentition [19].

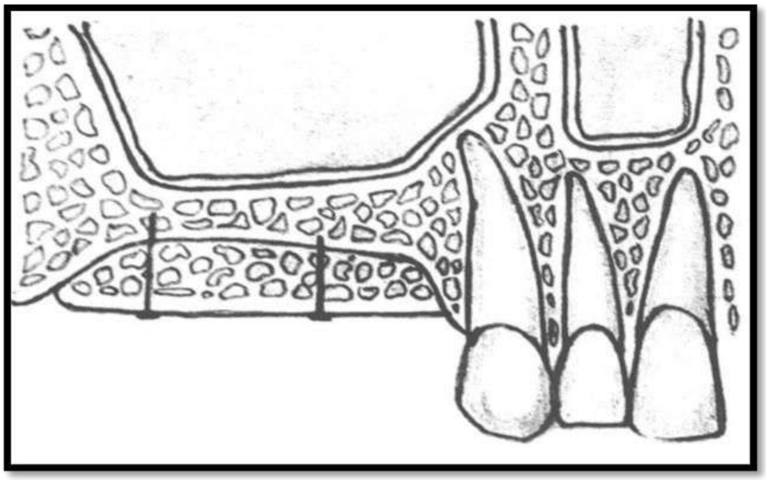

Figure 1: Block Onlay graft (Source: Goyal M, Mittal N, Gupta GK, Singhal M. Ridge augmentation in implant dentistry. J Int Clin Dent Res Organ 2015;7:94-112).

ii. Direct Particulate Onlay Grafting

Indication

It is performed to correct horizontal deficiencies in the anterior maxilla and for saddle depressions, i.e., vertical deficiency. Three-walled and four-walled defect morphology recipient sites with an apical stop are considered to be best amenable to direct particulate onlay grafting.

Technique

It is performed as a staged or simultaneous procedure (Fig. 2). To visualize the defect, the planned recipient area is exposed by raising a mucoperiosteal flap. The releasing incisions should be placed to ensure direct visualization of the defect and tension-free closure. The particulate graft is condensed over the defect after drilling holes in the recipient bed to ensure osseointegration. Demineralized grafts are preferred over mineralized grafts for defects with poorly contained boundaries, (i.e., maxillary sinus) due to their slower resorption [12]. The coverage with membranes is often recommended but can be omitted for small defects with sufficient neighbouring walls to provide volume stability [20,21]. The malleability and workability of particulate graft can be enhanced with tissue adhesives, i.e., fibrin sealants or protein-based regenerative gels.

Figure 2: Particulate graft (Source: Goyal M, Mittal N, Gupta GK, Singhal M. Ridge augmentation in implant dentistry. J Int Clin Dent Res Organ 2015;7:94-112).

iii. Subperiosteal Tunnel Grafting

Indication

It is indicated for small to moderate buccal plate defects. The morphology of such defects is characterized by wider buccal base with narrow crestal width (≤4 mm) and intact lingual wall with optimum vertical dimensions [22].

Technique

Access incision is placed distant (often mesially) from the recipient site after administration of local anesthesia, Subperiosteal tunnelling from the incision to graft site is performed with the help of a periosteal elevator. The demineralized particulate bone graft is placed in this subperiosteal tunnel with the help of modified 1 ml carrier syringe. To conform to the recipient bed in the desired form, the graft may need digital manipulation. The mesial incision is closed in a tension-free manner to ensure uneventful healing with minimal risks of dehiscence and graft exposure.

c. Interpositional Bone Graft (Sandwich Grafting)

Indication

It is indicated for vertical ridge defects with alveolar dimensions of 4-5 mm by placing two different layers of bone grafts and then cover them with a barrier membrane, creating a structure like the cross-section of the bone [22].

Technique

The facial aspect of the planned area of augmentation is exposed by giving a vestibular incision in nonkeratinized mucosa. Vertical corticotomies and osteotomies are performed using micro reciprocating and sees to the preservation of ≈2 mm of bone around the roots of neighbouring teeth followed by horizontal corticotomy and osteotomy to mobilize the segment.

There should be a minimum clearance of ≈3-5 mm from vital structures such as the maxillary sinus or mandibular canal. It is critical to perform only as much advancement as permitted by the soft tissue envelope to achieve tension-free closure. After careful transportation preserving soft tissue attachments, the bone graft block is sandwiched between the transported segment and basal bone with the advantages of reducing the need for compliance and less infection [23]. The graft fixation is achieved with miniplates. Periosteal releasing incisions are placed to aid tension free closure.

d. Ridge Split Procedure (RSP) (Fig. 3)

Indication

It was introduced in 1970s by Dr. Hilt Tatum to expand the existing residual ridge of the atrophic maxilla and mandible for implant insertion and augmentation has been referred to as ridge splitting, bone spreading, ridge expansion or the osteotome technique [24]. It is also known as Book Bone Flap. It is a technique-sensitive procedure that may be performed with many different instruments, ranging from chisel and mallet to scalpel blades, spatula, osteotomes, piezoelectric surgical systems, lasers and ultra-fine fissure burs. Osteotomes are the most popular used for ridge expansion ones amongst the various instruments and chisel and (hand) mallet are traditionally used devices [25,26].

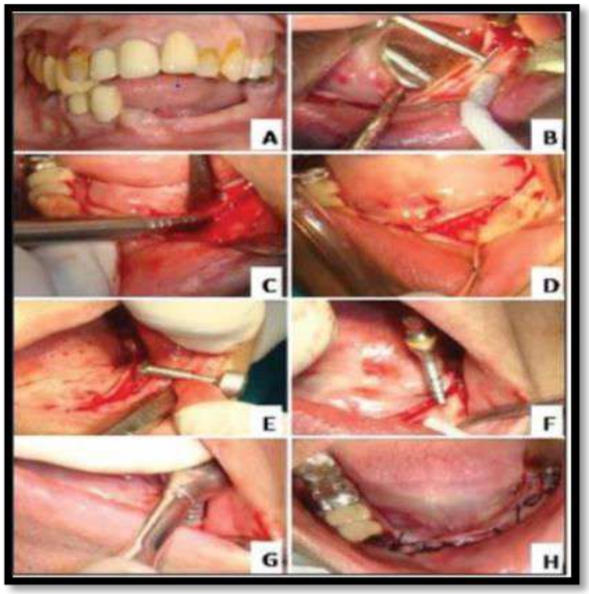

Figure 3: Ridge split. (A) thin alveolar ridge; (B) ridge split using MCT disk (3-mm radius); (C)expansion using rigid osteotome; (D)flexible chillet; (E) MCT ridge splitter; (F) bone expanders; (G) implant placement; (H)closure (Source: Goyal M, Mittal N, Gupta GK, Singhal M. Ridge augmentation in implant dentistry. J Int Clin Dent Res Organ 2015;7:94-112).

Technique I: Maxillary Single-Stage Alveolar RSP

This procedure usually consists of a single-stage, though occasionally a two-stage technique can be performed with the delayed placement of implant. 3 mm of alveolar width and 7 mm of alveolar length (between teeth) should be present for a single-tooth edentulous ridge to undergo RSP. The buccal-palatal dimension can be decreased and a full thickness incision of the appropriate length is performed in the edentulous area at the crest of the ridge. It is recommended to use a papilla-preservation approach. The developed flap is a limited crestal (not buccal) full-thickness flap just large enough to see the top of the alveolar crest with no formation or wide reflection of the buccal flap should occur.

Technique II: Mandibular Two-Stage Alveolar RSP

In the mandible, the procedure usually has 2 stages: stage 1 consists of corticotomy and stage 2 consists of splitting and grafting, which is performed 3-5 weeks later.

Stage 1: Corticotomy

The goal of corticotomy is to section through the exposed buccal cortex around the periphery of the buccal bony plate, which is to be laterally repositioned at the stage-2 surgery.

Stage 2: Splitting and Grafting

This procedure is done in a manner similar to a single stage of the maxillary ridge split, using a limited-reflection flap. A crestal incision just wide enough to see the crestal corticotomy is performed (closed approach). The operator should feel for the crestal groove created at the stage-1 surgery with the scalpel blade. The blade should be held firmly in this groove and run the full extension of this bony groove. Papilla-sparing curved incisions should be created toward the buccal and lingual side at the mesial and distal extensions of the groove. Tissue should be reflected to the lingual side as needed, but the tissue on the buccal side should only be elevated at the points where the buccal curved incisions are carried onto the adjacent bone. The spatula osteotome is tapped to depth with the osteotome of the next thickness and a controlled lateral force should begin to be used to mobilize the buccal plate. Thus, a buccal mucoosteo-periosteal flap with its own buccal soft-tissue blood supply is created and can be manipulated (widened). An overall ridge expansion up to 8-10 mm is usually adequate and grafting is performed. Primary closure of the wound is not needed nor is it usually possible. A 4 to 6 month waiting period is suggested before an implant treatment. The most common regions of the jaws that undergo RSP are the anterior and posterior maxilla and the posterior mandible [27].

RSP Using Piezosurgery

A papillary sparing crestal incision is performed on the atrophic ridge under local or general anaesthesia followed by two vertical releasing incisions beyond the mucogingival line. A full thickness mucoperiosteal flap is raised and when the bone surface is exposed, the planned osteotomies are outlined using tip number one at low power, in order to avoid oscillation of the tip and obtain a cut depth 1 mm [28]. Care must be taken to keep the lingual/palatal periosteum attached to the bony surface. The first osteotomy is carried out at the centre of the occlusal aspect of the ridge by tracing it, extending the incision in anteroposterior direction for the planned length. Subsequently, the vertical osteotomies are performed on the proximal and distal ends of the crestal incision. In surgical procedure, the vertical osteotomies are convergent and oblique, going from the outer surface of the vestibular cortex to the cancellous bone. The distance between the two vertical osteotomies is greater on the outer side than on the inner side of the vestibular cortical plate. The osteotomy lines should be traced using the tips progressively in order of size, varying the power level of the characteristics of the incision change too [29]. The tips are used in progression from number one to number five to deepen the osteotomies. As the groove on the bone surface becomes retentive, the tips can be used at high power resulting in more aggressive and faster cutting. The tips are calibrated to achieve the exact depth of cut desired but, if the cortical width exceeds 5 mm, a normal tip or chisels can be used to complete the osteotomy. Once the desired depth of the crestal and vertical osteotomies are achieved, the caudal ends of the vertical osteotomies are connected by a horizontal incision and the incision is a partial thickness osteotomy. The greenstick fracture is made using chisels. A cortical bone graft of appropriate size and shape is harvested from the ipsilateral mandibular ramus by means of the aforementioned tips and chisels. Bone chips are collected from the same donor site. The cortical graft is gently hammered between the vestibular and lingual cortex, acting as a bone wedge until the desired separation of the two cortices is reached. It is then stabilized using titanium osteosynthesis screws. In order to obtain supracrestal regeneration, the bone graft between the vestibular and lingual/palatal cortices can be fixed at a higher level in order to let it protrude from the occlusal aspect of the two bone plates. Finally, the grafted site is covered by a resorbable collagen membrane. The mucoperiosteal flap is repositioned and sutured.

e. Distraction Osteogenesis

Indication

It was developed by Gavriel Ilizarov in 1989 to treat skeletal deformities which works on principle of "tension-stress" with slowly incorporated tensile stress promoting histogenesis [30]. Bone traction generates tension and promotes osteogenesis, which occurs parallel to the distraction site and can be in vertical and/or a horizontal direction.

Technique

This technique allows significant augmentation of both hard and soft tissues in areas with extensive tissue loss in a staged manner [31-34]. A transport segment is mobilized in a similar manner as for interpositional bone grafting, preserving attachment to the crestal and lingual tissues.30 The distractor is fixed to transport basal bone segments with approximately 1-2 mm gap between the two segments. This is left in situ for a latency period of 5-7 days to allow the formation of soft tissue callus between the two segments and then activation is started at the rate of 0.5-2 mm/day for periodic distraction. After completion of the desired amount of distraction, the distraction device is removed and quality of the bone is explored. The newly formed bone is hourglass shaped and placement of additional grafts may be required for proper implant placement at this time. The implant placement is performed after a period of 4-6 months. It undergoes a more active remodeling process because of the better vascularization when compared to a block graft and minor complications could be averted using an appropriate technique [35,36].

f. Orthodontic Extrusion

In this method, forces are applied to the periodontally hopeless teeth, which brings the alveolar bone along with it. Elongation of the tooth in its alveolus causes shifting of gingival and Periodontal Ligament (PDL) fibres. The slow orthodontic extrusion technique is used to obtain a good amount of hard and soft tissue before dental implant placement. This technique avoids the surgical steps of the bone regeneration technique and is more simply managed by the clinicians. However, this technique requires more time to see the final results compared with surgical Guided Bone Regeneration (GBR). It is a non-traumatic technique whereas GBR is usually associated with pain and swelling in the immediate post op period [37,38].

g. Sinus Lift Procedure

It was proposed by Tatum for implant placement when there is insufficient bone between the maxillary alveolus and sinus [24]. The two procedures of sinus lift available are lateral window technique (lateral or direct sinus lift) and crestal approach (crestal or indirect sinus lift) [39-44].

Crestal Approach (Indirect Sinus Lift)

Indication

It is indicated when the Residual Alveolar Bone (RAB) is less than 6-8 mm.

Technique

After local anaesthesia is given, a pilot drill is used, followed by drills in increasing diameters and the osteotomy site is prepared. Care is taken to ensure that the drill length is maintained at 2 mm away from the floor of the sinus. As drills of higher diameter are introduced, it is observed that the sinus floor gets fractured and the sinus is slowly elevated to avoid injury to the Schneiderian membrane, by using a surgical mallet/osteotome with controlled force. Autogenous graft material is inserted within the socket, if required.

Lateral Window Technique (Direct Sinus Lift)

Indication

It is indicated when the residual alveolar bone is 5 mm or less.

Technique

A full-thickness flap is raised giving a crestal incision and a vertical releasing incision. The bone is exposed and sometimes a bluish hue is seen on the bony surface, which is indicative of the sinus. Then a window is made either using bur or piezosurgical instruments to delineate the sinus. After the window is prepared, it is slowly disengaged to expose the sinus. Care is taken to avoid perforation of the Schniederian membrane that lines the sinus. The sinus is then slowly elevated using the appropriate sinus lift instruments. If the window created has not been totally disengaged, it could be placed below the relocated sinus to form its floor. The empty void created between the elevated sinus and the basal bone is filled with either autologous or allogeneic graft material and a membrane is stabilized over it.

3. Soft Tissue Augmentation Procedures

a. Onlay Graft Procedures

Indication

It was first described by Seibert in 1983 for correcting horizontal deficiencies in the anterior maxillary arch and for saddle depressions, i.e. vertical deficiency [45,46].

Technique

A recipient bed is prepared with two parallel split-thickness incisions in the lamina propria of the edentulous area and the epithelium is removed in order to expose the underlying connective tissue. A free gingival graft is then harvested from the palate and secured on the recipient vascular bed with interrupted and compressive sutures, with the amount of augmentation depending on the thickness of the applied graft. There is no shrinkage of the tissue grafted, but a varying amount of volume is lost during the healing phase for which, it is frequently necessary to repeat the surgical procedure at 2 to 3 month intervals in order to reach the desired ridge height [45-48].

b. Roll Flap Technique:

Indication

It was introduced by Abrams in 1980 to correct small or moderate soft tissue defects associated with buccolingual defects of ridge [49].

Technique

It involves a connective tissue pedicle flap that originates from the de epithelialization of the palatal tissue close to the edentulous area in which two parallel incisions are made from the occlusal edentulous area towards the palate and connected with a horizontal incision. A split-thickness palatal flap is then elevated and a pouch is prepared in the defect area with a split dissection of the supra periosteal connective tissue. The palatal flap is 'rolled' into the pouch area and then sutured [50].

Modified Roll Technique

Indication

This technique is a modification of the roll technique which was introduced by Scharf and Tarnow for class I deformities wherein the epithelium over the connective tissue is not scraped but preserved to cover the donor site [51].

Technique

An incision is made using a Bard-Parker blade from the crest to the palatal area to include a sufficient length of the tissue to be rolled to the desired area on the buccal aspect. A similar incision is made on the other side to include sufficient width of the graft and the two vertical incisions are connected by a horizontal incision. A partial-thickness trap door-type flap is reflected. The pedicle is rolled on the buccal aspect and stabilized using a horizontal mattress suture.

c. Interpositional (Inlay) Graft Procedures

Indication

It was described in 1979 by Meltzer which involves the placement of graft without scraping the epithelium from the connective tissue to treat buccolingual and apicocoronal ridge defects [52].

Technique

A pouch is prepared in the defect area and a free graft derived from the palatal or maxillary tuberosity is harvested which is partially de-epithelialized and the exposed connective tissue is inserted in the pouch area like a wedge (inlay graft). Thus, the epithelialized part of the graft remained outside the pouch and sutured at the level of the epithelial surface of the surrounding tissues [45,46,52-54].

d. Combination Onlay-Inlay Grafts

Indication

It was introduced by Seibert and Louis in 1996 to treat buccolingual and apicocoronal ridge defects [55].

Technique

It is done to obtain simultaneous tissue augmentation in the horizontal and vertical dimensions. The donor site is prepared with a full-thickness coronal dissection and a partial thickness apical dissection. The graft is thus composed of two parts: the coronal part, which is epithelialized and the apical part, which is formed of connective tissue only. On the defect area, the crestal surface is de-epithelialized with a beveled incision and the apical surface is prepared with a partial-thickness dissection with two vertical-releasing incisions extended apically, without involving the adjacent papillae to create a pouch area. The onlay section (epithelialized area) of the graft is sutured on the crestal surface of the defect, while the inlay section (connective tissue) is inserted and secured in the vestibular pouch area.

e. Pouch Procedures

Indication

It was put forward by Burton Langer and Lawrence Calagna to treat ridge deformities in which a connective tissue graft was procured from the palatal area or maxillary tuberosity to increase the thickness of the soft tissue on the buccal surface of ridge [56,57].

Technique

A pouch is prepared with a split dissection of the supra periosteal connective tissue and the connective tissue graft is sutured to

the periosteum and then the flap is sutured in its original position and covers the connective tissue graft completely.

Discussion

The onlay technique is done mostly with an autogenous bone graft. Before the year 2000, most implants were immediately placed together with the bone grafts. The implants were used to secure the graft. The capacity and volume of the bone grafts are variable between the studies. These differences could be explained by different follow-up periods, timing of implants placement, different sites and different bone grafting material. Over all the resorption rate is higher in the first year, but stabilizes after it [18].

Alveolar distraction is only indicated for the mandible because of the pneumatization of the sinus in the maxilla. A disadvantage is the early resorption of the distracted bone. It undergoes a more active remodeling process because of the better vascularization when compared to a block graft as reported by Hodges NE [35].

The ridge split technique has been used in horizontal deficiency requiring 2-5 mm of augmentation. It is a minimally invasive technique indicated for alveolar ridges with adequate height, which enables immediate implant placement and eliminates morbidity and overall treatment time. The classical approach of the technique involves splitting the alveolar ridge into 2 parts with use of ostetomes and chisels. Tatum developed specific instruments including tapered channel formers and D-shaped osteotomes to expand the resorbed residual ridges of both the upper and lower jaws having a ridge width of <3 mm [24-26].

Ridge Expansion is indicated in patients with ridge width <6 mm. A full-thickness flap is raised to expose the bone. Scipioni, et al., reported a 98% 5-year implant survival rate when utilizing ridge expansion with simultaneous implant placement [58]. The split-crest technique had previously been compared to lateral ridge augmentation with autogenous bone block graft disclosing no significant differences in implant survival between the two treatment modalities, although the gain in alveolar ridge width was significantly higher with lateral ridge augmentation with autogenous bone block graft [59].

Liu J, et al., stated that guided bone regeneration is a surgical procedure that uses barrier membranes with or without particulate bone grafts or/and bone substitutes [60]. Wang HL, et al., stated that four principles need to be met to ensure successful GBR [13]. Sandwich grafting is done with vertical ridge deficiency with preexisting minimal vertical alveolar dimensions of 4-5 mm and without any soft tissue deficit. Choi BH, et al., concluded that sandwich osteotomy combined with interpositional allografts technique was safe although it leads to some resorption of the superior and anterior parts of the alveolar fragment [23].

Interpositional graft procedures were described by Meltzer which involves the placement of graft without scraping the epithelium from the connective tissue to treat buccolingual and apicocoronal ridge defects [52]. Tatum proposed a technique, "sinus lift procedure", for implant placement when there is insufficient bone between the maxillary alveolus and sinus [24]. Alveolar height <10 mm is often an indication for sinus lift surgery via the crestal (indirect) approach, while alveolar height <5 mm via is an indication for the lateral (direct) approach.

In orthodontic extrusion, forces are applied to the periodontally hopeless teeth, which will bring the alveolar bone along with it. Salama and Salama have documented clinical cases employing forced eruption on hopeless teeth to augment bony tissues in implant sites and also proposed a classification for extraction socket according to their morphology and placement of the implant into the socket [37]. PDL cells play a crucial role at a molecular level, thereby aiding in optimal results after implant placement [38].

The Roll technique introduced by Abrams was employed to correct small or moderate soft tissue defects associated with buccolingual defects of ridge [49]. Padhye, et al., compared the Subepithelial Connective Tissue Graft (SCTG) and buccally displaced flap [61]. The results showed that there was an increase in the width and thickness of keratinized mucosa in the buccally displaced flap group than the SCTG group, with reduced surgical sites, less postoperative pain and good blood supply. Pouch procedures were put forward by Burton Langer and Lawrence Calagna to treat ridge deformities in which a connective tissue graft was used which was procured from the palatal area or maxillary tuberosity to increase the thickness of the soft tissue on the buccal surface of ridge [56,57].

Conclusion

Reconstructive surgical procedures aimed at restoration of the alveolar ridge to its former dimensions are increasingly prescribed, particularly in the anterior region where esthetic issues are concerned. Nevertheless, there is a lack of clinical studies in the literature investigating this concern and therefore evidence- based conclusions cannot be drawn. Furthermore, because of the high esthetic impact it is advised that patient-centered outcomes be incorporated in clinical trials.

Conflict of Interests

The authors have no conflict of interest to declare.

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(57) Abstract :
One of the most common non-commutable types of chronic inflammatory disease is Periodontitis. It is the sixth most common disease affecting nearly 750 million population worldwide every year. It is very important to treat such Intrabony Osseous Defects, as if left untreated, it may lead to increased risk of disease progression sometimes leading to loss of teeth. Research studies suggest that piezoelectric surgical instruments with accurate precision would provide correct prediction of periodontal osseous defects. Any immediate reduction in periodontal dental angulation could be detected by bone swaging. Proposed is a System and Method to Detect the Depth of Intrabony Osseous Defect using Machine Learning. Input Cone Beamed Computed Tomography (CBCT) which provides inter-relational images in three orthogonal planes namely axial, sagittal and coronal and also customized planes are subject to Image Pre-Processing. Images are converted to Gray Scale and Binarization of images is carried out using Social Edge Detection to increase the object recognition rate. Target object recognition is trained using Convolutional Neural Networks. Multiclass Classifier and Bounding Box Regressor employed for each convolutional and pooling layers for accurate detection of depth of intrabony osseous defects.

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Original Article

Assessment of neurovascular channels in lateral maxillary sinus wall using cone-beam computed tomography: An imperative clinicians guide for implant placements

ABSTRACT

Background: The aim of this study is to evaluate the location and radio morphometric features of the posterior superior alveolar artery (PSAA) in patients undergoing rehabilitation of posterior maxilla and other sinus augmentation surgical procedures by cone-beam computed tomography (CBCT).

Materials and Methods: A total of 816 CBCT scans were included. Various radio morphometric measurements were done to assess the PSAA location, diameter, and distances to the sinus floor and alveolar crest.

Results: The PSAA was mostly intraosseous in the maximum in the age group 31–51 years (56%), in males (53.4%), and in dentate patients (57.4%). The artery tends to be wider in older patients. Distances to the sinus floor or the alveolar crest tend to be shorter in women.

Conclusions: This study suggests that CBCT is a valuable pre-surgical tool and the evaluation of the PSAA on CBCT images could reduce the likelihood of excess bleeding during surgery in the maxillary posterior region.

Keywords: Alveolar antral artery, cone-beam computed tomography, maxillary sinus, posterior superior alveolar artery

INTRODUCTION

The posterior superior alveolar artery (PSAA) can be damaged during a number of surgical procedures and must be carefully analyzed during pre-assessment of the dental implantation site using CBCT.[1] Damage to this artery results in the potential risk of bleeding during the procedure which obscures the vision of the operator and may also lead to perforation of the Schneiderian membrane.[2] During placement of implants in the maxillary posterior region, the amount of residual bone present in this region plays a key role in its success. This may be affected by the maxillary sinus pneumatization, loss of alveolar bone due to tooth extraction, or vertical loss of residual bone. Therefore, careful pre-assessment of the amount of residual bone from the alveolar crest to the maxillary sinus should be considered in planning implantation in this region.[3] Cone-beam computed tomography (CBCT) aids in providing the best treatment plan by determining the location and characteristics of important anatomical landmarks before surgery.[4] Limited data are available to assess PSAA and residual bone together in posterior maxillae in Indian sub-populations. Hence, we aimed to investigate the information about the differences in radio morphometric measurements of PSAA and residual bone in the premolar and molar areas which may be useful for the rehabilitation of the maxillary posterior regions. The null hypothesis is that there is no statistical difference in the

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prevalence and location of PSAA and residual bone among different age groups, genders, and dentate status.

MATERIALS AND METHODS

This retrospective cross-sectional study was performed on 1000 CBCT volumes who had retrospectively undergone CBCT imaging at the Outpatient Department of Oral Medicine and Radiology for treatment purposes. The protocol ethics were approved by the research committee of the Institute, in accordance with the Helsinki Declaration. However, the final sample size was determined as 811 CBCT scans that met the inclusion criteria of the study and on the minimum radiologic prevalence of PSAA in the literature (i.e., 50%) which was necessary for calculating the maximum sample size, and a precision of $d = 0.05$ at a 95% level of confidence.

The study population was divided into three age groups: 10–30 years, 31–51 years, and 52–72 years. Comparisons were made age wise, gender wise, and dentate status, i.e., dentulous or partially edentulous. For Ethical Clearance was obtained from Institute of Dental Studies and Technologies Institutional Ethical Committee with Ref no IDST/IERBC/2017-20/25 dated 23/11/2017. A written consent was obtained from each patient to access their CBCT data for research.

CBCT Measurements

The cases were sampled randomly from the archive of existing CBCT volumes obtained from Kodak CS 9300 (Carestream Dental, Atlanta, USA) dental imaging system. Linear measurements were carried out to localize the mediolateral and vertical position of the posterior superior alveolar artery in postero-lateral wall of the maxillary sinus and its proximity to the floor of the maxillary sinus using CS 3D imaging 3.7.0 software program. The exposure settings during the scan included 60 kVp, 12 mA, voxel size 0.2 mm, and FOV 11 × 5 cm with an exposure time of 15s. Reformatting of the 3D reconstructions was created by using the axial CBCT scans on a local workstation using CS 3D imaging 3.7.0 dental imaging software. The cross-sectional images were obtained with 1 mm of slice thickness.

The exclusion criteria comprised poor quality scans, scans with artifacts and pathological lesions disrupting normal sinus anatomy, and severe periodontal bone loss.

Each CBCT scan was oriented prior to the location of PSAA. The cross sections were obtained of the 1st and 2nd premolar and 1st and 2nd molar region in dentulous or edentulous maxillary scans and evaluated for the optimal visualization of the radiolucent PSAA in postero-lateral wall of the maxillary sinus. The relative position of PSAA to mediolateral wall of the maxillary sinus was determined as: (a) Type I: intrasinusal (b) Type II: intraosseous, and (c) Type III: superficial. [Figure 1] The location of PSAA was assessed in most caudal position of PSAA by using the following measurements: distance from PSAA to mesial wall of sinus (D1) [Figure 2], height from alveolar bone crest to floor of sinus (H2) [Figure 3], height from lower border of PSAA to alveolar bone crest (H1) [Figure 4].

The measurements were used to estimate the interobserver reliability. The resulting intra-class correlation coefficients ranged between 95 and 99%, indicating excellent inter-observer agreements.

Statistical analysis

Descriptive statistics and 95% confidence intervals (CI) were calculated. The data were analyzed using SPSS version 21.0 (IBM Corporation, New York, USA). Distribution of artery localization and radio morphometric measurements according to age and gender were carried out using Chi-square test and one-way ANOVA test, respectively. $P \leq 0.05$ was considered as statistically significant.

RESULTS

Overall, the PSAA canal was detected in 810 patients (99.87%) out of 811 approved subjects irrespective of age, gender, and dentate status. The prevalence of PSAA was seen maximum in 31–51 years (41.9%) and least in 52–72 years (23%). Of the 810 patients, 474 (58.4%) were males and 336 (41.4%) were females. There were 158 (19.5%) partially edentulous regions and 652 (80.4%) dentulous regions in which the canal was observed. Artery localization and tooth-wise distribution according to age, gender, and dentate status are described in Tables 1 and 2.

A detailed description of the distribution of PSAA and its various radiographic morphometric measurements according to age, gender, and dentate status are described in Tables 3-6.

The minimum artery diameter (0–1 mm) was seen maximum in the age group 31 to 51 years, in males and in dentate subjects, whereas the maximum artery diameter (>2.0 mm) was seen maximum in 31 to 51 years, in males and in dentate subjects, and the results were statistically significant ($P = 0.001$) [Table 3].

The mean height from lower border of PSAA to alveolar bone crest (H1) in both 10–30 and 31–51 years was found maximum at 1st premolar and minimum at 2nd molar region, whereas for 52–72 years, it was found maximum at 2nd premolar and minimum at 2nd molar region. In males, it was maximum at

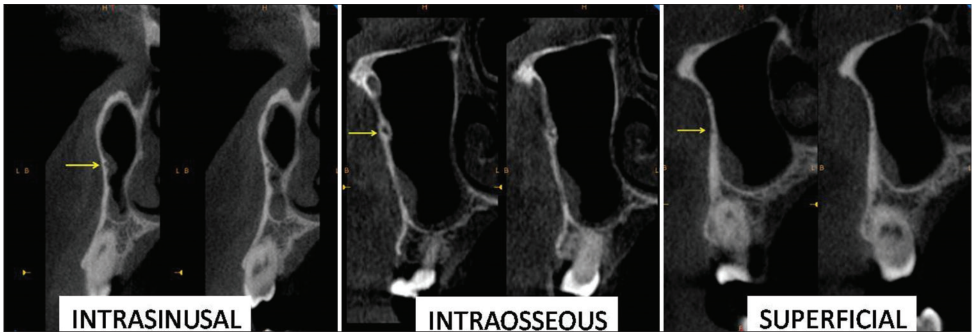

Figure 1: TYPE OF PSAA

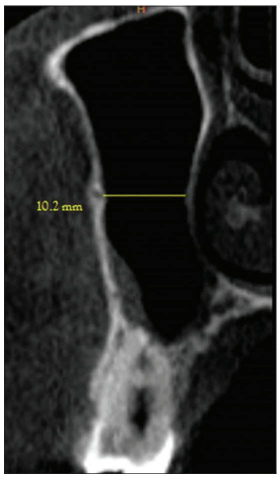

Figure 2: Distance from PSAA to medial wall of sinus (D1)

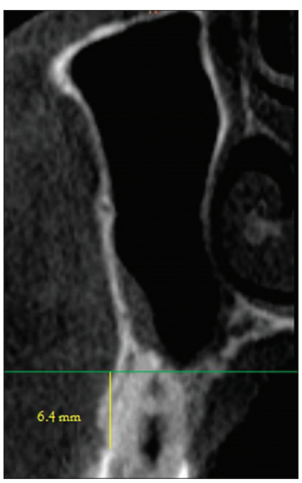

Figure 3: Height from alveolar crest to floor of sinus

1st premolar and minimum at 1st molar region, whereas for females, it was maximum at 1st premolar and minimum at 2nd molar region. According to dentate status in dentates, it was maximum at 1st premolar and minimum at 2nd molar region, whereas for partially dentates, it was maximum at 1st premolar and minimum at 2nd molar region and the results were statistically significant for the age group 10–30 years, gender wise and partially dentates ($P = 0.001$) [Table 4].

The mean height from alveolar bone crest to floor of sinus (H2) was found maximum at 1st premolar in all three age groups, whereas it was minimum at 2nd molar region for 10–30 years, at 1st molar region for 31–51 years, and at 2nd premolar region for 52–72 years, respectively. Irrespective of gender, it was maximum at 1st premolar and minimum at 1st molar region. According to dentate status in dentates, it was maximum at 1st premolar and minimum at 1st molar region, whereas for partially dentates, it was maximum at 1st premolar and minimum at 2nd molar region and the results were statistically significant ($P = 0.001$), except for males ($P = 0.029$). [Table 5]

The mean distance from PSAA to medial wall of sinus (D1) in all age groups was found minimum at 1st premolar region except for 52–72 years where it was at 2nd premolar region, whereas maximum was found at 2nd molar region. Irrespective of gender and dentate status, it was maximum at 2nd molar region and minimum at 1st premolar region and the results were statistically significant ($P = 0.001$), except for dentates ($P = 0.033$). [Table 6]

DISCUSSION

The challenges faced by surgeons during the rehabilitation of edentulous posterior maxilla depend on alveolar bone loss, post-extraction, or sinus pneumatization.[5] Common complications encountered during the surgical intervention in this region include perforation of the Schneiderian membrane and hemorrhage as a result of damage to PSAA bvgt65t. This may further lead to reduced visibility, postoperative hematoma, infection, and complete loss of graft.[5,6]

Therefore, a thorough knowledge of the blood supply of this region is of utmost important for the surgeon before planning any intervention. PSAA anastomoses with the infraorbital artery and supply the lateral wall of the maxillary sinus.[4]

The advent of CBCT and the vast array of advantages of using this advanced imaging modality have revolutionized the diagnosis and treatment planning in dentistry. In cases of dental rehabilitation of the posterior maxillary region, CBCT has proven to be a boon to surgeons and implantologists as it aids in radiological pre-assessment of the implant site in terms of one density assessment and other morphometric measurements of the implant site.[5,6]

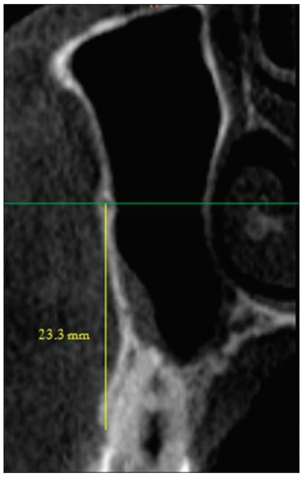

Figure 4: Height from lower of border PSAA to alveolar crest

The current study assessed gender-wise age-wise, tooth-wise differences in dentulous and edentulous patients in terms of localization, diameter of PSAA, height from lower border of PSAA to alveolar bone crest, height from lower border of PSAA to floor of sinus, distance from PSAA to medial wall of sinus, and height from alveolar bone crest to floor of sinus.

Further, the current study included 474 males and 336 females. Similar studies have been conducted in the past by Danesh-Sani *et al*.[5] and Tehranchi *et al*.[7] In the present study, PSAA was observed in dentate ($n = 652$) and partially edentulous

Table 1: Artery localization according to age, gender, and dentate status

		Absent	Type I	Type II	Type III	p value
		N (%)	N (%)	N (%)	N (%)	
Age	**10–30 years**	0	138 (49.6%)	140 (50.4%)	0	
	31–51 years	1 (0.3%)	74 (21.7%)	191 (56%)	75 (22%)	**0.0001***
	52–72 years	0	54 (28.1%)	108 (56.3%)	30 (15.6%)	
Gender	**Males**	0	164 (34.6%)	253 (53.4%)	57 (12%)	0.290
	Females	1 (0.3%)	102 (30.3%)	186 (55.2%)	48 (14.2%)	
Dentate status	**Dentate**	1 (0.2%)	234 (35.9%)	375 (57.4%)	43 (6.6%)	**0.0001***
	Partially Dentate	0	32 (20.3%)	64 (40.5%)	62 (39.2%)	

*P value significant at $P<0.05$, Chi-square test applied

Table 2: Tooth-wise distribution of different types of PSAA according to age, gender, and dental status

Variable		N (%)	PM1	PM2	M1	M2	p value
			N (%)	N (%)	N (%)		
Age	**10–30 years**	**Type I**	1 (0.7%)	74 (54.0%)	19 (13.2%)	44 (32.1%)	**0.001**
		Type II	57 (40.7%)	83 (59.3%)	0	0	
		Type III	0	0	0	0	
	31–51 years	**Type I**	26 (35.1%)	0	6 (8.1%)	42 (56.8%)	**0.001**
		Type II	47 (24.6%)	44 (23%)	74 (38.7%)	26 (13.6%)	
		Type III	0	27 (36%)	48 (64%)	0	
	52–72 years	**Type I**	0	29 (53.7%)	25 (46.3%)	0	**0.001**
		Type II	0	53 (49.1%)	30 (27.8%)	25 (23.1%)	
		Type III	0	0	30 (100%)	0	
Gender	**Males**	**Type I**	26 (15.9%)	103 (62.8%)	0	35 (21.3%)	**0.001**
		Type II	42 (16.6%)	145 (57.3%)	66 (26.1%)	0	
		Type III	0	27 (47.4%)	30 (52.6%)	0	
	Females	**Type I**	1 (1%)	0	50 (49%)	51 (50%)	**0.001**
		Type II	62 (33.3%)	35 (18.8%)	38 (20.4%)	51 (27.4%)	
		Type III	0	0	48 (100%)	0	
Dentate status	**Dentate**	**Type I**	27 (11.2%)	77 (33%)	44 (18.9%)	86 (36.9%)	**0.001**
		Type II	81 (21.6%)	149 (39.7%)	104 (27.7%)	41 (10.9%)	
		Type III	0	27 (62.8%)	16 (37.2%)	0	
	Partially dentate	**Type I**	0	26 (81.3%)	6 (18.8%)	0	**0.001**
		Type II	23 (35.9%)	31 (48.4%)	0	10 (15.6%)	
		Type III	0	0	62 (100%)	0	

*P value significant at $P<0.05$, Chi-square test applied

Table 3: Artery diameter distribution according to age, gender, and dental status

		0–1 mm N (%)	1–1.5 mm N (%)	1.5–2.0 mm N (%)	>2.0 mm N (%)	p value
Age	10–30 years	137 (49.5%)	98 (35.4%)	42 (15.2%)	0	
	31–51 years	222 (65.1%)	118 (34.6%)	0	1 (0.3%)	0.001
	52–72 years	55 (28.6%)	137 (71.4%)	0	0	
Gender	Males	218 (46%)	213 (44.9%)	42 (8.9%)	1 (0.2%)	
	Females	196 (58.3%)	140 (41.7%)	0	0	0.001
Dentate status	Dentate	301 (46.2%)	308 (47.2%)	42 (6.4%)	1 (0.2%)	
	Partially Dentate	113 (71.5%)	45 (28.5%)	0	0	0.001

*P value significant at $P < 0.05$, Chi-square test applied

Table 4: Mean height from the lower border of PSAA to alveolar bone crest (H1) according to different parameters

		PM1	PM2	M1	M2	p value
Age	10–30 years	28.05±2.81	24.72±3.63	20.8±0.0	16.2±5.24	0.001
	31–51 years	27.24±2.06	22.68±3.91	20.33±2.41	16.28±1.54	0.030
	52–72 years	-	21.17±1.99	17.34±2.43	17.5±0.0	0.014
Gender	Males	27.13±2.07	24.06±3.18	18.12±2.05	20.09±1.37	0.001
	Females	28.10±2.73	17.42±0.91	20.08±2.88	15.27±2.63	0.001
Dentate status	Dentate	27.26±2.57	24.21±3.34	19.12±3.19	16.30±3.21	0.030
	Partially dentate	29.20±0.0	19.31±1.99	19.63±0.98	19.0±0	0.001

*P value significant at $P<0.05$, ANOVA applied

Table 5: Mean height from alveolar bone crest to floor of sinus (H2) according to different parameters

		PM1	PM2	M1	M2	p value
Age	10–30 years	23.57±2.19	15.08±3.84	13.3±0.0	11.20±3.32	0.001
	31–51 years	14.64±0.58	10.48±1.42	7.07±3.34	7.87±3.00	0.001
	52–72 years	14.63±3.79	6.31±0.62	9.40±0.0	10.27±4.64	0.001
Gender	Males	19.78±4.48	14.21±3.84	7.56±1.99	13.66±0.80	0.029
	Females	17.32±4.63	11.55±3.59	7.12±3.69	7.69±2.05	0.001
Dentate status	Dentate	19.26±4.94	14.63±3.81	8.44±2.37	9.74±2.67	0.001
	Partially dentate	15.5±0.0	10.72±2.52	4.57±2.97	2.60±0.0	0.001

*P value significant at $P<0.05$, ANOVA applied

Table 6: Mean distance from PSAA to medial wall of sinus (D1) according to different parameters

		PM1	PM2	M1	M2	p value
Age	10–30 years	3.52 ± 1.36	8.71 ± 2.54	10.50 ± 0.0	16.58 ± 2.01	0.001
	31–51 years	6.19 ± 0.08	10.96 ± 1.17	12.98 ± 1.54	17.18 ± 1.06	0.001
	52–72 years	-	10.61 ± 0.94	11.67 ± 1.46	17.0 ± 0.0	0.001
Gender	Males	4.29 ± 1.47	9.87 ± 1.83	12.02 ± 1.89	17.74 ± 0.99	0.001
	Females	5.79 ± 1.38	8.53 ± 3.94	12.49 ± 1.44	16.68 ± 1.39	0.001
Dentate status	Dentate	4.73 ± 1.65	9.49 ± 2.33	12.49 ± 1.51	16.79 ± 1.30	0.033
	Partially dentate	6.30 ± 0.0	10.75 ± 1.11	11.83 ± 1.91	19.0 ± 0.0	0.004

*P value significant at $P < 0.05$, ANOVA applied

patients ($n = 158$). Similar studies were conducted in the past by Danesh-Sani *et al*.[5] and Ibrahim *et al*.[8]

The prevalence of PSAA in our study was 99.87% close to previously conducted cadaveric studies which was 100%.[9] In this study, age wise the most common course of PSAA was identified to be Type II (intraosseous) irrespective of age group but at different locations; at 2nd premolar region in 10–30 years ($n = 83$), at 1st molar region in 31–51 years ($n = 74$), and at 2nd premolar region in 52–72 years ($n = 53$). Gender wise it was again identified to be Type II (intraosseous) but at different locations; at 2nd premolar region in males ($n = 145$) and at 1st premolar region in females ($n = 62$). Dentate wise it was identified to be Type II (intraosseous) at 2nd premolar region in dentates ($n = 149$) and Type III (superficial) at 1st molar region in partially dentates ($n = 62$) and the results were statistically significant, respectively ($P = 0.001$) [Table 2]. Danesh-Sani *et al*.,[5] Tehranchi *et al*.,[7] Ibrahim *et al*.,[8] Chitsazi *et al*.,[9] and Ilguy *et al*.[10] Localization of the course of PSAA age wise, gender wise, and dentate wise in this study provides a better understanding PSAA in addition to other studies.

The diameter of PSAA has a direct impact on the extent and severity of hemorrhage. In this study, age wise the diameter of PSAA was found to be 0–1 mm in maximum 31–51 years (65.1%), 1–1.5 mm in maximum 52–72 years (71.4%), 1.5–2 mm in maximum 10–30 years (15.2%), and >2 mm in maximum 31–51 years (0.3%) and the results were found to be statistically significant ($P = 0.001$). However, Danesh-Sani *et al*.[5] and Rathod *et al*.[6] found no significant correlation between age and the size of the PSAA. Furthermore, different studies in the past have found the mean diameter of PSAA as 1.15 (±0.38) mm (Ibrahim *et al*.[8]); 1.52 (±0.47) mm (Kim *et al*.[11]); 1.3 (±0.5) mm (Güncü *et al*.[12]). These values are more than the results of the current study which could be attributable to ethnic differences and methodological differences. Gender-wise males had a larger diameter of PSAA with 0–1 mm found maximum in 46%, 1–1.5 mm found maximum in 44.9%, 1.5–2.0 mm found maximum in 8.9%, and >2 mm found maximum in 0.2% and the results were statistically significant ($P = 0.001$). The greater value in males could be attributed to larger skeletal features within males. Also, it has been reported by Ibrahim *et al*.[8] that genetic variance and racial differences could have an impact on these measurements. Dentate status wise it was more in dentate than partially dentate and 0–1 mm was maximum in 46.2%, 1–1.5 mm was maximum in 47.2%, 1.5–2.0 mm was maximum in 6.4%, and >2.0 mm was maximum in 0.2% Similar studies have been conducted in past by Kim *et al*.[11] where irrespective of age, gender, and dentate status almost no cases of PSAA diameter >2 mm were noted. Therefore, it can be assumed that the study population might have lowest risk of severe bleeding as a result of damage to the PSAA.

The mean distance between the lower border of PSAA to alveolar bone enables the clinician to assess length of implant planned or the extent of sinus elevation required to avoid risk of iatrogenic injury to PSAA. In the present study, irrespective of age it was shortest for 2nd molar and longest for 1st premolar except for 52–72 years where it was longest for 2nd premolar and the result was statistically significant ($P = 0.001$, $P = 0.030$, $P = 0.014$, respectively). Gender wise for males it was shortest for 1st molar and longest for 1st premolar for females it was shortest for 2nd molar and longest for 1st premolar and the result were statistically significant for both ($P = 0.001$). Dentate wise for dentate it was shortest for 2nd molar and longest for 1st premolar for partially dentate it was shortest for 2nd molar and longest for 1st premolar and the results were statistically significant ($P = 0.030$ and $P = 0.001$, respectively). These results were concurrent with other published studies by Chitsazi *et al*.,[9] Ilguy *et al*.,[10] Güncü *et al*.,[12] Watanabe *et al*.,[13] Kqiku *et al*.[14]

The mean height from the alveolar bone crest to floor of sinus was determined to assess the height of the alveolar ridge in the posterior maxilla which aids in the localization of PSSA. In the present study, for the age group 10–30 years it was shortest for 2nd molar and longest for 1st premolar, for 31–51 years it was shortest for 1st molar and longest for 1st premolar, for 52–72 years it was shortest for 2nd premolar and longest for 1st premolar and the result was statistically significant for all age groups ($P = 0.001$, respectively). Gender wise irrespective of gender it was shortest for 1st molar and longest for 1st premolar and males had a larger value with statistically significant results for both ($P = 0.029$, $P = 0.001$). Dentate wise for dentate it was shortest for 1st molar and longest for 1st premolar and for partially dentate it was shortest for 2nd molar and longest for 1st premolar and the results were statistically significant for both ($P = 0.001$, respectively). These results were similar to previous studies conducted by Kqiku *et al*.[14] and Apostolakis *et al*.,[15] where the values irrespective of age or gender or dentate status are minimum at 1st molar region increase slightly at 2nd molar region and are maximum at 1st premolar region. This may be attributed to the anatomy of the sinus which gets higher anteriorly. Also, PSAA's course in the anterior region moves superiorly to anastomose with the infraorbital artery. However, Shams *et al*.[16] did not have significant changes from the posterior side (8.0 mm) to the anterior side (4.0 mm). Also, Lee *et al*.,[17] found that the mean height of PSAA from floor of sinus was almost similar in the 2nd premolar, 1st molar, and 2nd molar regions.

The mean distance of PSAA to the medial wall of sinus is considered a more stable landmark for evaluation of the mediolateral position of PSAA as vertical dimensions are affected by sinus lift or ridge augmentation procedures. In the present study, irrespective of age it was shortest for 1st premolar, the values gradually increased and were maximum for 2nd molar except for 52–72 years where it was longest for 2nd molar and shortest for 2nd premolar. The results were statistically significant ($P = 0.001$, respectively). Gender wise irrespective of gender was shortest for 1st premolar the values gradually increased and were maximum for 2nd molar. The results were statistically significant for both ($P = 0.001$, respectively). Dentate wise irrespective of dentate status was shortest for 1st premolar the values gradually increased and were maximum for 2nd molar. The result was statistically significant for both ($P = 0.033$ and $P = 0.004$, respectively). In our study, the results showed that dentition status influenced the location of PSAA and partially dentate patients showed higher values. Pandharbale *et al*.[18] found similar results and suggested that it could be due to progressive atrophy of the alveolar bone. However, the results were not in accordance with those of Velasco-Torres *et al*.[19] and Hayek *et al*.[20] which showed that dentate had larger measurements.

CONCLUSIONS

The study supports that a careful evaluation of PSAA is imperative before surgical treatment of the maxillary sinus since it may complicate intraoperative bleeding and affect the integrity of the sinus and its membrane during the procedure. The intraosseous type was the most common variant of PSAA. Age-wise, gender-wise, and dentate wise the morphometric measurements of PSAA differ significantly in the study population. 3D imaging modality such as CBCT is useful to localize the PSAA as it provides finer details and should be recommended in clinical practices.

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Conflicts of interest

There are no conflicts of interest.

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Cheiloscopy and Rugoscopy: A Scientific Approach for Sex Determination.

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KEYWORDS

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ABSTRACT:

Introduction: The major areas of forensic dentistry include determining a patient's gender, age, race, and size as well as gathering dental evidence and reconstructing a patient's face over skeletal remains. Lip prints are said to be unique to a person and similar to fingerprints. The palatal rugae pattern has been regarded as one of the pertinent indicators for human identification in the field of forensic medicine because of its stability and uniqueness.

Objectives: To evaluate the effectiveness of palatal rugae pattern and lip prints for gender distinction and human identification. The objectives of the study were to distinguish between male and female lip prints and palatal rugae based on gender.

Methods: Subjects were randomly chosen from the OPD and an informed consent was obtained. Study was performed on 136 subjects equally divided into two groups according to gender. For rugoscopy all the dental casts were collected, duplicated and later analyzed. The legal age of the subject was confirmed using the case history proforma of the patients submitted along with the casts. The relevant demographic data including name, age, sex, address as well as findings from clinical examination were recorded for each selected individual in a specially designed Proforma.

Results: Considering both the lips, type V pattern was most predominant pattern in males followed by type III while type I pattern was most predominant pattern in females followed by type I. Predominant shape of rugae in females is wavy followed by curved and straight and in males is curved followed by wavy, straight and unification.

Conclusions: Both cheiloscopy and rugoscopy have the potential to identify an individual also lip prints are more reliable in identifying the sex of an individual as compared to palatal rugae patterns.

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1. Introduction

Determining a person's identification by skeletal and dental characteristics yields extensive information and persuasive proof that is crucial for regular forensic investigations.[1,2] Forensic odontology deals with the proper handling and examination of dental evidence and evaluation and presentation of dental findings.[3,4]

Human identification is one of the principal areas of research in forensic science and can be accomplished by determining patient's gender, age and race. Comparative identification and reconstructive identification are common methods.[4,5,6,7]

Even though standard methods like DNA profiling, finger prints, anthropometric data, and dental records can be used, there are times when it makes sense to use some of the less common and uncommon ancillary methods, like cheiloscopy, palatoscopy, and other odontometric measurements, which, when carried out, yield relatively reliable results.[5]

Study of these lip prints and palatal rugae are respectively known as cheiloscopy and rugoscopy. These anatomical structures are said to be unique to a person. Lip prints develop during sixth week, whereas rugae develop during the third month of intrauterine life.[6,7]

Lip prints seldom alter in pattern and can withstand a variety of pathological conditions, however, palatal rugae are protected by lips, cheeks, tongue, teeth, and bone thus making them stable in position and shape, with the exception of length changes caused by growing.[4,8]

Both lip prints and rugae pattern can be directly or indirectly recorded at a crime scene.[7,8] Lip prints and palatal rugae patterns are distinctive personal traits that, in forensic odontology, can lead to crucial information and aid in the identification of an individual. Nevertheless, there aren't many examples that compare the accuracy of rugoscopy with cheiloscopy for identifying people.[5,6] Therefore, the study's objective was to evaluate the validity of palatal rugae pattern and lip prints for gender identification.

2. Objectives

The objectives of the study is to ascertain how lip prints are used to identify people,to distinguish between male and female lip prints based on gender,to identify the palatal rugae pattern in humans, to compare the patterns of palatal rugae in males and females in order to distinguish between genders and to assess how reliable palatal rugae patterns and lip prints are for identifying people and separating genders.

3. Methods

A total of 136 subjects were randomly selected from the outpatient department of Oral Medicine & Radiology and a detailed case history proforma was filled. The subjects were equally divided into two groups according to gender. The gender of an individual was blinded for the study. An informed consent was obtained from every patient. Inclusion criteria included participants in good health and had not undergone any orthodontic treatment, or suffering from any inflammation, trauma, or congenital anomalies involving lips or palate. Those with lip or palatal lesions, cleft lips/palate, history of plastic or reconstructive surgery, and hypersensitivity to lip sticks and dental materials were excluded from the study. The study protocol was approved by of Institutional Ethical committee.

For cheiloscopy, lipstick was applied using applicator brushes, which was applied at the midline and proceeding laterally. To distribute the lip stick uniformly, the subjects were instructed to rub both lips. After letting the lipstick dry for roughly two minutes, lip prints were captured. Scotch MagicTM tape was used to take individual lip prints. These prints were adhered to white paper using a technique akin to that expounded by Sivapathasundharam et al. Each person's lip prints were digitized at a resolution of 600 ppi using an image scanner. The pictures were scanned in grayscale after being inverted. For optimal detail, they were saved as TIFF (Tagged Image File Format) files. As recommended by Augustine et al., the most readable prints of each lips taken separately were cropped, and vertical lines were made to divide the lips into three pieces using Adobe® Photoshop® 7.0 software. Lip prints was classified according to the Suzuki and Tsuchihashi (1970).[9] The data obtained from various measurements was recorded on the proforma.

For rugoscopy high quality alginate impressions were made of maxillary arch and dental casts were obtained using Dental stone (Gypsum Type 4). A pointed graphite pencil was used in sufficient light to trace the

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outline of rugae on casts. The magnifying glass was used to examine the palatal rugae pattern. Modified Lysell classification was used to do the analysis.[10] Based on their shape, the rugae were classified into four categories. The rugae pattern was categorized as straight if it ran straight from the origin to the termination, circular if it formed a distinct continuous ring, wavy if it was slightly curved at the origin and termination, and undetermined if it did not fit into any of the aforementioned categories.

Statistical anaylsis was performed using the Statistical Package for Social Sciences (SPSS) version 16 and Epi Info version 6.0. Paired, Unpaired t- test, ANOVA , Chi-Squrae test and Pearson's correlation coefficient tests was used to determine the various parameters.

4. Results

The present study was done on 136 subjects (age above the 18 years) of both genders (68 males and 68 females). Table 1 shows predominant pattern of lip print in males and females. Type V pattern was most predominant in 36 (52.94%) males and Type I and I' was least common in 1 (1.47%) males respectively. Type I pattern was most predominant in 32(47.06%) females and none of the females showed type III and type V pattern. The results were statistically highly significant for type I, type I', type II and type V patterns ($p<0.01$).

Table 2 shows predominant pattern of rugae in males and females. Curved pattern was most predominant in 32(47.06%) males and unification was least common in 1(1.47%) male. Wavy pattern was most predominant in 42 (61.76%) females and none of the females showed unification pattern. The results were statistically highly significant for type I, type I', type II and type V patterns ($p<0.01$). A highly significant difference was found for curved pattern ($p<0.01$) and significant difference for wavy pattern ($p<0.05$) were found.

Table 3 shows distribution of total number of primary rugae in males and females.The mean number of primary rugae in male was 7.85(±1.91) and in female it was 8.31(±1.62). However, the results were non significant.

5. Discussion

In the current study, we sought to determine the differences in lip and rugae patterns as well as the relative validity of palatal rugae patterns and lip prints for gender differentiation and human identity in 136 participants. Similar studies have been previously reported in literature.[11,12,13,14,15] A small number of scholars have split each lip print into the central section, left lateral, and right lateral.[12,13] Few studies have focused on the 10 mm-wide central region of the lower lip as done in our study.[14,15] Additionally, Vanguru et al (2023)[16] separated lip prints into eight quadrants. The midline of the lip print was used to split it into two quadrants, each of which was then further separated into equal sections called medial and lateral. In this study the lip prints were categorized following the scheme Suzuki and Tsuchihashi published in 1970.

Researchers have previously studied lip prints to demonstrate that there is a gender difference in lip prints. The results in the current study showed a predominance of the type I pattern was seen in males. The results results of this study was not in accordance with previous report by Manikya S et al (2018) where Type I and type I patterns were shown to be dominant in females, but type II and type IV patterns were prominent in men.[17] Another research by Uzomba GC et al (2023)[18] revealed that male participants had distinct patterns whereas all four quadrants with the same type of lip prints were more common in female subjects. Six variations of type V patterns have been described by Vitosyte M et al (2023).[19] These include "cartwheel appearance", "pineapple skin appearance", "trifurcation", "bridge or "H"pattern", "horizontal lines" and "multiple branching appearances." Uzomba GC et al (2023)[18] have depicted "circular shaped area with minute dots,""oval shaped area with horizontal lines," and "small leaf like structure with central line and branching lines" among others. people categorized as type V. In the current study no further classification of Type V was done.

While analyzing palatal rugae patterns, no significant difference was found in the total number of primary rugae and length of primary rugae in males and females, reinforcing the fact described by other researchers.[20,21] But, few studies revealed that males showed a higher in total number of primary rugae.[22,23,24]

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Some of the studies concluded that the wavy shape was more common in females while curved shape was more common in males. But, few of studies observed that the wavy pattern was common in males as well as females.[21,23] In the current study, curved shape was more common in males while wavy shape was more common in females.

Thus it can be put forth that lip prints and rugae pattern can act not only as a means of identifying individuals but they also have a high rate of accuracy in gender determination. But they have a major drawback too, as lips and rugae are soft tissue structures they are prone to changes post mortem and can also be injured in course of accidents etc. Very little data base is available on lip prints and rugae worldwide right now as the major emphasis is on structures which tend to remain stable postmortem. Lip prints and rugae pattern though may not be very valuable in cases of mass disasters where the body is mutilated or decomposed these can be very valuable in cases where both the victims and suspected perpetrators can be examined soon after the incident.

In conclusion, the study proves that both cheiloscopy and rugoscopy have the potential to identify an individual also lip prints are more reliable in identifying the sex of an individual as compared to palatal rugae patterns. Thus, lip prints and palatal rugae hold potential as a supplementary tool, along with the dentition, to establish the identity of an individual. Nevertheless, the larger samples should be examined in detail to further validate the findings of this study and come to definitive conclusions.

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Table 1: Genderwise predominant pattern of lip print

Predominant pattern of lip print	**Gender**		**P value**
	Male (%)(n=68)	**Female (%) (n=68)**	
I	1(1.47)	32(47.06)	<0.01
I'	1(1.47)	27(39.70)	<0.01
II	7(10.29)	9(13.23)	>0.05
III	19 (27.94)	0 (0.0)	<0.01
IV	6(8.82)	3 (4.41)	>0.05
V	36(52.94)	0 (0.0)	<0.01

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Table 2 : Genderwise predominant shape of rugae

Predominant shape of rugae	**Gender**		**P value**
	Male(%)(n=68)	**Female(%)(n=68)**	
Curved	32(47.06)	14(20.59)	<0.01
Wavy	29(42.65)	42(61.76)	<0.05
Straight	11(16.17)	12(17.65)	>0.05
Unification	1(1.47)	0 (0.0)	>0.05

Table 3: Distribution of total number of primary rugae in males and females

Gender	**N**	**Mean**	**SD**	**Mean Difference**	**95%Cl of the Mean difference**		**P value**
					Lower	Upper	
Male	68	7.85	1.91	-0.46	-1.06	0.14	>0.05
Female	68	8.31	1.62				

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Unveiling Biological and Therapeutic Properties of Calotropis Procera: A Promising Traditional Medicine

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KEYWORDS

Calotropis procera; Phytochemistry; Traditional medicine; Pharmacognosy; Anti-cancer; Anti-inflammatory; Antioxidant, Oral Health, Dental Disorders, Dentistry

ABSTRACT:

Since the dawn of civilization, people have utilized plants as a secure and efficient form of treatment for a variety of illnesses. A number of traditional medicines are formed from certain plants with medicinal and therapeutic properties. It has long been known that Calotropis procera offers potential as a therapy for many different conditions. This xerophytic, erect shrub is native to the tropics of Asia and Africa, where it reaches a height of roughly 6 meters. Numerous illnesses, such as rheumatism, fever, diarrhea, diabetes, malaria, asthma, and many more, have been treated using its constituents.

The latex has demonstrated strong benefits against inflammation, cancer, wound healing, hepatoprotection, inflammation prevention, nerve regeneration, antiulcer, insecticidal, and antimalarial bacteria. The study also discovered that consuming too much has detrimental impacts on health. The study found a wealth of documentation supporting the biological assessment of C. procera in both in vitro and in vivo animal models. However, human safety and efficacy remain to be fully investigated, and more carefully planned clinical trials are needed to validate preclinical results. Establishing a standard dose and ensuring its safety are crucial.

This review provides the biological information that is currently available about the potential therapeutic and biological uses of C. procera for the management of various illnesses with an insight on its potential applications in oral health and dentistry.

1. INTRODUCTION

Herbal remedies have been employed over thousands of years to cure ailments in individuals as well as animals.[1] Plants have historically been trusted as a reliable source of both preventive medicine and therapy in many cultures. In many parts of the developing world, herbal remedies continue to be the main source of healthcare.[2] Traditional medicines are used to address prevalent healthcare concerns by 80% of the global population, primarily in developing countries. In nearly all cultural backgrounds, they are used as nutrition and as a medicine. [3,4] Even more astounding is the fact that plants serve as the foundation for around 25% of modern medications.[4] Their use greatly enhances the provision of basic medical care and they are seen as indispensable sources of medicinal items, including herbal remedies. The healthcare and biopharmaceutical sectors have made bioactive plant products an essential component of their scientific and technological advancement. [5] A species of plant in the Asclepediaceae family called *Calotropis procera (C. procera*), commonly known as "Madar," has been utilized for centuries in ancient therapy. This shrub is continuously subjected to harsh conditions, but it nevertheless yields latex and grows well in natural environments.[5,6] The plant discharges a creamy latex substance, which is particularly prevalent in its aerial segments, when it is wounded. In addition to being rich in beneficial additional chemicals and enzymes, it shields the plant against damage and has been revered in traditional medicine for its diverse therapeutic properties.[5,6] Indigenous communities have utilized various parts of the plant for centuries, recognizing its potential in treating a range of ailments. The latex extracted from *Calotropis procera* has demonstrated notable anti-inflammatory properties, making it valuable in managing conditions like arthritis and skin disorders. Additionally, the plant exhibits antimicrobial effects, contributing to its application in wound healing and skin infections. [7,8]

The roots of *C. procera* have been traditionally employed for their analgesic qualities, offering relief from pain associated with conditions such as rheumatism and muscular injuries. Its efficacy in addressing respiratory issues has also been acknowledged, attributing the plant's use in overall well-being.[8] Furthermore, it has shown potential as an anti-cancer agent, with certain compounds exhibiting cytotoxic effects on cancer cells that has sparked interest in its potential role in modern medicine. [9] This review aimed to conduct a thorough literature assessment on the biological and therapeutic importance of its constituent parts. This article also discusses its potential benefits for dental health and how its ingredients are used in dentistry.

2. METHODS

An electronic search through PubMed, Scopus and Google Scholar for “Calotropis procera”, “antioxidant”, “traditional medicine”, “anti diabetic”, “anti bacterial”, “anti viral”, “anti microbial”, “ethnopharmacology”, “toxicity”, investigating a number of studies. Then, we consecutively screened abstracts and, full-text articles published in English. A total of 138 articles were found in PubMed and 9 duplicate papers were excluded. Additionally, 85 articles were excluded as they were case reports, case series, editorials, letter to editor, commentaries and conference proceedings. Finally, 45 papers published in last 20 years were analyzed in this article. In Figure 1, were analyzed in this review.

3. REVIEW

Anti inflammatory property

In pharmacologic models of formaldehyde-induced arthritis, cotton pellet granuloma, and carrageenin-induced foot oedema in rats, significant dose-related activity was demonstrated for a chloroform-soluble fraction ($p<0.001$). When it came to preventing the development of foot oedema, the extract at a specific and substantial doze was effective.[10] Macroscopic and microscopic analyses has revealed that colonic mucosal damage in colitic rats is much decreased after receiving Methanol extract of dried latex (MeDL) therapy, and oxidative stress level in tissues and proinflammatory mediators were recovered.[11] Also the plant extract exhibits the strongest anti-inflalmmatory effects with IC50 values of 7.6 μM against 5-LOX and 2.7 μM against 15-LOX,. [12] The extract administered at 100 and 200 mg/kg, significantly reduced inflammation. At these dozes, the extract shows 21.6 and 71.6% inhibition, respectively. This extract at doses 50 and 500 mg/kg has also proven to decrease inflammation in rats with arthritis.[13] In vivo testing at dosages of 200 and 400 mg/kg, respectively has also shown considerable anti-inflammatory effectiveness employing hydroalcoholic and chloroform extracts of this plant.[14]

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Anti microbial property

Studies have demonstrated both antibacterial and antifungal properties of *C. Procera* in it different forms. These properties have been found in cardenolide (proceragenin) against S. aureus, S. pyogens and S. saprophyticus and in the ethanol extract of the leaves and latex against E. coli and P. aeruginosa of this plant. Water-soluble extract (250 µg/mL) has been found effective against C. perfringens and S. faecalis. The maximum efficiency against the examined bacterial strains has been demonstrated by the crude flavonoid fraction and the leaf and bark extracts prepared with 50% methanol are effective against B. subtilis and K. pneumonia. [16]

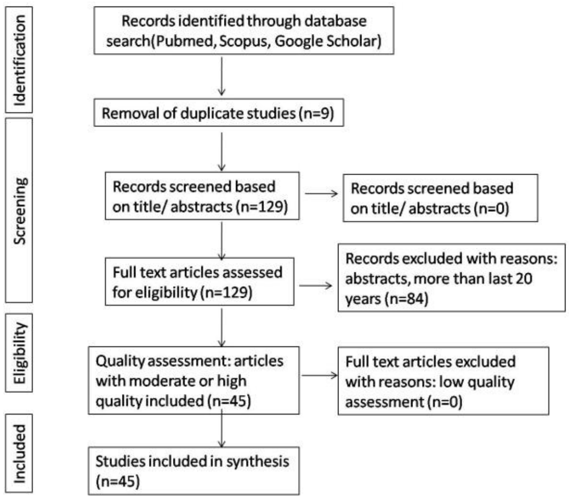
Many antifungal properties have also been found in it's extract, however, ethanol and chloroform extracts showed remarkable performance over water extract and were effective against C. albicans.[16] Crude flavonoids were the most effective portion of flavonoids, which had 30 mm-diameter inhibitory zones against C. albicans. T. rubrum and A. terreus after being treated with Latex silver nanoparticles. The IC50 values of all the peptidases (procerain and procerain B) evaluated in previous studies were approximately 50 µg/mL thereby inhibiting the fungi in vitro.[17]

Antioxidant and anti–cancer property

Studies have demonstrated that the plant extracts accounts for 42–90% free radical scavenging activity with 2,2-Diphenylpicrylhydrazyl (DPPH) radical scavenging assay. Also in the assays using hydrogen peroxide and hydroxyl radicals, the methanol extract exhibited maximum scavenging activity (83.63%) at 500 µg/mL over ferric thiocyanide, while the DPPH assay revealed least activity (50.82%).[18] The use of dry latex of this plant for 31 days, decreases Thiobarbituric acid-reactive substances (TBARS) levels. Root extracts and ethanol floral extract have lowest level of antioxidants (IC50 = 0.27 mg/mL, IC50 = 142 µg/mL), while lyophilized latex extracts and aqueous flower extract have greatest values (IC50 = 0.060 mg/mL, IC50 = 85 µg/mL) as a radical scavenger.[19] For DPHH, the ethyl acetate extract has the most radical scavenging activity (95%), followed by ethanolic floral extract (88.1%) and aqueous extract of methanol (85.5%).[20] Antioxidant property by the phenolics is exhibited by the location of the functional groups surrounding their nucleus and the quantity and configuration of their H-donating hydroxyl groups present within calotropogenin, calotropin, latex and calotoxin parts of the plant.[21]

Wound healing Activity

In a study topical application of sterile latex solution has improved wound healing due to its ability to stimulate collagen, DNA, and protein production resulting in re-epithelization of the wound.[22] Similar studies on rats demonstrated faster wound healing time and wound contraction after application of the extract.[23]



4. DISCUSSION

4.1 Provenance of the plant and phytochemistry

C. procera, erect, velvety woody shape achieves a height of 2.5–6 m. It is found everywhere in the world because it prefers temperatures that are warm, dry, sandy, and alkaline soils. It grows well in a range of various habitats, such as sand dunes, highway channels, swamps, waste dumps, and derelict areas.[24] It harbors a rich tapestry of phytochemical constituents, contributing to its diverse therapeutic properties. The phytochemical profile of this plant encompasses a variety of compounds, each playing a distinct role in its pharmacological activities. [25]

Alkaloids and Terpenoids:

Calotropin and Uscharin are notable alkaloids found in *C. procera*, contributing to its anti-inflammatory

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properties. These compounds have been associated with inhibiting inflammatory mediators. Terpenoids like β-sitosterol contribute to the overall pharmacological profile of *C. procera* and is a phytosterol with potential anti-inflammatory and analgesic effects. Tannins, including gallic acid, contribute to the astringent properties of *C. procera*. These compounds may play a role in wound healing and tissue repair. [26]

Flavonoids and Glycosides:

C. procera contains flavonoids with antioxidant properties such as Quercetin and Kaempferol Derivatives. These compounds play a role in scavenging free radicals and contribute to the plant's overall therapeutic potential. An active glycoside found in the latex of *C. procera*, known for its antimicrobial properties is Calotropin, which contributes to the plant's efficacy in addressing various microbial infections. Certain parts of *C. procera* contain cardiac glycosides, such as calotoxin. However, caution is advised in their use due to potential toxic effects, emphasizing the importance of proper dosage and preparation. [27,28]

4.2 <u>Biological and Therapeutic activities pertaining to oral health</u>

C. procera emerges as a versatile traditional medicine, offering a spectrum of therapeutic benefits. From addressing inflammatory and microbial challenges to providing relief in pain management of various dental disorders, the plant also holds promise across various healthcare domains.

4.2.1 Anti-Inflammatory and Analgesic Activity:

The presence of compounds like calotropin and uscharin present in the latex of this plant atribute to this activity. These compounds inhibit the synthesis of prostaglandins, suppress pro-inflammatory cytokines and inhibit NF- kB activation ultimately leading to overall anti-inflammatory effect. Root extracts of *C. procera* showcase analgesic properties, offering relief from pain associated with rheumatism and muscular injuries thereby attributing in pain management.[29]

4.2.2 Antimicrobial Potency:

The robust antimicrobial activity against bacteria and fungi is due to presence of proceroside, proteolytic enzymes, syriogenine, cardenolides, carbohydrates, cardiac-active glycosides, calactin, calotropain, calotoxin, alkaloids, tannins, flavonoids, and procerain present in the plant. It disrupts the integrity of cell membrane, inhibits the ergosterol synthesis and alters the fungal cell wall components collectively contributing to the antifungal effect.[30,31]

4.2.3 Antioxidant and Anti-Cancer Potential:

Flavanol glycosides, cardinolides and lignans present in this plant exhibit promising cytotoxic effects on cancer cells, suggesting a potential role in cancer treatment. The exploration of its anti-cancer pharmacology opens avenues for further research in oncological applications.[29]

4.2.4 Wound Healing activity

The extract from this plant contains triterpenoids such as amyrin, flavonoids, cardiac glycosides, cardenolide anthocyanins, mudarine, lupeol, sitosterol, flavanols, resin, a nontoxic proteolytic enzyme called calotropin, and a strong bacteriolytic enzyme called calactin. These products stimulate the proliferation of fibroblasts and collagen deposition, facilitating tissue repair and regeneration. Additionally, these extracts exhibit analgesic effects, which alleviate pain associated with wounds. The plant's ability to enhance angiogenesis, the formation of new blood vessels, further supports tissue repair by ensuring an adequate blood supply to the wounded area.[32]

4.3 <u>Biological and Therapeutic activities pertaining to general and overall health</u>

4.3.1 Respiratory Health Benefits:

The plant's products are effective in managing respiratory conditions such as asthma and bronchitis. Active compounds contribute to bronchodilation and anti-inflammatory effects, supporting its traditional use in respiratory ailments.[33]

4.3.2 Antifertility Activity:

This is attributed to its ability to disrupt various stages of reproductive function. It may inhibit spermatogenesis in males and interfere with ovarian function in females, leading to contraceptive effects.[34]

4.3.3 Antiglaucoma Activity:

Studies have shown that extracts of *C. procera* possess is believed to reduce intraocular pressure, which is a key factor in the pathogenesis of glaucoma, thereby helping to manage the condition.[35]

4.3.4 Antimalarial Activity:

Its bioactive compounds have been found to inhibit the growth and replication of the malaria parasite, making it

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a promising candidate for malaria treatment and prevention.[36]

4.3.5 Antidiarrheal Activity:

The products of this plant have the ability to reduce intestinal motility and secretion, alleviating diarrhea by exerting an inhibitory effect on various pathways involved in diarrheal mechanisms.[37]

4.3.6 Anticonvulsant Activity:

Calotropis procera demonstrates anticonvulsant effects, making it potentially useful in the management of epilepsy and other seizure disorders. Its bioactive constituents modulate neurotransmitter activity and neuronal excitability, thereby reducing the frequency and severity of seizures.[38]

4.3.7 Antidiabetic Activity:

Studies have indicated that *Calotropis procera* exhibits antidiabetic properties by lowering blood glucose levels and improving insulin sensitivity. Its mechanisms of action include enhancing pancreatic function, promoting glucose uptake by cells, and inhibiting carbohydrate digestion and absorption.[39]

4.3.8 Hepatoprotective Activity:

Calotropis procera demonstrates hepatoprotective effects, which can help safeguard the liver against various insults and toxins. It aids in the regeneration of liver cells, reduces oxidative stress, and inhibits inflammation, thereby promoting liver health and function.[40]

4.4 Toxicology:

Despite its therapeutic promise, it's essential to approach the use of *C. procera* with caution, as improper dosage or preparation can lead to adverse effects. Integrating traditional knowledge with contemporary research will enhance our understanding of this plant's medicinal potential and pave the way for its responsible incorporation into modern healthcare practices. Caution is warranted in the utilization of *C. procera*, as certain parts of the plant contain toxic compounds, including cardiac glycosides. Improper dosage or preparation may lead to adverse effects. Rigorous studies on toxicology are imperative to establish safe usage guidelines and mitigate potential risks associated with its traditional medicinal applications.[41]

5. CONCLUSION:

Nature contains vast array of compounds that may be used to create remedies for a variety of chronic diseases. Numerous therapeutic plants and their components have been shown to –provide great therapeutic benefits and one such plant is *C. procera*. Calotropis procera's journey from phytochemistry to pharmacology unfolds a narrative of diverse therapeutic potential. As research progresses, understanding its toxicological aspects becomes paramount for safe integration into healthcare practices. This comprehensive review sheds light on the intricate interplay of phytochemical constituents, pharmacological actions, therapeutic applications, and the imperative need for cautious exploration in the realm of *C. procera*.

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Systematic Review Article

Human Urinary Metabolomics as Biomarkers in Tobacco Users: A Systematic Review

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Abstract

Aim: Urine as a biofluid has been rarely used as a diagnostic fluid in oral diseases. The article aims to systematically review the utility of human urinary carcinogen metabolites as an approach for obtaining important information about tobacco and cancer. **Materials and Methods:** The following article reviews the use of urine and its metabolites as biomarkers in various lesions of the oral cavity including oral squamous cell carcinoma and as a screening method in evaluating tobacco and its components. A bibliographic comprehensive search was carried out in the main databases: PUBMED, SciELO, Google Scholar, VHL, and LILACS for articles that were published from 1985 to 2020. The inclusion criteria were “urinary metabolites,” “oral cancer/HNSCC,” “body fluids,” “tobacco,” and “metabolomics.” A total of 55 articles were collected which included laboratory studies, systematic reviews, and literature of urinary metabolites in tobacco users. **Results:** Most of the studies carried out show accurate results with high sensitivity of urinary metabolite biomarkers in individuals with tobacco-based habits and lesions caused by them. **Conclusion:** The review indicates that urinary metabolite analysis demonstrates its applicability for the diagnosis and prognosis of disease. Urine is a remarkable and useful biofluid for routine testing and provides an excellent resource for the discovery of novel biomarkers, with an advantage over tissue biopsy samples due to the ease and less invasive nature of collection.

Keywords: *Biomarkers, body fluids, carcinogenesis, metabolites, urine*

Introduction

The use of body fluids can be an interpretative tool in the diagnosis of various diseases.[1] Body fluids such as blood and urine have been used in pathology for quite some time.[2] Laboratory tests carried out in these body fluids can help know the presence or absence of disease to its severity and prognosis in a patient.[1] Recent advances in the field of biologic science have sparked new interest in the area of identifying biomarkers in body fluids. It has been shown that mutations present in the primary tumors or disease can also be identified in the body fluids of the affected patients.[2,3] Cancer-related analysis in blood, urine, and cerebrospinal fluid has been used successfully as cancer biomarkers.[4]

The oldest known test on body fluids was done on urine in ancient times (before 400 BC).[5] Urine is a very useful biofluid for routine testing and a wonderful means for discovering novel biomarkers. It has an advantage over tissue biopsies due to the ease and noninvasive nature of collection.[6] The current article is an attempt to review such urinary biomarkers that can be studied in tobacco users and oral squamous cell carcinoma (OSCC) patients.

Tobacco kills half of its users. More than 8 million tobacco users are killed annually. Eighty percent of the world’s tobacco users are from developing nations. Smoked and smokeless tobacco forms are the two main ways to consume tobacco. Both are equally damaging to health and addictive.[7] These forms of tobacco contain toxic chemicals and constituents that are carcinogenic having cancer-promoting substances. Vast epidemiological studies conclude the risk of oral cancers and premalignant conditions attributed to tobacco use and dependence.[8] Other possible causative risk factors such as age, gender, alcohol, diet, and human papillomavirus may be associated, but tobacco is the most common.[9,10]

The incidence of head-and-neck (H and N) cancer exceeds half a million cases annually worldwide.[11] Oral cancer is the sixth most

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common human cancer, with a high morbidity rate and an overall 5-year survival rate of <50%.[12] About 75% of H and N cancers are oral cancers, and 90% of oral cancers are diagnosed as OSCCs.[13] It has been proven that the development of OSCC is associated with tobacco use. Various studies show how tobacco can cause epigenetic alteration of oral epithelial cells through its toxic metabolites and induce OSCC.[8] H and N cancers tend to be malignant in nature with chances of recurrence. Their prognosis has not improved despite technological and therapeutic advances.[14,15] There is an urgent need to discover more biomarkers for diagnosis, prognosis, therapeutic response prediction, and population screening of human cancers, which can hopefully improve treatment and reduce cancer mortality. Pathophysiological stimuli by such risk factors such as tobacco can alter the metabolic profile of biofluids such as urine, serum, saliva, and blood which can be used as an advanced and precise screening modality in disease state.[16] Urinary metabonomic analysis demonstrates its applicability for the diagnosis and prognosis of disease[17-19] and can be used as a complementary approach for early detection of oral cancer (OSCC)[20,21] [Figure 1].

Materials and Methods

The present systematic review was conducted according to the guidelines provided by the PRISMA statement. Published literature was searched to discuss the use of urinary metabolites as a biomarker for oral lesions as a screening tool in tobacco users. A comprehensive bibliographic search in the main electronic databases: PubMed (www.pubmed.gov), SciELO (www.scielo.org), Google Scholar (www.scholar.google.com.br), BVS (http//bvsalud.org/), and LILACS (http://lilacs.bvsalud.org) was performed using the inclusion criteria "urinary metabolites," "tobacco," "biomarkers," "body fluids," and "metabolomics." We collected papers with cross-references that were published from 1985 to 2020. The search included original laboratory studies, systematic reviews, and literature that were developed on human species. The search included a total of 55 articles from wherein we reviewed the utility of urinary metabolites as biomarkers in tobacco users.

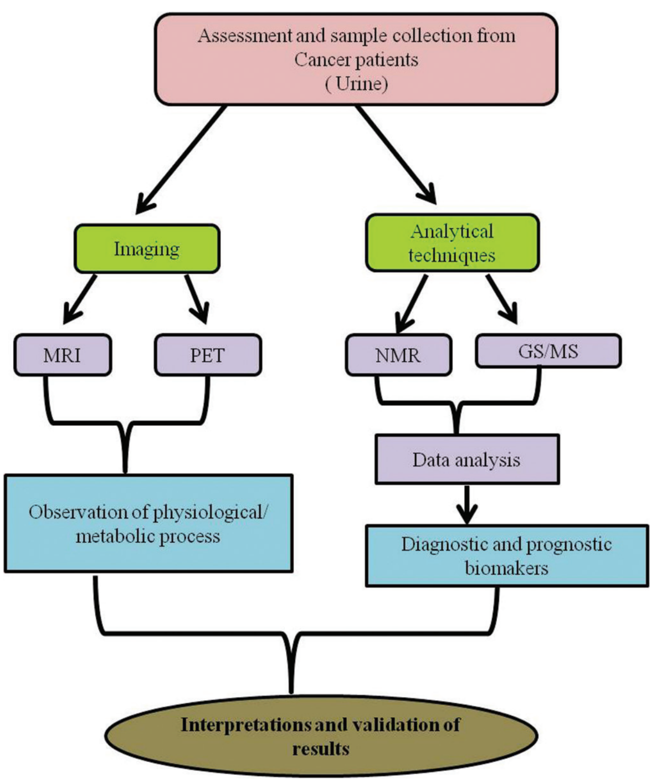


Figure 1: Step-wise method to use urinary metabolites as biomarkers in cancer screening

Urinary carcinogenic metabolites

Measurement of human urinary carcinogen metabolites is a practical approach for obtaining important information about tobacco and cancer.[22] Studies and research material show that OSCC and precancerous lesions are not only because of aberrant expression of genes and proteins but also abnormal concentrations of endogenous metabolites. Urine samples are not commonly used in H and N cancer metabolomic studies as compared to other body fluids, whereas it is widely used by metabolomic researchers for other conditions or diseases as it is easy to obtain and has a wide metabolic cover.[23]

Several types of carcinogenic biomarkers have been used till date. Human urinary carcinogenic metabolites can be an alternative means of detecting toxicity and carcinogenesis in subjects with tobacco habits [Figure 2]. Biomarkers from urine can help us understand tobacco-related cancer mechanisms. This will also help us develop preventive strategies which may decrease the toll of cancers[24] [Figure 3].

Urinary metabolites in tobacco smokers and nonsmokers

Carcinogenesis links nicotine addiction and cancers. Tobacco is consumed in various forms by millions of people in India. Individuals who do not smoke are exposed to passive smoking. These tobacco products contain thousands of chemical constituents including major alkaloids (nicotine) and minor alkaloids (noricotine, anabasine, anatabine, etc.). These alkaloids can react with nitrite to form nitrosamines such as 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone (NNK) and 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanol (NNAL), which are called tobacco-specific nitrosamines. These tobacco constituents are important progenitors in the formation of tobacco-specific nitrosamines.[25] The major constituents of tobacco such as nicotine, cotinine, and nitrites + nitrates are excreted in the urine of tobacco-exposed individuals and used as the markers of tobacco exposure. Methods such as thin-layer chromatography, high-performance liquid chromatography (HPLC), gas chromatography (GC), and mass spectrophotometry (MS) can be used to estimate urine cotinine and nicotine levels in urine. Tobacco exposure to electrophilic moieties increases

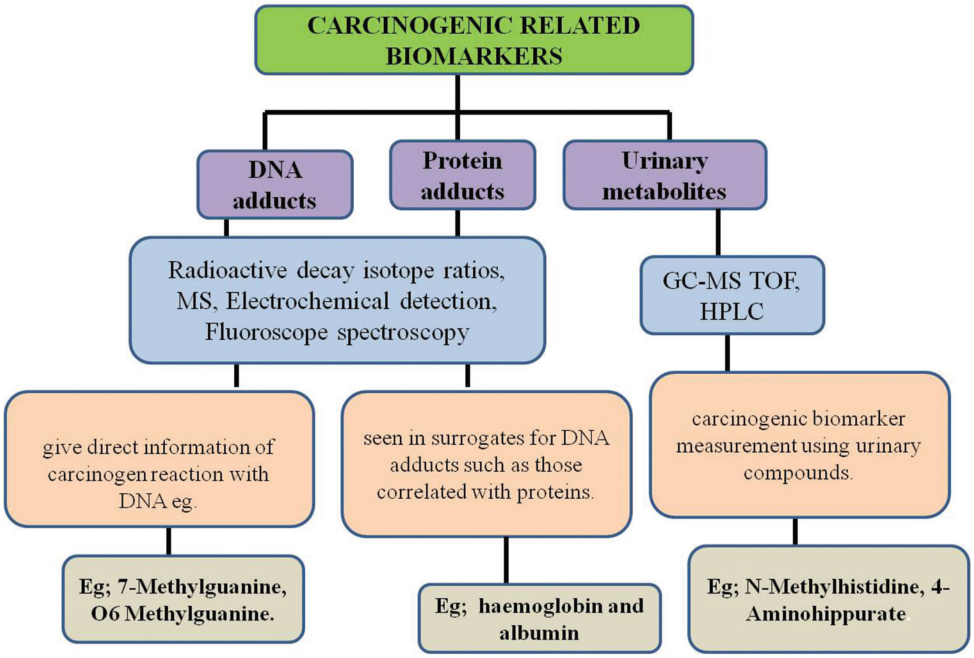


Figure 2: Types of carcinogenic biomarkers

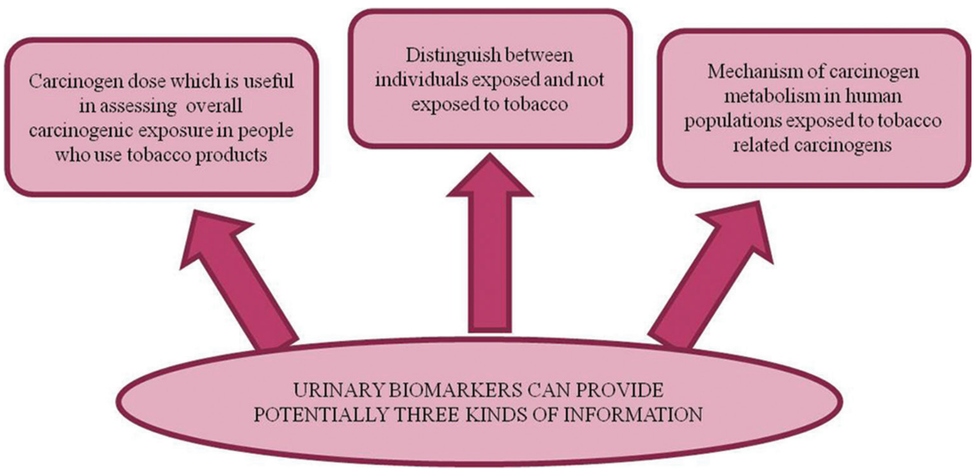


Figure 3: Uses of urinary biomarkers

urinary thioether levels which is another useful biomarker of tobacco exposure.[16,24-26]

Measurements of urinary compounds have many advantages. Important among these is their quantity which is sufficient enough with the use of modern analytical methods giving reliable data. Urine is simple to obtain in large quantity, and compliance is not a problem.[5,22,27]

Results

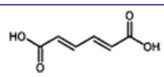
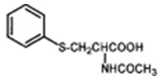
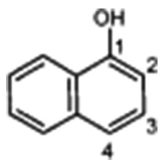
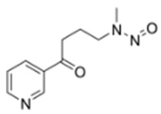
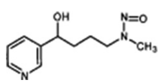
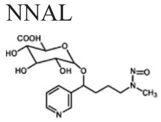
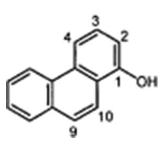
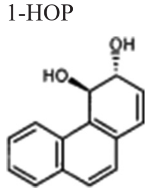
While reviewing the articles and literature, we came across various studies where urinary metabolites were assessed in smokers and nonsmokers. The studies showed results which supported and favored the presence of biomarkers in the urine of individuals with varying tobacco habits. The results of all those studies are summarized in Table 1 and further talked over in the discussion.

Discussion

Nuclear magnetic resonance (NMR) spectroscopy is a commonly used analytical method to analyze the small molecule composition that is the metabolome of body fluids such as urine and blood serum. Metabolite concentration is associated with the biochemical state of the organism. Conditions such as disease state and response to chemical treatment can change these metabolic concentrations. Recent studies demonstrate the applicability of NMR-based metabolomics using serum and urine samples for the diagnosis and prognosis of disease.[21]

Multiple researches on tobacco demonstrate that nicotine-derived nitrosamines such as NNK and NNN as well as nornicotine-, anabasine-, and anatabine-derived nitrosamines significantly contribute to tobacco carcinogenesis.[41] Wei

Table 1: Common Urinary Biomarkers

Chemical compound	Chemical structure of the urinary biomarker studies	Results in various studies and type of tobacco habit	
		Smokers	Nonsmokers
Benzene metabolite	 tt-MA	Significantly elevated levels in the urine of smokers. 1.4–4.8 times greater than nonsmokers[28] Boogaard *et al*.; no significant difference between tobacco habits[29]	No significant levels detected Mixed results obtained by environmental tobacco smoke-exposed subjects[22]
	 S-PMA	Significantly higher in smokers[30]	No significant levels detected
	 1-and 2-naphthol	Various studies suggest elevated levels in smokers[31,32] Nan *et al*. reported almost twice the levels in smokers and significant results (P<0.01)[33]	No significant levels were detected in studies
N-nitrosamine	 NNK		
	Strongest detected carcinogen that plays an important role in cancer induction (oral cancer, leukoplakia, and lung cancer)[34]		
	Ratio of the following two metabolites of NNK have been intensively studied and detected in the urine of tobacco habit users in assessing exposure and screening oral cancers		
	 NNAL	Identified in urine along with NNAL-O-Gluc as NNAL is not present in cigarette smoke[35]	Not excreted in urine[35] Exceptionally high levels of both NNAL and NNAL-O-Gluc excreted[36]
	 NNALgluc (conjugated glucuronide form of NNAL-O-Gluc)	Present in urine, comprise 50±25% of total NNAL-0-Gluc[37] Both NNAL and NNAL-O-Gluc found[34]	Present in urine, comprise 24±12% of total NNAL-0-Gluc[37] Both metabolites of NNK are readily determined in tobacco chewers and snuff dippers. Same levels as smokers[34]
Polyaromatic hydrocarbon	 1-HOP	Significantly higher levels in smokers in most studies. Many studies show twice and even more levels of 1-HOP in smokers than nonsmokers[22,38]	Nonsignificant levels detected
	 Phenenthrene-1,2-dihydrodiol and phenanthrene-3,4-dihydrodiol	The ratio between these two metabolites decreases further with an increase in smoking	Studies done by Jacob *et al*.[39] and Heudorf and Angerer[40] show similar results of lower ratio of the two metabolites in both habit groups

tt-MA: Trans,trans-muconic acid; S-PMA: S-phenylmercapturic acid; 1-HOP: 1-hydroxypyrene; NNK: 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone; NNAL: 4-(methylnitrosamino)-1-(-3pyridyl)-1-butanol

et al. in their study established that NNK levels in the urine of tobacco-exposed individuals can help investigators ascertain the best means to protect people's health and help prevent cancer.[42] As mentioned in Table 1, Murphy *et al*. in their study using urine samples analyzed NNAL, and its glucuronide NNAL-O-Gluc along with 1-hydroxypyrene and anatabine found a positive correlation between anatabine and urinary NNAL and NNAL-O-Gluc (both metabolites of the tobacco-specific carcinogen NNK) showing their usefulness as a biomarker of tobacco exposure.[36,43] Kresty *et al*. concluded a potentially important finding and relationship between the levels of NNAL, NNAL-Gluc along with cotinine in urine, and the presence of oral leukoplakia in their study.[34] Experiments have shown the induction of oral tumors in rat mucosa on applying a mixture of NNK metabolites validating the role of these products in inducing precancerous lesions of the oral cavity.[44]

One of the first attempts to study urine metabolites in screening oral lesions was done by Xie *et al*. using GC-MS in a combination of three differential metabolites. They used 6-hydroxynicotic acid, cysteine, and tyrosine to segregate between OSCC and OLK. Their study had a sensitivity and specificity of 85% and 89.7%, respectively, with an accuracy of 92.7%. Their study clearly indicated that urinary metabolite profiling can be a promising diagnostic tool for the early stages of OSCC and for differentiating between other oral lesions and conditions.[16]

As discussed in Table 1, benzene metabolites such as trans, trans-muconic acid (tt-MA) and S-phenylmercapturic acid (S-PMA) have been studied extensively to assess tobacco exposure and significantly high levels of these metabolites have been found in the urine of smokers.[28,29] Both tt-MA and S-PMA are the most sensitive biomarkers, the latter being more according to Boogaard.[29] Similarly, Nan *et al*. using benzene metabolites 1- and 2-naphthols came to the conclusion of the presence of high levels of these metabolites in smokers although no significant levels were noted in nonsmokers.[33]

The presence of polycyclic aromatic hydrocarbon metabolites in urine was first demonstrated by Jongeneelen[38] using HPLC, and since then, many variations to this method have been used to study the presence of these metabolites in the urine of tobacco-exposed individuals.

Besides the metabolites discussed above, studies to assess the role of tobacco habits as a risk factor for the development of oral cancer have been done by evaluating other urinary metabolites such as nicotine, cotinine, thioether, nitrite, and nitrate levels that have been compared in subjects with and without tobacco habit as discussed in the following section. Modified HPLC using a UV detector is used to analyze urinary nicotine and cotinine levels. Levels of nitrites + nitrates in tobacco and urine and urinary thioether levels are estimated by spectrophotometry. It has shown that tobacco chewing and smoking habits are prominent risk factors for the development of oral cancer. Urinary nicotine, cotinine, nitrite + nitrate, and thioether levels can be helpful for screening programs for oral cancer.[24,26]

Patel *et al*. in a study done in Gujarat, India, evaluated urinary nicotine, cotinine, thioether, and NO2 + NO3 levels in healthy individuals without habits of tobacco, healthy individuals with habits of tobacco, patients with oral precancers, and oral cancer patients; their results confirmed that tobacco chewing and smoking habits are prominent risk factors for the development of oral cancer. Urinary nicotine, cotinine, NO2 + NO3, and thioether levels can be helpful for screening programs for oral cancer.[24] In another study, Behera *et al*. using HPLC assay analyzed the urine of smokers and chewers for nicotine and cotinine levels and found these components as useful markers to assess the effects of different tobacco types.[45] Similarly, a study by Oberoi and Oberoi concluded a significant increase in urinary cotinine levels among smokers and smokeless tobacco individuals compared to nonsmokers.[46] Urinary cotinine is a widely used biomarker as it has the advantage of being 4–6 times more than blood or salivary cotinine and is highly sensitive when assessed.[47,48] Both smoked and chewed forms of tobacco are highly linked to the induction of OSCC. Higher risk is associated with greater amounts and longer duration of tobacco use.[24,41]

Urine metabolomics has emerged as an outstanding noninvasive realm in discovering biomarkers that can detect the slightest of metabolic discrepancies in response to a specific disease or therapeutic interpretation.[49] The development and advances in LC-MS/MS have revolutionized analytical studies of biomolecules including urine metabolome by enabling their accurate identification and in an unprecedented manner.[50] A study done by the Internal Radiation and Clinical Oncology Department, Maria Sklodowska-Curie Institute-Oncology Center, Poland, showed that metabolic alterations using NMR can be detected already at the beginning of the treatment, making it possible to monitor the patients with a higher risk.[51] MS-based metabolomic technology has provided exciting opportunities in the field of health and medical science. It is believed that, with the continuous progress in technologies, there will be more and more effective biomarkers for the diagnosis of clinical diseases and treatment.[52]

Conclusion

Urinary metabolomics is an efficient and accurate means to retrieve data about tobacco exposure and oral cancer. The biomarkers discovered and obtained from urine can enhance our knowledge and understanding of tobacco-related cancer mechanisms, which can help us evolve new strategies and action plans to help combat the loss of life to cancers. Various studies performed demonstrate that this robust and noninvasive profiling approach can be a promising screening tool for the early diagnosis of oral cancer. Furthermore, studies can highlight the applicability of urinary metabolite markers that can be used as a stratification tool in the diagnosis of different oral conditions, complementary to the existing clinical procedures.

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Conflicts of interest

There are no conflicts of interest.

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(57) Abstract :

One of the most common non-commutable types of chronic inflammatory disease is Periodontitis. It is the sixth most common disease affecting nearly 750 million population worldwide every year. It is very important to treat such Intrabony Osseous Defects, as if left untreated, it may lead to increased risk of disease progression sometimes leading to loss of teeth. Research studies suggest that piezoelectric surgical instruments with accurate precision would provide correct prediction of periodontal osseous defects. Any immediate reduction in periodontal dental angulation could be detected by bone swaging. Proposed is a System and Method to Detect the Depth of Intrabony Osseous Defect using Machine Learning. Input Cone Beamed Computed Tomography (CBCT) which provides inter-relational images in three orthogonal planes namely axial, sagittal and coronal and also customized planes are subject to Image Pre-Processing. Images are converted to Gray Scale and Binarization of images is carried out using Social Edge Detection to increase the object recognition rate. Target object recognition is trained using Convolutional Neural Networks. Multiclass Classifier and Bounding Box Regressor employed for each convolutional and pooling layers for accurate detection of depth of intrabony osseous defects.

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Cheiloscopy and Rugoscopy: A Scientific Approach for Sex Determination.

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KEYWORDS

Forensic dentistry, Human identification, Lip prints, Cheiloscopy, Palatal rugae.

ABSTRACT:

Introduction: The major areas of forensic dentistry include determining a patient's gender, age, race, and size as well as gathering dental evidence and reconstructing a patient's face over skeletal remains. Lip prints are said to be unique to a person and similar to fingerprints. The palatal rugae pattern has been regarded as one of the pertinent indicators for human identification in the field of forensic medicine because of its stability and uniqueness.

Objectives: To evaluate the effectiveness of palatal rugae pattern and lip prints for gender distinction and human identification. The objectives of the study were to distinguish between male and female lip prints and palatal rugae based on gender.

Methods: Subjects were randomly chosen from the OPD and an informed consent was obtained. Study was performed on 136 subjects equally divided into two groups according to gender. For rugoscopy all the dental casts were collected, duplicated and later analyzed. The legal age of the subject was confirmed using the case history proforma of the patients submitted along with the casts. The relevant demographic data including name, age, sex, address as well as findings from clinical examination were recorded for each selected individual in a specially designed Proforma.

Results: Considering both the lips, type V pattern was most predominant pattern in males followed by type III while type I pattern was most predominant pattern in females followed by type I. Predominant shape of rugae in females is wavy followed by curved and straight and in males is curved followed by wavy, straight and unification.

Conclusions: Both cheiloscopy and rugoscopy have the potential to identify an individual also lip prints are more reliable in identifying the sex of an individual as compared to palatal rugae patterns.

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1. Introduction

Determining a person's identification by skeletal and dental characteristics yields extensive information and persuasive proof that is crucial for regular forensic investigations.[1,2] Forensic odontology deals with the proper handling and examination of dental evidence and evaluation and presentation of dental findings.[3,4]

Human identification is one of the principal areas of research in forensic science and can be accomplished by determining patient's gender, age and race. Comparative identification and reconstructive identification are common methods.[4,5,6,7]

Even though standard methods like DNA profiling, finger prints, anthropometric data, and dental records can be used, there are times when it makes sense to use some of the less common and uncommon ancillary methods, like cheiloscopy, palatoscopy, and other odontometric measurements, which, when carried out, yield relatively reliable results.[5]

Study of these lip prints and palatal rugae are respectively known as cheiloscopy and rugoscopy. These anatomical structures are said to be unique to a person. Lip prints develop during sixth week, whereas rugae develop during the third month of intrauterine life.[6,7]

Lip prints seldom alter in pattern and can withstand a variety of pathological conditions, however, palatal rugae are protected by lips, cheeks, tongue, teeth, and bone thus making them stable in position and shape, with the exception of length changes caused by growing.[4,8]

Both lip prints and rugae pattern can be directly or indirectly recorded at a crime scene.[7,8] Lip prints and palatal rugae patterns are distinctive personal traits that, in forensic odontology, can lead to crucial information and aid in the identification of an individual. Nevertheless, there aren't many examples that compare the accuracy of rugoscopy with cheiloscopy for identifying people.[5,6] Therefore, the study's objective was to evaluate the validity of palatal rugae pattern and lip prints for gender identification.

2. Objectives

The objectives of the study is to ascertain how lip prints are used to identify people,to distinguish between male and female lip prints based on gender,to identify the palatal rugae pattern in humans, to compare the patterns of palatal rugae in males and females in order to distinguish between genders and to assess how reliable palatal rugae patterns and lip prints are for identifying people and separating genders.

3. Methods

A total of 136 subjects were randomly selected from the outpatient department of Oral Medicine & Radiology and a detailed case history proforma was filled. The subjects were equally divided into two groups according to gender. The gender of an individual was blinded for the study. An informed consent was obtained from every patient. Inclusion criteria included participants in good health and had not undergone any orthodontic treatment, or suffering from any inflammation, trauma, or congenital anomalies involving lips or palate. Those with lip or palatal lesions, cleft lips/palate, history of plastic or reconstructive surgery, and hypersensitivity to lip sticks and dental materials were excluded from the study. The study protocol was approved by of Institutional Ethical committee.

For cheiloscopy, lipstick was applied using applicator brushes, which was applied at the midline and proceeding laterally. To distribute the lip stick uniformly, the subjects were instructed to rub both lips. After letting the lipstick dry for roughly two minutes, lip prints were captured. Scotch MagicTM tape was used to take individual lip prints. These prints were adhered to white paper using a technique akin to that expounded by Sivapathasundharam et al. Each person's lip prints were digitized at a resolution of 600 ppi using an image scanner. The pictures were scanned in grayscale after being inverted. For optimal detail, they were saved as TIFF (Tagged Image File Format) files. As recommended by Augustine et al., the most readable prints of each lips taken separately were cropped, and vertical lines were made to divide the lips into three pieces using Adobe® Photoshop® 7.0 software. Lip prints was classified according to the Suzuki and Tsuchihashi (1970).[9] The data obtained from various measurements was recorded on the proforma.

For rugoscopy high quality alginate impressions were made of maxillary arch and dental casts were obtained using Dental stone (Gypsum Type 4). A pointed graphite pencil was used in sufficient light to trace the

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outline of rugae on casts. The magnifying glass was used to examine the palatal rugae pattern. Modified Lysell classification was used to do the analysis.[10] Based on their shape, the rugae were classified into four categories. The rugae pattern was categorized as straight if it ran straight from the origin to the termination, circular if it formed a distinct continuous ring, wavy if it was slightly curved at the origin and termination, and undetermined if it did not fit into any of the aforementioned categories.

Statistical anaylsis was performed using the Statistical Package for Social Sciences (SPSS) version 16 and Epi Info version 6.0. Paired, Unpaired t- test, ANOVA , Chi-Squrae test and Pearson's correlation coefficient tests was used to determine the various parameters.

4. Results

The present study was done on 136 subjects (age above the 18 years) of both genders (68 males and 68 females). Table 1 shows predominant pattern of lip print in males and females. Type V pattern was most predominant in 36 (52.94%) males and Type I and I' was least common in 1 (1.47%) males respectively. Type I pattern was most predominant in 32(47.06%) females and none of the females showed type III and type V pattern. The results were statistically highly significant for type I, type I', type II and type V patterns ($p<0.01$).

Table 2 shows predominant pattern of rugae in males and females. Curved pattern was most predominant in 32(47.06%) males and unification was least common in 1(1.47%) male. Wavy pattern was most predominant in 42 (61.76%) females and none of the females showed unification pattern. The results were statistically highly significant for type I, type I', type II and type V patterns ($p<0.01$). A highly significant difference was found for curved pattern ($p<0.01$) and significant difference for wavy pattern ($p<0.05$) were found.

Table 3 shows distribution of total number of primary rugae in males and females.The mean number of primary rugae in male was 7.85(±1.91) and in female it was 8.31(±1.62). However, the results were non significant.

5. Discussion

In the current study, we sought to determine the differences in lip and rugae patterns as well as the relative validity of palatal rugae patterns and lip prints for gender differentiation and human identity in 136 participants. Similar studies have been previously reported in literature.[11,12,13,14,15] A small number of scholars have split each lip print into the central section, left lateral, and right lateral.[12,13] Few studies have focused on the 10 mm-wide central region of the lower lip as done in our study.[14,15] Additionally, Vanguru et al (2023)[16] separated lip prints into eight quadrants. The midline of the lip print was used to split it into two quadrants, each of which was then further separated into equal sections called medial and lateral. In this study the lip prints were categorized following the scheme Suzuki and Tsuchihashi published in 1970.

Researchers have previously studied lip prints to demonstrate that there is a gender difference in lip prints. The results in the current study showed a predominance of the type I pattern was seen in males. The results results of this study was not in accordance with previous report by Manikya S et al (2018) where Type I and type I patterns were shown to be dominant in females, but type II and type IV patterns were prominent in men.[17] Another research by Uzomba GC et al (2023)[18] revealed that male participants had distinct patterns whereas all four quadrants with the same type of lip prints were more common in female subjects. Six variations of type V patterns have been described by Vitosyte M et al (2023).[19] These include "cartwheel appearance", "pineapple skin appearance", "trifurcation", "bridge or "H"pattern", "horizontal lines" and "multiple branching appearances." Uzomba GC et al (2023)[18] have depicted "circular shaped area with minute dots,""oval shaped area with horizontal lines," and "small leaf like structure with central line and branching lines" among others. people categorized as type V. In the current study no further classification of Type V was done.

While analyzing palatal rugae patterns, no significant difference was found in the total number of primary rugae and length of primary rugae in males and females, reinforcing the fact described by other researchers.[20,21] But, few studies revealed that males showed a higher in total number of primary rugae.[22,23,24]

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Some of the studies concluded that the wavy shape was more common in females while curved shape was more common in males. But, few of studies observed that the wavy pattern was common in males as well as females.[21,23] In the current study, curved shape was more common in males while wavy shape was more common in females.

Thus it can be put forth that lip prints and rugae pattern can act not only as a means of identifying individuals but they also have a high rate of accuracy in gender determination. But they have a major drawback too, as lips and rugae are soft tissue structures they are prone to changes post mortem and can also be injured in course of accidents etc. Very little data base is available on lip prints and rugae worldwide right now as the major emphasis is on structures which tend to remain stable postmortem. Lip prints and rugae pattern though may not be very valuable in cases of mass disasters where the body is mutilated or decomposed these can be very valuable in cases where both the victims and suspected perpetrators can be examined soon after the incident.

In conclusion, the study proves that both cheiloscopy and rugoscopy have the potential to identify an individual also lip prints are more reliable in identifying the sex of an individual as compared to palatal rugae patterns. Thus, lip prints and palatal rugae hold potential as a supplementary tool, along with the dentition, to establish the identity of an individual. Nevertheless, the larger samples should be examined in detail to further validate the findings of this study and come to definitive conclusions.

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Table 1: Genderwise predominant pattern of lip print

Predominant pattern of lip print	**Gender**		**P value**
	Male (%)(n=68)	**Female (%) (n=68)**	
I	1(1.47)	32(47.06)	<0.01
I'	1(1.47)	27(39.70)	<0.01
II	7(10.29)	9(13.23)	>0.05
III	19 (27.94)	0 (0.0)	<0.01
IV	6(8.82)	3 (4.41)	>0.05
V	36(52.94)	0 (0.0)	<0.01

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Table 2 : Genderwise predominant shape of rugae

Predominant shape of rugae	Gender		P value
	Male(%)(n=68)	Female(%)(n=68)	
Curved	32(47.06)	14(20.59)	<0.01
Wavy	29(42.65)	42(61.76)	<0.05
Straight	11(16.17)	12(17.65)	>0.05
Unification	1(1.47)	0 (0.0)	>0.05

Table 3: Distribution of total number of primary rugae in males and females

Gender	N	Mean	SD	Mean Difference	95%Cl of the Mean difference		P value
					Lower	Upper	
Male	68	7.85	1.91	-0.46	-1.06	0.14	>0.05
Female	68	8.31	1.62				

Case Report

Radiological Study of Synovial Chondromatosis of the Temporomandibular Joint

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Abstract

Temporomandibular joint disorders (TMDs) are usually accompanied by changes in the bone structure of the TMJ brought on by degenerative processes. Osteophytes, erosion, flattening, subchondral sclerosis, pseudocysts, TMJ remodeling, articular cartilage abrasion, bone degradation, and synovial inflammation are among the characteristics of degenerative joint disease. Synovial chondromatosis (SC) is one of the degenerative joint conditions, which is defined by the growth of cartilaginous nodules, which are typically loose in the joint space of the synovial membrane. Its appearance in the TMJ, however, is more uncommon than in other large joints such as the knee and hip and is accompanied by preauricular pain, swelling, and restricted mouth opening. However, we recently encountered cases of degenerative joint disorder, i.e., of SC of TMJ, which showed the typical histopathological findings along with the typical imaging findings on Panoramic radiography (PAN) TMJ and cone-beam computed tomography images.

Keywords: *Cone-beam computed tomography, degenerative joint disease, synovial chondromatosis, temporomandibular joint, temporomandibular joint disorders*

Introduction

TMD stands for temporomandibular disorder, which refers to a group of clinical signs and symptoms involving the masticatory muscles, temporomandibular joint (TMJ), and associated tissues, or both, and is one of the most common causes of orofacial pain. Pain, joint noises, and restricted mandibular movements are all symptoms of TMDs.[1] Temporomandibular joint loose bodies mainly prompt synovial chondromatosis (SC). Mainly involves large joints like the knee, but its presence in a smaller joint like TMJ have been observed, with the propensity in females in their fourth and fifth decades of life and rare in children.[2] Flattening, erosion, osteophytes, subchondral bone sclerosis, pseudocysts, etc., are all associated with TMJ disc displacement and degenerative alterations.[3,4]

Radiographic examination is a crucial factor for better understanding the disease dysfunction and organizing appropriate treatment strategies. Panoramic and transcranial radiography, magnetic resonance imaging (MRI), arthrography, ultrasonography, computed tomography (CT), and cone-beam CT (CBCT) are some of the techniques that can be utilized to study the bone changes in the TMJ (CBCT).[5] However, CBCT has been increasingly used for the diagnosis of degenerative TMJs due to its advantages over other imaging modalities such as being cost-effective, lower radiation dose, and high diagnostic quality.[3,4] This article presents two cases of degenerative changes in TMJ with the correlation of the suitable imaging modalities.

Case Reports

Case 1

A 52-year-old female reported to the department of oral medicine and radiology with the complaint of pain in the preauricular area while opening and closing the mouth for the past 2–3 months with no relevant medical and dental history. Extraoral examination revealed a diffuse swelling on the right and left preauricular region. On palpation, tenderness was revealed on the right and left preauricular region, left and right masseter muscle, with the mouth opening (35 mm) with right side mandibular deviation.

On radiologic evaluation, the panoramic radiograph showed no significant

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Figure 1: PAN temporomandibular joint image showing flattening and beaking of the condylar head. PAN: Panoramic radiography

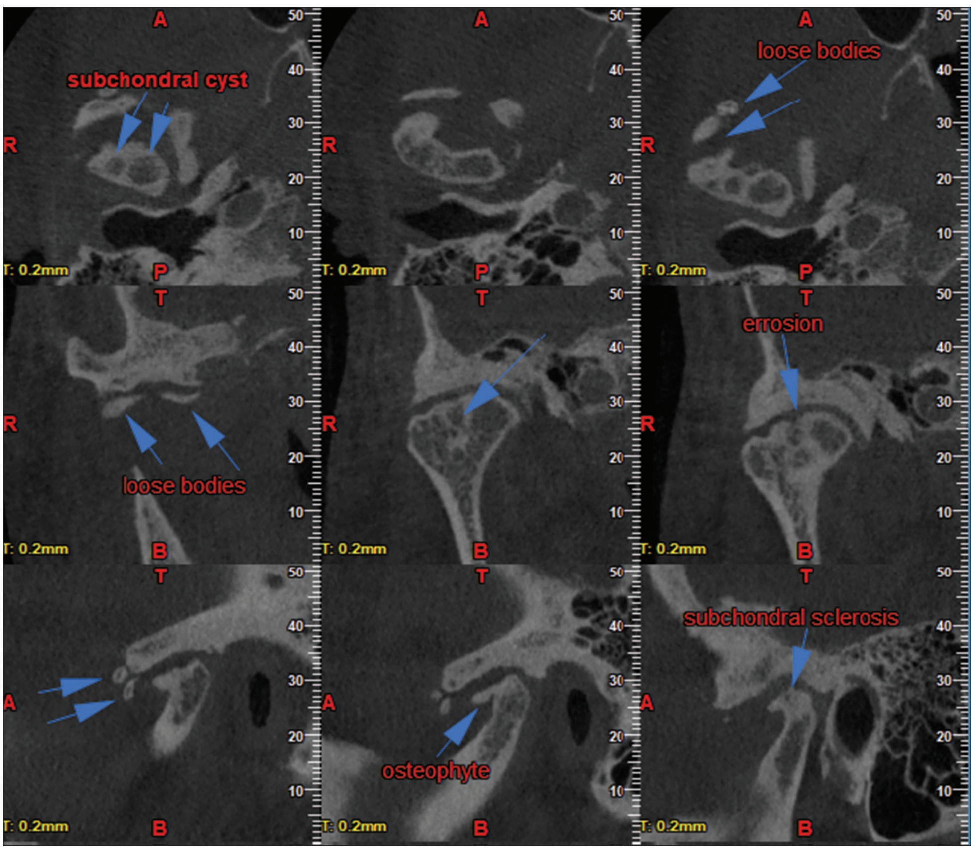

Figure 2: Cone-beam computed tomographic images. Sagittal, coronal, and axial view showing subchondral cyst, sclerosis, osteophytes, erosion, and loose bodies (blue arrows)

pathological bony changes and the PAN TMJ radiograph reveals the beaking of the right condyle [Figure 1]. Hence, the final clinico-radiological diagnosis for the present case was given as arthralgia with respect to right and left TMJ and degenerative joint disorder with respect to right TMJ. The patient were given pharmacologic intervention along with the physical therapy (low-level laser therapy) for 45 days. After treatment and follow-up sessions, the patient was relieved from the signs and symptoms, and the treatment was stopped. After one and half years, he revisited with the same complaint with an active mouth opening of 29 mm. The right and left TMJ, masseter muscles were tender on palpation. The occlusion remains unchanged, but a clicking sound was detected on the left and right TMJ.

The patient was advised CBCT and right TMJ revealed the presence of focal areas of erosion on the articulating surface of the condyle with mild subchondral sclerosis, a bony projection on the anterior aspect of the condylar head

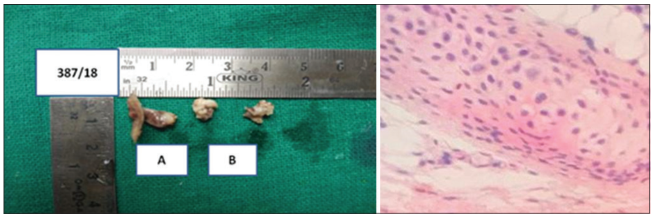

Figure 3: (A) Multiple calcified nodules with variable sizes creamish brown in color excised from the joint space. (B) Histopathological observation showing dense collagen fibers and nodules with typical chondrocytes in chondroid matrix

and a subchondral cyst on the middle superior third of the condylar head. There are separate multifocal calcified loose bodies evident at the articular eminence level. On left TMJ, a focal area of mild erosion and mild subchondral sclerosis suggestive of early changes of arthritis with mild flattening on the articulating surface of the condyle is evident [Figure 2]. Hence, the clinical and radiological impression of SC with respect to right TMJ and osteoarthritis with respect to left TMJ was given.

Ethical approval was obtained from the legal and ethical committee of the institute. The patient was explained about the procedure and informed consent was obtained. Under general anesthesia, surgical removal of the mass through a preauricular approach was performed. Microscopically, the biopsy revealed connective tissue with several isolated chondroid matrix nodules and calcified regions. The synovial cover was hyperplastic with larger chondrocytes. Multiple nodules of hyaline cartilage with an even distribution of chondrocytes made up the loose bodies and histopathological assessment showed chondroid metaplasia with fibrosis and calcifications, which gave a definitive diagnosis of SC [Figure 3]. The patient's mouth opening improved significantly over the course of a year and in the clinical illustration, there were no unpleasant symptoms.

Case 2

A 45-year-old female was referred to the department of oral medicine and radiology with pain on the right and left TMJ region while chewing for the past 3–5 months with no significant medical and dental history. After an extraoral examination, a preauricular swelling along with spontaneous pain, with a limited mouth opening of 30 mm, and deviation of the mandible to the left side was observed. On palpation, tenderness was revealed on the masseter muscle.

On radiological evaluation, the panoramic and PAN TMJ radiograph showed no significant pathological bony changes. Hence, the final clinic-radiological diagnosis for the present case was given as disc displacement with reduction and myositis. The patient was given treatment with pharmacologic and physical therapy (low-level laser therapy). After 1 month of treatment and follow-up sessions, the patient was relieved from the signs and symptoms, and the treatment was stopped. After 5 months, she revisited with the complaint of restricted mouth opening of 25 mm with pain on the right and left TMJ. The occlusion remains the same as before, but a crepitus sound was detected on the right and left right TMJ.

The patient was advised CBCT and right and left TMJ revealed the presence of focal areas of erosion on the articulating surface of the condyle with mild subchondral sclerosis. The articulating surface of the condyle has a flattening. Hence, the clinical and radiological impression of SC and osteoarthritis with respect to right and left TMJ was given.

Discussion

SC is a benign, chronic, and progressive condition which usually affects large joints such as the knee or shoulder and small joints like TMJ. SC of TMJ is mainly seen more in females as compared to males (4:1) and usually involves the right TMJ (right TMJ:left TMJ ratio is 4:1).[6] Due to psychological variables such as stress, the progression and severity of bone changes on the TMJ advances with age. The presented case was consistent with the case reported by Bae *et al*.,[3] Pinto *et al*.[7] where they reported the predilection for females in the fourth to fifth decade of life. The hormonal impacts of estrogen and prolactin, which may worsen cartilage deterioration in addition to activating a series of immunologic responses in the TMJ, could explain female predominance.[4]

In both of the above-mentioned cases, the patient complained of pain in the preauricular region, restricted mouth opening, and crepitus. Emshoff *et al*.[8] and Bae *et al*.[3] studies showed that TMJ pain might be associated with a high rate of degenerative changes such as osteophytes and erosion, which may prove pain-related variables in degenerative joint disorders. It is documented in the literature that the degenerative changes show some degree of inflammation and result in pain in the preauricular region, which was consistent with the present cases where the patient reported pain and swelling in the right and left TMJ region.[3]

In contrast to the above findings, there are studies that support the hypothesis that there is a poor correlation between bony changes and pain.[9]

Osteophytes, erosion, flattening, sclerosis, and pseudocysts are common bone deformations in degenerative joint disease. In the present study, we found that erosion, flattening, osteophytes, and sclerosis were the predominant findings of the degenerative process, which was also in agreement with the results of Bae *et al*.;[3] whereas dos Anjos Pontual *et al*.[4] presented somewhat different results with the others as they stated that only the flattening and osteophytes degenerative bone changes were frequently observed in the cases.

In the present study, both cases reported pain in the masseter muscle which can possibly be understood by the hypothesis behind this bone change which may be the result of an adaptive modification, the first change of progressive disease, or degenerative change linked to internal disturbance, which could explain flattening. Flattening is a degenerative change that occurs when the TMJ is overloaded, and it is linked to the involvement of the masseter and temporal muscles.[4]

Osteophytes form when the body adapts to reconstruct the joint at an advanced stage of degeneration. The osteophyte, which represents zones of neo-formed cartilage, appears to stabilize and widen the surface in an attempt to alleviate the overload caused by occlusal stresses. Erosion is the first sign of degenerative changes in the TMJ, signaling that it is unstable and those changes in bone surfaces will occur, most likely leading to occlusion alterations.[4]

According to various researchers, degenerative bone changes are significantly more frequent in the condyle than the articular eminence, which was in concurrence with the present case findings.[10]

SC is a rare pathological entity, especially in TMJ, which does not spontaneously respond to nonsurgical treatments. Therefore, surgical intervention is needed, mainly arthroscopy, open surgery, and combined with synovectomy, which is useful for the primary treatment of small and large loose bodies. Along with the surgical approach, follow-up examination is suggested initially because of the chances of recurrence.

A primary diagnosis is difficult due to the low incidence of SC in the TMJ and the lack of specific symptoms and indications. Thus, CBCT or MRI will probably be helpful imaging modalities for early diagnosis, which may promote adequate therapy and improve the prognosis.

In conclusion, SC is a benign pathological disorder that is more common in women, who are more prone to degenerative bone abnormalities in the TMJ. Degenerative bone changes become more common as people age, especially in their fourth and fifth decades. Erosion, sclerosis, flattening, and osteophytes are the most prevalent degenerative bone changes. Although the recurrence rate is modest, early detection is important for a better prognosis.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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Case Report

Sialolithiasis in Sublingual Glands Involving the Floor of the Mouth: A Case Report

Abstract

Sialolithiasis is a benign condition involving the formation of stones within the ducts of the major salivary glands: parotid, submandibular, and sublingual glands. It is the most frequent cause of salivary gland swelling, with a reported incidence of 1 in 10000–1 in 30000. It can obstruct the salivary ducts, leading to inflammation, superimposed bacterial infection termed sialadenitis, or, in rare cases, abscess formation. And decreased salivary flow rate. Treatment options for sialolithiasis, including sialogogues, direct massage of distal stones out of the duct, and other procedures, including interventional sialography, sialoendoscopy, and surgical management. In this article, we report a 20-year-old female presented with a case of sublingual gland Sialolithiasis treated with simply milking of the duct.

Keywords: *Salivary stone, salivary calculi, sublingual gland stone*

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Introduction

One of the most common disorders of the salivary glands is sialolithiasis. A history of pain or/and swelling in the salivary glands, especially during meals, suggests this diagnosis.[1] It can obstruct the salivary ducts, leading to inflammation, superimposed bacterial infection termed sialadenitis, or in rare cases, abscess formation. And decreased salivary flow rate.[2] Recent diagnostic techniques involve occlusal radiograph, ultrasound, computed tomography, magnetic resonance imaging, and direct visualization with sialoendoscopy.[2] Treatment options for sialolithiasis, including sialogogues, direct massage of distal stones out of the duct, and other procedures, including interventional sialography, sialoendoscopy, and surgical management. For small and accessible stones, conservative therapies like the milking of ducts with palliative therapy can produce satisfactory results. Surgical management should be considered when the stone is large in size as conservative therapies turned out to be unsatisfactory.[3,4] In this article, we present a case report of sialolithiasis in the sublingual gland treated surgically, maintaining its anatomy and patency of the excretory duct.

Case Report

A 20-year-old patient reported with the primary complaint of needing her teeth cleaned because she was concerned about maintaining proper oral hygiene. She was unaware of the condition of the stone in her sublingual duct. On examination, no gross facial asymmetry was detected [Figure 1], and intra-orally, a superficial salivary gland stone was found on the floor of the mouth as an incidental finding. A well-defined solitary nodular swelling was seen on the floor of the mouth which measured approximately 1 cm × 1 cm in its maximum dimension. The swelling showed a yellowish hue, and it was hard and nontender on palpation. No bleeding and discharge of pus was evident [Figure 2]. On asking for history, she revealed minimal swelling on the floor of the mouth during meals associated with slight discomfort for 3 months. However, as the swelling used to subside on its own, the patient never bothered to get a professional's help. The investigation included an occlusal radiograph which radioapaque well-defined structure on the floor of the mouth lingual to mandibular central incisors [Figure 3]. The features were suggestive of sialolithiasis on the floor of the mouth. As per the treatment plan, the patient was preoperatively given Vitamin C chewable tablets for 3 days to increase the salivary flow. After 3 days, the patient was recalled, and under local anesthesia the duct was stabilized and incision was placed over the stone region and the stone was removed by milking of the duct. Sutures were not

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taken to maintain the patency of the duct.Sutures were not taken to maintain the patency of the duct. The excised specimen showed a hard tissue mass of 0.5 cm × 0.6 cm in size, brownish yellow, and hard in consistency [Figure 4]. On 1-week follow-up, no postsurgical complaints were reported, and the area showed satisfactory healing with no salivary obstruction, suggesting the patency of the duct was intact [Figure 5]. All the necessary consents were obtained from the patient for documentation and publication.

Discussion

Sialolithiasis is defined as the formation of calcific concentrations within the parenchyma or ductal system of the major or minor salivary glands. Most common calcifications are found in soft tissues of the orofacial region. It is seen in both major and minor salivary glands.[5] Most stones develop in the Wharton's duct of the submandibular gland, followed by the Stensen's duct of the parotid gland. Only 1%–6.5% of stones occur in the ductal system of the sublingual gland.[1] In the present case, the stone involved the floor of the mouth in the sublingual ductal area. The clinical incidence of sublingual gland sialolithiasis is much lower than that of submandibular gland sialolithiasis. The reason for this low incidence remains from an anatomic viewpoint, the duct of the sublingual gland is shorter and has multiple openings that may drain mucoid saliva more efficiently. Even if a stone develops, it may not cause total obstruction of saliva outflow and subsequent infection. Therefore, most sublingual gland sialolithiasis might be asymptomatic and undetected in clinical practice.[4,5] Furthermore, because both the ductal systems of the sublingual gland and the submandibular gland duct are located beneath the mucosa of the mouth floor, a stone in the sublingual gland duct may be misdiagnosed as submandibular gland sialolithiasis in clinical practice, especially when it is large and near the gland. In the present case, the patient was asyptomatic, and it was an incidental finding, and the patient revealed that the minimal swelling during meals used to resolve on its own after meals. The location of the stone and the involved gland must be known preoperatively because sublingual gland sialolithiasis is usually treated with resection of the sublingual gland with the stone through a transoral

Figure 1: Extra-oral picture showing no gross facial asymmetry

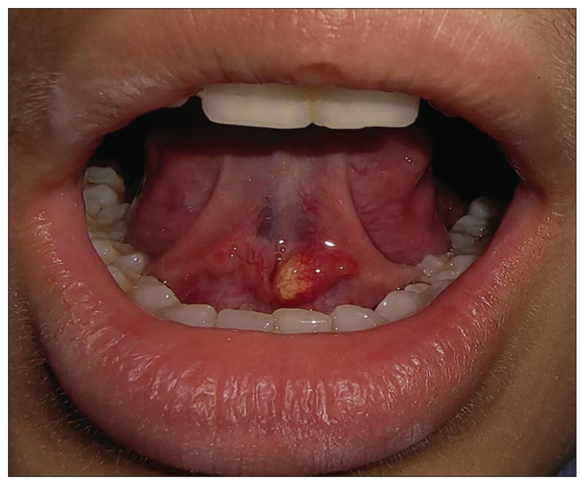

Figure 2: Intra-oral picture showing swelling on the floor of the mouth, which has a yellowish hue

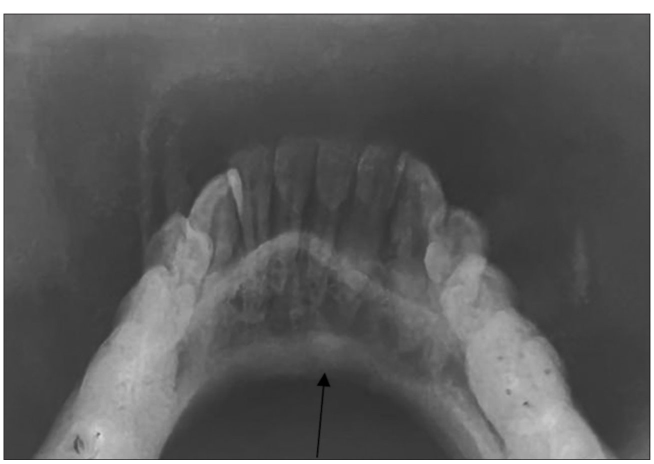

Figure 3: Occlusal radiograph shows the radiopaque structure (black arrow) suggesting salivary gland stone

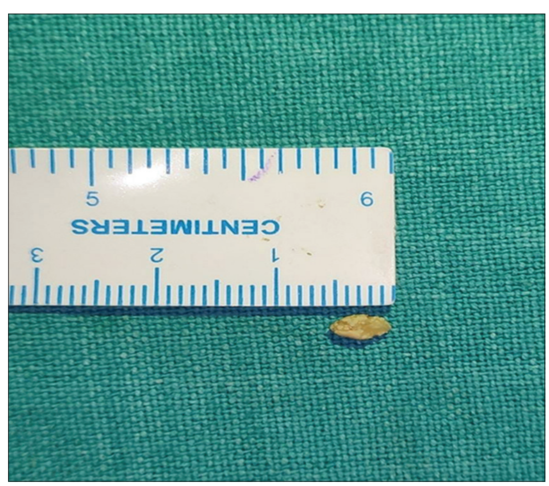

Figure 4: Excised specimen

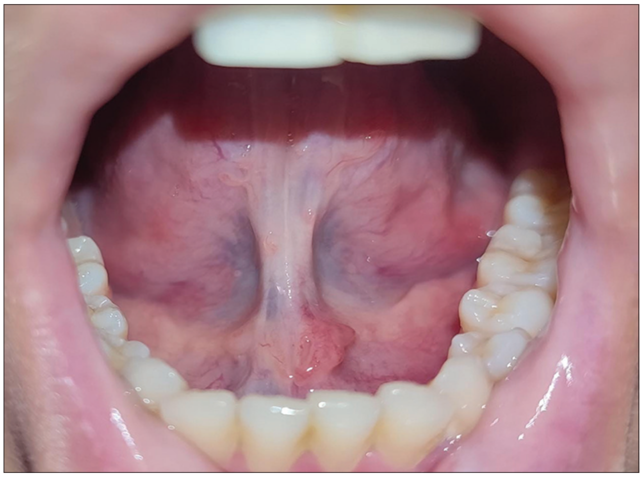

Figure 5: Intra-oral picture after 1 week showing satisfactory healing

approach.[5] Sialolithiasis is usually seen in adults between the ages of 20 and 40 years.[6,7] In the present report, the patient was in the second decade of life.

Treatment is most often surgical; however, when the sialolith is in the distal and end portion of the duct, manual milking or stimulation with lemon juice or sialogogues can be employed, which induces increased salivary secretion and favors the expulsion of the sialolith from inside the ductal lumen.[8] In the present case, management is done by stabilizing the lingual duct and then by giving an incision, facilitating stone removal by the milking of the duct. When the sialolith is located inside the glandular parenchyma, the excision of the gland should be considered. Other therapeutic modalities have been employed, such as CO_2 laser surgery, shock wave lithotripsy, and marsupialization of the duct with the placement of catheters inside, with satisfactory postsurgical results. Marsupialization does not promote ductal stenosis or total obstruction of its lumen by fibrous scar tissue.[1,3,5,6,8,9] When the surgical procedure cannot be performed, the application of botulinum toxin has been indicated, reducing saliva production and excretion.[8,9]

Conclusion

Sialolithiasis often affects the submandibular glands. In the present case, we present a case of involvement of the sublingual gland. The diagnosis should be based on clinical and radiographic features, on the basis of which we can decide the treatment. With minimal surgical intervention, the glandular structure can be saved, and the patency of the ductal system can be maintained, leading to an excellent prognosis.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient (s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and that due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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Original Article

Methylene Blue-mediated Photodynamic Therapy for the Treatment of Oral Leukoplakia

Abstract

Objective: To evaluate the efficacy of methylene blue-mediated photodynamic therapy (MB-PDT) for the treatment of oral leukoplakia (OL) and compare it to systemic Vitamin A therapy. **Materials and Methods:** Forty clinically and histopathologically confirmed cases of OL were included. They were divided into two groups: 20 were given systemic Vitamin A therapy and on the other group MB-PDT for 30 days. Pre- and posttreatment assessment of size of lesion and clinical appearance were done and followed up for 1 year to check for recurrence and delayed side effects. **Results:** The reduction in size of lesion pre- and posttreatment was statistically nonsignificant in the Vitamin A Group, but statistically highly significant in the PDT group according to unpaired *t*-test with no immediate or delayed side effects seen in both the groups. **Conclusion:** Both the treatment methods showed response in terms of reduction of size of lesion, but MB-PDT was a better treatment option for OL. **Clinical Relevance:** Oral cancer is often preceded by various premalignancies, OL being the most common among them. Early diagnosis and intervention will prevent malignant transformation thereby reducing the cost, side effect and mortality associated with oral cancer. Considering the prevalence, symptomless nature of OL, an effective, well-accepted mode of treatment with minimal side effects is of utmost need.

Keywords: *Leukoplakia, methylene blue, photodynamic therapy*

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Introduction

Oral cancer is regarded as one of the most common cancers in India, and it accounts for one-third of total oral cancer occurrences in the world.[1] It is preceded in a majority of cases by clinically evident oral potentially malignant disorders (OPMD), the most common of which is leukoplakia.[2] The WHO in 2005 redefined oral leukoplakia (OL) as "Leukoplakia should be used to recognize white patch of questionable risk having excluded other known diseases or disorders that carry no increased risk for cancer."[3] An increased risk of malignant transformation in association with OL is well documented; however, controversy still persists in terms of the appropriate management for these lesions.[4] Recognizing this relationship between OL and malignant transformation, early intervention and thereby prevention of malignant transformation becomes critical.

The etiology of OL is associated with various factors, of which tobacco in both smoking and smokeless forms is the most common.[5] The lesion of OL appears as a white keratotic adherent patch restricted to the epithelium.[6] Therefore, selective removal of this part of the epithelium seems to be a logical approach. Various techniques have been used for its treatment such as antioxidants like Vitamin A, C, and E, analogs of Vitamin A and beta-carotene, surgical excision, electrocautery, cryotherapy, and laser ablation, but there is still lack of a single well-accepted treatment for the lesion.

Photodynamic therapy (PDT) has been introduced as a method for diagnosis as well as treatment of potentially malignant and malignant disorders with no to minimal side effects or scar formation.[7,8] PDT involves two nontoxic components, i.e., light and photosensitizer (PS), that work together to induce cellular and tissue destruction in an oxygen-dependent manner. This technique is based on the administration of a PS which renders tumor tissue sensitive to light of a specific wavelength. On activation of the PS by light, a transfer of energy occurs from the light to molecular oxygen, resulting in generation of

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reactive oxygen species. This is the main mechanism by which PDT mediates tumor destruction. In addition, there are two other mechanisms: one being the damage of tumor-associated vasculature, leading to thrombus formation and subsequent tumor infarction, and another being PDT-associated activation of an immune response against tumor cells[9] [Figure 1]. PS may be injected intravenously, ingested orally, or applied topically depending on the type of agent.[10] In a number of previous studies, 5-aminolevulinic acid (ALA) has been successfully used in the diagnosis and treatment of neoplastic tissues.[7,8,11] ALA itself is not a PS but serves as the biological precursor of the PS, protoporphyrin IX. Cutaneous photosensitivity is a common adverse effect in clinical use of ALA as it takes 48 h to be cleared from the tissues and the body.[12] In the current study, we have used methylene blue (MB) as potential PS in the management of OL [Figure 1]. It is known to be an efficient singlet oxygen generator (and therefore potential PDT agent) and is highly biocompatible.

Thus, the aim of the present study was to evaluate the efficacy of MB-mediated PDT (MB-PDT) for the treatment of OL and compare it to the conventional treatment by systemic Vitamin A therapy.

Materials and Methods

Patient selection

This randomized controlled trial included a total of 40 participants, who were clinically diagnosed as OL. These patients were taken from the outpatient department of the hospital and the study was performed from December 2015 to November 2016.

Patients with systemic diseases, drug consumption, pregnancy, photosensitivity, age <20 years, or undergoing any other treatment for OL were excluded from the study. Patients who showed the presence of any local risk factors for the development of OL like sharp tooth edges were excluded as well.

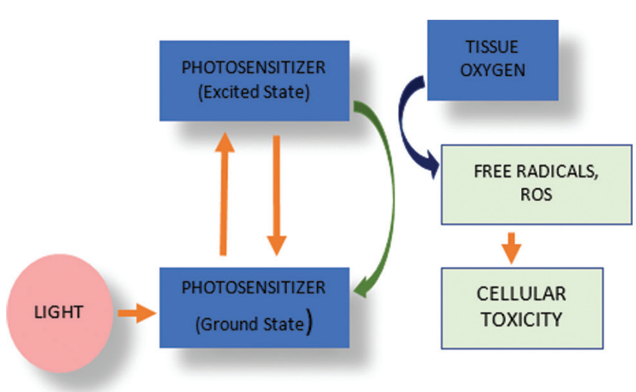

Figure 1: Mechanism of action of PDT. PDT = Photodynamic therapy, ROS = Reactive oxygen species

Procedure

The protocol of the study was approved by the ethical committee and informed consent was obtained from all subjects before commencement of the study. Clinical examination of the lesion was done on day 1 and clinical photographs of the lesions were taken. The patients were randomly divided into two groups:

A. Vitamin A group
B. PDT group.

All the patients had a habit of tobacco either in smoking or smokeless form. Counseling regarding the stoppage of habit and oral prophylaxis was performed 2 months before commencement of the study.

Vitamin A group

- Twenty Patients were prescribed systemic Vitamin A capsule (Aquasol A, 25,000 IU) twice a day for 30 days
- The patients were recalled on completion of course and then after 1 month.

Photodynamic therapy Group

- MB-PDT was performed on 20 patients. Twice a week for 3 weeks
- These patients were recalled 1 week after completion of treatment and then after 1 month.

Photodynamic therapy protocol

Commercially available 5% MB was used as PS for the study. The dye was applied on the lesion and marginal mucosa and left for 5 min. Following this, the patient was asked to rinse with water.

MB staining improved the visualization of the lesion in comparison to incandescent light. The lesion and 0.5 cm of their surrounding marginal zone was subsequently illuminated with diode laser (940 nm) in noncontact mode with a spot size of 1 cm^2. Large lesions were illuminated with multiple spots with two fractionations per week for 3 weeks [Figure 2].

Assessment

The lesions were examined clinically, and exact measurement of size was made, also clinical photographs were taken before and after the procedure and at each follow-up to evaluate for changes in appearance of the lesion. Follow-up was done up to 1 year to check for any recurrence. The response of the treatment was categorized as complete response (CR) - lack of detectable lesion on visual inspection; partial response (PR) - reduction of the lesion by at least 50% in diameter; and no response (NR) - stable lesion or reduction of lesion by <50% in diameter. The data were tabulated and statistical analysis was done. Unpaired Student's *t*-test was used for the comparison of changes in size of lesion; $P < 0.05$ was considered statistically significant.

Results

A total of 40 patients were included in the study with 20 patients in each group with maximum patients being Asian males (90%); the mean age of the patients was 45.27 and 44.67 in both groups, respectively [Table 1].

The mean size of the lesion at baseline in the Vitamin A and PDT group was 3.4 and 3.6 mm, respectively, which was statistically nonsignificant, stating that the samples were randomly distributed after matching the sizes.

The mean reduction in size of lesions seen in the Vitamin A group was statistically nonsignificant. A reduction was noted in the size of lesions in the PDT group from a mean of 3.6 mm to 2.51 mm, based on the paired Student t-test the results were statistically highly significant [Tables 2 and 3].

A statistically significant relationship was also obtained on comparison of the changes in size between the two groups according to unpaired *t*-test with $P < 0.05$ [Figure 3].

The overall response to the treatment was classified as complete, partial, or NR based on the earlier mentioned criteria. In the Vitamin A group, no patient showed CR and only 30% of patients showed PR, whereas in the PDT group, 40% of patients showed PR and three patients (15%) showed evidence of CR, i.e., absence of a clinically detectable lesion. No immediate or delayed side effects were seen in any patients in either of the groups. Repeated follow-up up to 1 year did not reveal any recurrence in any patient in both the groups except two patients in Vitamin A group, but this was related to the fact that these patients were unable to discontinue the habit soon after the completion of treatment [Table 4 and Figure 4].

Discussion

OL has the tendency to transform into oral cancer based on the amount of dysplasia and the extent of the lesion[13]

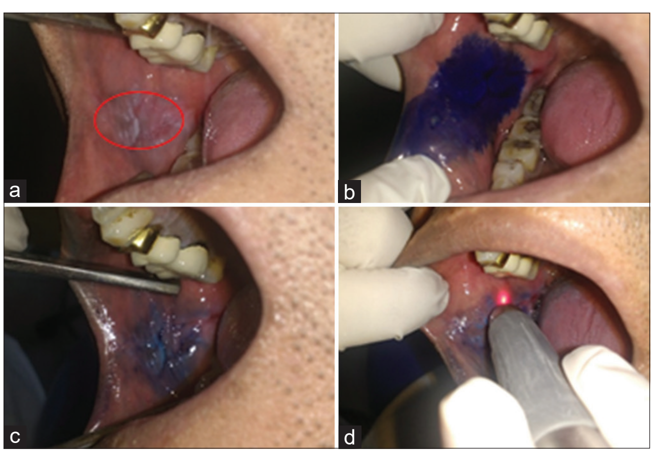

Figure 2: MB-PDT procedure on OL lesion: (a) OL lesion of the right buccal mucosa, the red circle marks the site of lesion (b) application of 5% methylene blue dye on the lesion by cotton applicator, (c) retained dye after rinsing with water, (d) application of 940 nm diode laser. MB-PDT = Methylene blue-mediated photodynamic therapy, OL = Oral leukoplakia

Since most of the lesions are asymptomatic, the primary objective of the treatment is the prevention of malignant transformation. The early diagnosis and intervention will not only avoid the morbidity and mortality associated with oral cancer but also save the cost of the expensive treatments and will drastically improve cure rate.[14]

Chemoprevention such as Vitamin A or other antioxidants can suppress or reverse the carcinogen, thus preventing its conversion to invasive stage.[15] Vitamin A is commonly

Table 1: Demographic data (*n*=40)

Age	
Group	Mean age
Vitamin A group	45.27
PDT group	44.67
Gender	
Male	36
Female	4
Location	
Buccal mucosa	37
Tongue	3
Total	40

PDT=Photodynamic therapy

Table 2: Changes in size of lesion in Vitamin A group

	Vitamin A group		*P*
	Mean	SD	
Baseline size of lesion	3.4	0.309	<0.05
Follow-up size of lesion	3.36	0.356	

SD=Standard deviation

Table 3: Changes in size of lesion in photodynamic therapy group

	PDT group		*P*
	Mean	SD	
Baseline size of lesion	3.6	0.452	>0.05
Follow-up size of lesion	2.51	0.99	

PDT=Photodynamic therapy, SD=Standard deviation

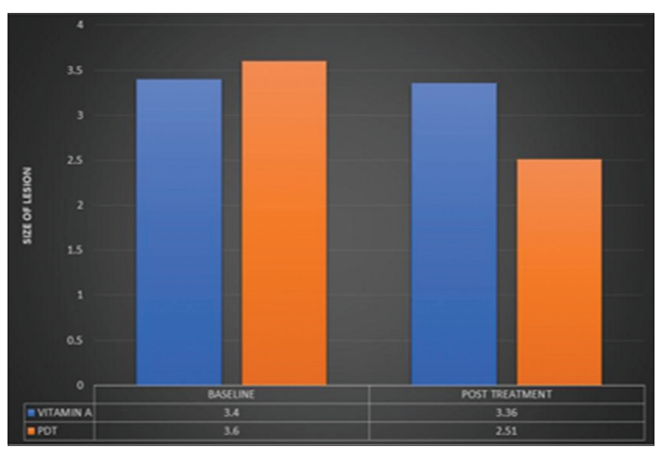

Figure 3: Graph showing reduction in size of lesion in response to Vitamin A and MB-PDT. MB-PDT = Methylene blue-mediated photodynamic therapy

Table 4: Overall response of lesion to treatment

	Vitamin A group, *n* (%)	PDT group, *n* (%)
No response	14 (70)	9 (45)
Partial response	6 (30)	8 (40)
Complete response	0	3 (15)
Total	20 (100)	20 (70)

PDT=Photodynamic therapy

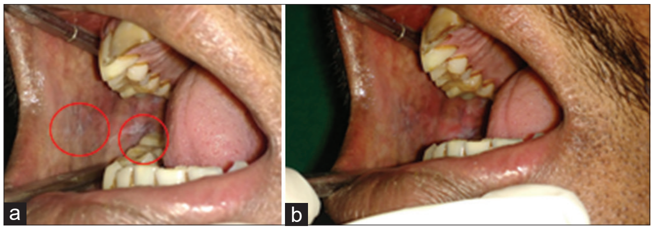

Figure 4: Response to PDT: (a) Pretreatment, red circle shows site of leion. (b) posttreatment picture of a lesion showing compete response. PDT = Photodynamic therapy

used in the treatment of OL can be administered in both topical and systemic forms, a number of studies in the past believe that the systemic administration is more effective for OL.[16] Its use is restricted due to its side effects: hypervitaminosis, toxicity, teratogenic effects, alterations in various organic systems, and high recurrence rates after short periods of discontinuance.[17]

PDT is a noninvasive technique which has evolved as an important treatment option for OPMD. A study by Pietruska *et al*., which used chlorine-e6 as PS, reported that PDT showed considerable reduction in size of the lesion of leukoplakia, which is similar to our present study.[18] The present study followed the protocol given by Chen *et al*., i.e., twice in a week rather than once as done in cases of oral lichen planus.[12] Kawczyk-Krupka *et al*. in their study compared the PDT for OL to cryotherapy, stated that it can be established as a minimally invasive, localized safe, and more esthetic treatment option for OL.[19] Although MB-PDT appears to be a promising therapy in cases of OLP without remarkable side effects,[20-22] randomized clinical trials regarding its use for OL are scarce.

Our present study used MB as a PS in contrast to the commonly and successfully used aminolevulinic acid. MB is a phenothiazine dye, whose administration is not associated with any side effects even at high doses topically or through intravenous injection in humans. It can be used for superficial lesions in skin and oral cavity and has good biocompatibility. Besides being an easily available and an economical option,[20] it also demonstrates natural antifungal and antibacterial properties, which can be increased through light activation.[23] However, the most important advantage in this regard would be good visualization of the lesion as staining by MB has nearly 90% sensitivity in detecting oral cancers or precancerous lesions.[24]

The present study though has effectively demonstrated the effect of MB-PDT for the diagnosis and treatment of OL, a small sample size compared to the prevalence of the lesion might be considered as one of limitations of our study.

Conclusion

Within the limitations of this present study, we can conclude that both the treatment modalities can be prescribed to the OL patients, but PDT can be a promising nonsurgical therapeutic strategy for OL. It has statistically demonstrated better impact on the leukoplakia lesion in terms of reduction in size and absence of recurrence. Based on the results of the present study and our knowledge about the mechanism by which these modalities act on oral premalignancies, it is logical to assume that the two may be synergistic to one another, thus opening further scope of studies in future.

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Conflicts of interest

There are no conflicts of interest.

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Cheiloscopy and Rugoscopy: A Scientific Approach for Sex Determination.

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KEYWORDS

Forensic dentistry, Human identification, Lip prints, Cheiloscopy, Palatal rugae.

ABSTRACT:

Introduction: The major areas of forensic dentistry include determining a patient's gender, age, race, and size as well as gathering dental evidence and reconstructing a patient's face over skeletal remains. Lip prints are said to be unique to a person and similar to fingerprints. The palatal rugae pattern has been regarded as one of the pertinent indicators for human identification in the field of forensic medicine because of its stability and uniqueness.

Objectives: To evaluate the effectiveness of palatal rugae pattern and lip prints for gender distinction and human identification. The objectives of the study were to distinguish between male and female lip prints and palatal rugae based on gender.

Methods: Subjects were randomly chosen from the OPD and an informed consent was obtained. Study was performed on 136 subjects equally divided into two groups according to gender. For rugoscopy all the dental casts were collected, duplicated and later analyzed. The legal age of the subject was confirmed using the case history proforma of the patients submitted along with the casts. The relevant demographic data including name, age, sex, address as well as findings from clinical examination were recorded for each selected individual in a specially designed Proforma.

Results: Considering both the lips, type V pattern was most predominant pattern in males followed by type III while type I pattern was most predominant pattern in females followed by type I. Predominant shape of rugae in females is wavy followed by curved and straight and in males is curved followed by wavy, straight and unification.

Conclusions: Both cheiloscopy and rugoscopy have the potential to identify an individual also lip prints are more reliable in identifying the sex of an individual as compared to palatal rugae patterns.

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1. Introduction

Determining a person's identification by skeletal and dental characteristics yields extensive information and persuasive proof that is crucial for regular forensic investigations.[1,2] Forensic odontology deals with the proper handling and examination of dental evidence and evaluation and presentation of dental findings.[3,4]

Human identification is one of the principal areas of research in forensic science and can be accomplished by determining patient's gender, age and race. Comparative identification and reconstructive identification are common methods.[4,5,6,7]

Even though standard methods like DNA profiling, finger prints, anthropometric data, and dental records can be used, there are times when it makes sense to use some of the less common and uncommon ancillary methods, like cheiloscopy, palatoscopy, and other odontometric measurements, which, when carried out, yield relatively reliable results.[5]

Study of these lip prints and palatal rugae are respectively known as cheiloscopy and rugoscopy. These anatomical structures are said to be unique to a person. Lip prints develop during sixth week, whereas rugae develop during the third month of intrauterine life.[6,7]

Lip prints seldom alter in pattern and can withstand a variety of pathological conditions, however, palatal rugae are protected by lips, cheeks, tongue, teeth, and bone thus making them stable in position and shape, with the exception of length changes caused by growing.[4,8]

Both lip prints and rugae pattern can be directly or indirectly recorded at a crime scene.[7,8] Lip prints and palatal rugae patterns are distinctive personal traits that, in forensic odontology, can lead to crucial information and aid in the identification of an individual. Nevertheless, there aren't many examples that compare the accuracy of rugoscopy with cheiloscopy for identifying people.[5,6] Therefore, the study's objective was to evaluate the validity of palatal rugae pattern and lip prints for gender identification.

2. Objectives

The objectives of the study is to ascertain how lip prints are used to identify people,to distinguish between male and female lip prints based on gender,to identify the palatal rugae pattern in humans, to compare the patterns of palatal rugae in males and females in order to distinguish between genders and to assess how reliable palatal rugae patterns and lip prints are for identifying people and separating genders.

3. Methods

A total of 136 subjects were randomly selected from the outpatient department of Oral Medicine & Radiology and a detailed case history proforma was filled. The subjects were equally divided into two groups according to gender. The gender of an individual was blinded for the study. An informed consent was obtained from every patient. Inclusion criteria included participants in good health and had not undergone any orthodontic treatment, or suffering from any inflammation, trauma, or congenital anomalies involving lips or palate. Those with lip or palatal lesions, cleft lips/palate, history of plastic or reconstructive surgery, and hypersensitivity to lip sticks and dental materials were excluded from the study. The study protocol was approved by of Institutional Ethical committee.

For cheiloscopy, lipstick was applied using applicator brushes, which was applied at the midline and proceeding laterally. To distribute the lip stick uniformly, the subjects were instructed to rub both lips. After letting the lipstick dry for roughly two minutes, lip prints were captured. Scotch MagicTM tape was used to take individual lip prints. These prints were adhered to white paper using a technique akin to that expounded by Sivapathasundharam et al. Each person's lip prints were digitized at a resolution of 600 ppi using an image scanner. The pictures were scanned in grayscale after being inverted. For optimal detail, they were saved as TIFF (Tagged Image File Format) files. As recommended by Augustine et al., the most readable prints of each lips taken separately were cropped, and vertical lines were made to divide the lips into three pieces using Adobe® Photoshop® 7.0 software. Lip prints was classified according to the Suzuki and Tsuchihashi (1970).[9] The data obtained from various measurements was recorded on the proforma.

For rugoscopy high quality alginate impressions were made of maxillary arch and dental casts were obtained using Dental stone (Gypsum Type 4). A pointed graphite pencil was used in sufficient light to trace the

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outline of rugae on casts. The magnifying glass was used to examine the palatal rugae pattern. Modified Lysell classification was used to do the analysis.[10] Based on their shape, the rugae were classified into four categories. The rugae pattern was categorized as straight if it ran straight from the origin to the termination, circular if it formed a distinct continuous ring, wavy if it was slightly curved at the origin and termination, and undetermined if it did not fit into any of the aforementioned categories.

Statistical anaylsis was performed using the Statistical Package for Social Sciences (SPSS) version 16 and Epi Info version 6.0. Paired, Unpaired t- test, ANOVA , Chi-Squrae test and Pearson's correlation coefficient tests was used to determine the various parameters.

4. Results

The present study was done on 136 subjects (age above the 18 years) of both genders (68 males and 68 females). Table 1 shows predominant pattern of lip print in males and females. Type V pattern was most predominant in 36 (52.94%) males and Type I and I' was least common in 1 (1.47%) males respectively. Type I pattern was most predominant in 32(47.06%) females and none of the females showed type III and type V pattern. The results were statistically highly significant for type I, type I', type II and type V patterns (p<0.01).

Table 2 shows predominant pattern of rugae in males and females. Curved pattern was most predominant in 32(47.06%) males and unification was least common in 1(1.47%) male. Wavy pattern was most predominant in 42 (61.76%) females and none of the females showed unification pattern. The results were statistically highly significant for type I, type I', type II and type V patterns (p<0.01). A highly significant difference was found for curved pattern (p<0.01) and significant difference for wavy pattern (p<0.05) were found.

Table 3 shows distribution of total number of primary rugae in males and females.The mean number of primary rugae in male was 7.85(±1.91) and in female it was 8.31(±1.62). However, the results were non significant.

5. Discussion

In the current study, we sought to determine the differences in lip and rugae patterns as well as the relative validity of palatal rugae patterns and lip prints for gender differentiation and human identity in 136 participants. Similar studies have been previously reported in literature.[11,12,13,14,15] A small number of scholars have split each lip print into the central section, left lateral, and right lateral.[12,13] Few studies have focused on the 10 mm-wide central region of the lower lip as done in our study.[14,15] Additionally, Vanguru et al (2023)[16] separated lip prints into eight quadrants. The midline of the lip print was used to split it into two quadrants, each of which was then further separated into equal sections called medial and lateral. In this study the lip prints were categorized following the scheme Suzuki and Tsuchihashi published in 1970.

Researchers have previously studied lip prints to demonstrate that there is a gender difference in lip prints. The results in the current study showed a predominance of the type I pattern was seen in males. The results results of this study was not in accordance with previous report by Manikya S et al (2018) where Type I and type I patterns were shown to be dominant in females, but type II and type IV patterns were prominent in men.[17] Another research by Uzomba GC et al (2023)[18] revealed that male participants had distinct patterns whereas all four quadrants with the same type of lip prints were more common in female subjects. Six variations of type V patterns have been described by Vitosyte M et al (2023).[19] These include "cartwheel appearance", "pineapple skin appearance", "trifurcation", "bridge or "H"pattern", "horizontal lines" and "multiple branching appearances." Uzomba GC et al (2023)[18] have depicted "circular shaped area with minute dots,""oval shaped area with horizontal lines," and "small leaf like structure with central line and branching lines" among others. people categorized as type V. In the current study no further classification of Type V was done.

While analyzing palatal rugae patterns, no significant difference was found in the total number of primary rugae and length of primary rugae in males and females, reinforcing the fact described by other researchers.[20,21] But, few studies revealed that males showed a higher in total number of primary rugae.[22,23,24]

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Some of the studies concluded that the wavy shape was more common in females while curved shape was more common in males. But, few of studies observed that the wavy pattern was common in males as well as females.[21,23] In the current study, curved shape was more common in males while wavy shape was more common in females.

Thus it can be put forth that lip prints and rugae pattern can act not only as a means of identifying individuals but they also have a high rate of accuracy in gender determination. But they have a major drawback too, as lips and rugae are soft tissue structures they are prone to changes post mortem and can also be injured in course of accidents etc. Very little data base is available on lip prints and rugae worldwide right now as the major emphasis is on structures which tend to remain stable postmortem. Lip prints and rugae pattern though may not be very valuable in cases of mass disasters where the body is mutilated or decomposed these can be very valuable in cases where both the victims and suspected perpetrators can be examined soon after the incident.

In conclusion, the study proves that both cheiloscopy and rugoscopy have the potential to identify an individual also lip prints are more reliable in identifying the sex of an individual as compared to palatal rugae patterns. Thus, lip prints and palatal rugae hold potential as a supplementary tool, along with the dentition, to establish the identity of an individual. Nevertheless, the larger samples should be examined in detail to further validate the findings of this study and come to definitive conclusions.

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Table 1: Genderwise predominant pattern of lip print

Predominant pattern of lip print	**Gender**		**P value**
	Male (%)(n=68)	**Female (%) (n=68)**	
I	1(1.47)	32(47.06)	<0.01
I'	1(1.47)	27(39.70)	<0.01
II	7(10.29)	9(13.23)	>0.05
III	19 (27.94)	0 (0.0)	<0.01
IV	6(8.82)	3 (4.41)	>0.05
V	36(52.94)	0 (0.0)	<0.01

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Table 2 : Genderwise predominant shape of rugae

Predominant shape of rugae	Gender		P value
	Male(%)(n=68)	**Female(%)(n=68)**	
Curved	32(47.06)	14(20.59)	<0.01
Wavy	29(42.65)	42(61.76)	<0.05
Straight	11(16.17)	12(17.65)	>0.05
Unification	1(1.47)	0 (0.0)	>0.05

Table 3: Distribution of total number of primary rugae in males and females

Gender	N	Mean	SD	Mean Difference	95%Cl of the Mean difference		P value
					Lower	Upper	
Male	68	7.85	1.91	-0.46	-1.06	0.14	>0.05
Female	68	8.31	1.62				

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प्रमाणित किया जाता है कि संलग्न प्रति में वर्णित डिजाइन जो *MOUTH PROP FOR MOUTH OPENING IN LOCKED JAW CONDITION* से संबंधित है, का पंजीकरण, श्रेणी 24-02 में 1.Dr. Deepankar Misra 2. Dr. Akansha Misra 3.Dr. Manish Khatri 4.Dr. Nutan Tyagi 5.Dr. Gaurav Issar 6.Dr. Mansi Bansal 7.Dr. Sumit Bhateja 8.Dr. Akansha Budakoti 9.Dr. Jasdeep Kaur 10.Dr. Vashishtha Singh के नाम में उपर्युक्त संख्या और तारीख में कर लिया गया है।

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Cheiloscopy and Rugoscopy: A Scientific Approach for Sex Determination.

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KEYWORDS

Forensic dentistry, Human identification, Lip prints, Cheiloscopy, Palatal rugae.

ABSTRACT:

Introduction: The major areas of forensic dentistry include determining a patient's gender, age, race, and size as well as gathering dental evidence and reconstructing a patient's face over skeletal remains. Lip prints are said to be unique to a person and similar to fingerprints. The palatal rugae pattern has been regarded as one of the pertinent indicators for human identification in the field of forensic medicine because of its stability and uniqueness.

Objectives: To evaluate the effectiveness of palatal rugae pattern and lip prints for gender distinction and human identification. The objectives of the study were to distinguish between male and female lip prints and palatal rugae based on gender.

Methods: Subjects were randomly chosen from the OPD and an informed consent was obtained. Study was performed on 136 subjects equally divided into two groups according to gender. For rugoscopy all the dental casts were collected, duplicated and later analyzed. The legal age of the subject was confirmed using the case history proforma of the patients submitted along with the casts. The relevant demographic data including name, age, sex, address as well as findings from clinical examination were recorded for each selected individual in a specially designed Proforma.

Results: Considering both the lips, type V pattern was most predominant pattern in males followed by type III while type I pattern was most predominant pattern in females followed by type I. Predominant shape of rugae in females is wavy followed by curved and straight and in males is curved followed by wavy, straight and unification.

Conclusions: Both cheiloscopy and rugoscopy have the potential to identify an individual also lip prints are more reliable in identifying the sex of an individual as compared to palatal rugae patterns.

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1. Introduction

Determining a person's identification by skeletal and dental characteristics yields extensive information and persuasive proof that is crucial for regular forensic investigations.[1,2] Forensic odontology deals with the proper handling and examination of dental evidence and evaluation and presentation of dental findings.[3,4]

Human identification is one of the principal areas of research in forensic science and can be accomplished by determining patient's gender, age and race. Comparative identification and reconstructive identification are common methods.[4,5,6,7]

Even though standard methods like DNA profiling, finger prints, anthropometric data, and dental records can be used, there are times when it makes sense to use some of the less common and uncommon ancillary methods, like cheiloscopy, palatoscopy, and other odontometric measurements, which, when carried out, yield relatively reliable results.[5]

Study of these lip prints and palatal rugae are respectively known as cheiloscopy and rugoscopy. These anatomical structures are said to be unique to a person. Lip prints develop during sixth week, whereas rugae develop during the third month of intrauterine life.[6,7]

Lip prints seldom alter in pattern and can withstand a variety of pathological conditions, however, palatal rugae are protected by lips, cheeks, tongue, teeth, and bone thus making them stable in position and shape, with the exception of length changes caused by growing.[4,8]

Both lip prints and rugae pattern can be directly or indirectly recorded at a crime scene.[7,8] Lip prints and palatal rugae patterns are distinctive personal traits that, in forensic odontology, can lead to crucial information and aid in the identification of an individual. Nevertheless, there aren't many examples that compare the accuracy of rugoscopy with cheiloscopy for identifying people.[5,6] Therefore, the study's objective was to evaluate the validity of palatal rugae pattern and lip prints for gender identification.

2. Objectives

The objectives of the study is to ascertain how lip prints are used to identify people,to distinguish between male and female lip prints based on gender,to identify the palatal rugae pattern in humans, to compare the patterns of palatal rugae in males and females in order to distinguish between genders and to assess how reliable palatal rugae patterns and lip prints are for identifying people and separating genders.

3. Methods

A total of 136 subjects were randomly selected from the outpatient department of Oral Medicine & Radiology and a detailed case history proforma was filled. The subjects were equally divided into two groups according to gender. The gender of an individual was blinded for the study. An informed consent was obtained from every patient. Inclusion criteria included participants in good health and had not undergone any orthodontic treatment, or suffering from any inflammation, trauma, or congenital anomalies involving lips or palate. Those with lip or palatal lesions, cleft lips/palate, history of plastic or reconstructive surgery, and hypersensitivity to lip sticks and dental materials were excluded from the study. The study protocol was approved by of Institutional Ethical committee.

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For rugoscopy high quality alginate impressions were made of maxillary arch and dental casts were obtained using Dental stone (Gypsum Type 4). A pointed graphite pencil was used in sufficient light to trace the

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outline of rugae on casts. The magnifying glass was used to examine the palatal rugae pattern. Modified Lysell classification was used to do the analysis.[10] Based on their shape, the rugae were classified into four categories. The rugae pattern was categorized as straight if it ran straight from the origin to the termination, circular if it formed a distinct continuous ring, wavy if it was slightly curved at the origin and termination, and undetermined if it did not fit into any of the aforementioned categories.

Statistical anaylsis was performed using the Statistical Package for Social Sciences (SPSS) version 16 and Epi Info version 6.0. Paired, Unpaired t- test, ANOVA , Chi-Squrae test and Pearson's correlation coefficient tests was used to determine the various parameters.

4. Results

The present study was done on 136 subjects (age above the 18 years) of both genders (68 males and 68 females). Table 1 shows predominant pattern of lip print in males and females. Type V pattern was most predominant in 36 (52.94%) males and Type I and I' was least common in 1 (1.47%) males respectively. Type I pattern was most predominant in 32(47.06%) females and none of the females showed type III and type V pattern. The results were statistically highly significant for type I, type I', type II and type V patterns ($p<0.01$).

Table 2 shows predominant pattern of rugae in males and females. Curved pattern was most predominant in 32(47.06%) males and unification was least common in 1(1.47%) male. Wavy pattern was most predominant in 42 (61.76%) females and none of the females showed unification pattern. The results were statistically highly significant for type I, type I', type II and type V patterns ($p<0.01$). A highly significant difference was found for curved pattern ($p<0.01$) and significant difference for wavy pattern ($p<0.05$) were found.

Table 3 shows distribution of total number of primary rugae in males and females.The mean number of primary rugae in male was 7.85(±1.91) and in female it was 8.31(±1.62). However, the results were non significant.

5. Discussion

In the current study, we sought to determine the differences in lip and rugae patterns as well as the relative validity of palatal rugae patterns and lip prints for gender differentiation and human identity in 136 participants. Similar studies have been previously reported in literature.[11,12,13,14,15] A small number of scholars have split each lip print into the central section, left lateral, and right lateral.[12,13] Few studies have focused on the 10 mm-wide central region of the lower lip as done in our study.[14,15] Additionally, Vanguru et al (2023)[16] separated lip prints into eight quadrants. The midline of the lip print was used to split it into two quadrants, each of which was then further separated into equal sections called medial and lateral. In this study the lip prints were categorized following the scheme Suzuki and Tsuchihashi published in 1970.

Researchers have previously studied lip prints to demonstrate that there is a gender difference in lip prints. The results in the current study showed a predominance of the type I pattern was seen in males. The results results of this study was not in accordance with previous report by Manikya S et al (2018) where Type I and type I patterns were shown to be dominant in females, but type II and type IV patterns were prominent in men.[17] Another research by Uzomba GC et al (2023)[18] revealed that male participants had distinct patterns whereas all four quadrants with the same type of lip prints were more common in female subjects. Six variations of type V patterns have been described by Vitosyte M et al (2023).[19] These include "cartwheel appearance", "pineapple skin appearance", "trifurcation", "bridge or "H"pattern", "horizontal lines" and "multiple branching appearances." Uzomba GC et al (2023)[18] have depicted "circular shaped area with minute dots,""oval shaped area with horizontal lines," and "small leaf like structure with central line and branching lines" among others. people categorized as type V. In the current study no further classification of Type V was done.

While analyzing palatal rugae patterns, no significant difference was found in the total number of primary rugae and length of primary rugae in males and females, reinforcing the fact described by other researchers.[20,21] But, few studies revealed that males showed a higher in total number of primary rugae.[22,23,24]

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Some of the studies concluded that the wavy shape was more common in females while curved shape was more common in males. But, few of studies observed that the wavy pattern was common in males as well as females.[21,23] In the current study, curved shape was more common in males while wavy shape was more common in females.

Thus it can be put forth that lip prints and rugae pattern can act not only as a means of identifying individuals but they also have a high rate of accuracy in gender determination. But they have a major drawback too, as lips and rugae are soft tissue structures they are prone to changes post mortem and can also be injured in course of accidents etc. Very little data base is available on lip prints and rugae worldwide right now as the major emphasis is on structures which tend to remain stable postmortem. Lip prints and rugae pattern though may not be very valuable in cases of mass disasters where the body is mutilated or decomposed these can be very valuable in cases where both the victims and suspected perpetrators can be examined soon after the incident.

In conclusion, the study proves that both cheiloscopy and rugoscopy have the potential to identify an individual also lip prints are more reliable in identifying the sex of an individual as compared to palatal rugae patterns. Thus, lip prints and palatal rugae hold potential as a supplementary tool, along with the dentition, to establish the identity of an individual. Nevertheless, the larger samples should be examined in detail to further validate the findings of this study and come to definitive conclusions.

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Table 1: Genderwise predominant pattern of lip print

Predominant pattern of lip print	**Gender**		**P value**
	Male (%)(n=68)	**Female (%) (n=68)**	
I	1(1.47)	32(47.06)	<0.01
I'	1(1.47)	27(39.70)	<0.01
II	7(10.29)	9(13.23)	>0.05
III	19 (27.94)	0 (0.0)	<0.01
IV	6(8.82)	3 (4.41)	>0.05
V	36(52.94)	0 (0.0)	<0.01

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Table 2 : Genderwise predominant shape of rugae

Predominant shape of rugae	Gender		P value
	Male(%)(n=68)	**Female(%)(n=68)**	
Curved	32(47.06)	14(20.59)	<0.01
Wavy	29(42.65)	42(61.76)	<0.05
Straight	11(16.17)	12(17.65)	>0.05
Unification	1(1.47)	0 (0.0)	>0.05

Table 3: Distribution of total number of primary rugae in males and females

Gender	**N**	**Mean**	**SD**	**Mean Difference**	**95%Cl of the Mean difference**		**P value**
					Lower	Upper	
Male	68	7.85	1.91	-0.46	-1.06	0.14	>0.05
Female	68	8.31	1.62				

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For rugoscopy high quality alginate impressions were made of maxillary arch and dental casts were obtained using Dental stone (Gypsum Type 4). A pointed graphite pencil was used in sufficient light to trace the

outline of rugae on casts. The magnifying glass was used to examine the palatal rugae pattern. Modified Lysell classification was used to do the analysis.[10] Based on their shape, the rugae were classified into four categories. The rugae pattern was categorized as straight if it ran straight from the origin to the termination, circular if it formed a distinct continuous ring, wavy if it was slightly curved at the origin and termination, and undetermined if it did not fit into any of the aforementioned categories.

Statistical anaylsis was performed using the Statistical Package for Social Sciences (SPSS) version 16 and Epi Info version 6.0. Paired, Unpaired t- test, ANOVA , Chi-Squrae test and Pearson's correlation coefficient tests was used to determine the various parameters.

4. Results

The present study was done on 136 subjects (age above the 18 years) of both genders (68 males and 68 females). Table 1 shows predominant pattern of lip print in males and females. Type V pattern was most predominant in 36 (52.94%) males and Type I and I' was least common in 1 (1.47%) males respectively. Type I pattern was most predominant in 32(47.06%) females and none of the females showed type III and type V pattern. The results were statistically highly significant for type I, type I', type II and type V patterns (p<0.01).

Table 2 shows predominant pattern of rugae in males and females. Curved pattern was most predominant in 32(47.06%) males and unification was least common in 1(1.47%) male. Wavy pattern was most predominant in 42 (61.76%) females and none of the females showed unification pattern. The results were statistically highly significant for type I, type I', type II and type V patterns (p<0.01). A highly significant difference was found for curved pattern (p<0.01) and significant difference for wavy pattern (p<0.05) were found.

Table 3 shows distribution of total number of primary rugae in males and females.The mean number of primary rugae in male was 7.85(±1.91) and in female it was 8.31(±1.62). However, the results were non significant.

5. Discussion

In the current study, we sought to determine the differences in lip and rugae patterns as well as the relative validity of palatal rugae patterns and lip prints for gender differentiation and human identity in 136 participants. Similar studies have been previously reported in literature.[11,12,13,14,15] A small number of scholars have split each lip print into the central section, left lateral, and right lateral.[12,13] Few studies have focused on the 10 mm-wide central region of the lower lip as done in our study.[14,15] Additionally, Vanguru et al (2023)[16] separated lip prints into eight quadrants. The midline of the lip print was used to split it into two quadrants, each of which was then further separated into equal sections called medial and lateral. In this study the lip prints were categorized following the scheme Suzuki and Tsuchihashi published in 1970.

Researchers have previously studied lip prints to demonstrate that there is a gender difference in lip prints. The results in the current study showed a predominance of the type I pattern was seen in males. The results results of this study was not in accordance with previous report by Manikya S et al (2018) where Type I and type I patterns were shown to be dominant in females, but type II and type IV patterns were prominent in men.[17] Another research by Uzomba GC et al (2023)[18] revealed that male participants had distinct patterns whereas all four quadrants with the same type of lip prints were more common in female subjects. Six variations of type V patterns have been described by Vitosyte M et al (2023).[19] These include "cartwheel appearance", "pineapple skin appearance", "trifurcation", "bridge or "H"pattern", "horizontal lines" and "multiple branching appearances." Uzomba GC et al (2023)[18] have depicted "circular shaped area with minute dots,""oval shaped area with horizontal lines," and "small leaf like structure with central line and branching lines" among others. people categorized as type V. In the current study no further classification of Type V was done.

While analyzing palatal rugae patterns, no significant difference was found in the total number of primary rugae and length of primary rugae in males and females, reinforcing the fact described by other researchers.[20,21] But, few studies revealed that males showed a higher in total number of primary rugae.[22,23,24]

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Some of the studies concluded that the wavy shape was more common in females while curved shape was more common in males. But, few of studies observed that the wavy pattern was common in males as well as females.[21,23] In the current study, curved shape was more common in males while wavy shape was more common in females.

Thus it can be put forth that lip prints and rugae pattern can act not only as a means of identifying individuals but they also have a high rate of accuracy in gender determination. But they have a major drawback too, as lips and rugae are soft tissue structures they are prone to changes post mortem and can also be injured in course of accidents etc. Very little data base is available on lip prints and rugae worldwide right now as the major emphasis is on structures which tend to remain stable postmortem. Lip prints and rugae pattern though may not be very valuable in cases of mass disasters where the body is mutilated or decomposed these can be very valuable in cases where both the victims and suspected perpetrators can be examined soon after the incident.

In conclusion, the study proves that both cheiloscopy and rugoscopy have the potential to identify an individual also lip prints are more reliable in identifying the sex of an individual as compared to palatal rugae patterns. Thus, lip prints and palatal rugae hold potential as a supplementary tool, along with the dentition, to establish the identity of an individual. Nevertheless, the larger samples should be examined in detail to further validate the findings of this study and come to definitive conclusions.

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Table 1: Genderwise predominant pattern of lip print

Predominant pattern of lip print	**Gender**		**P value**
	Male (%)(n=68)	**Female (%) (n=68)**	
I	1(1.47)	32(47.06)	<0.01
I'	1(1.47)	27(39.70)	<0.01
II	7(10.29)	9(13.23)	>0.05
III	19 (27.94)	0 (0.0)	<0.01
IV	6(8.82)	3 (4.41)	>0.05
V	36(52.94)	0 (0.0)	<0.01

Table 2 : Genderwise predominant shape of rugae

Predominant shape of rugae	Gender		P value
	Male(%)(n=68)	**Female(%)(n=68)**	
Curved	32(47.06)	14(20.59)	<0.01
Wavy	29(42.65)	42(61.76)	<0.05
Straight	11(16.17)	12(17.65)	>0.05
Unification	1(1.47)	0 (0.0)	>0.05

Table 3: Distribution of total number of primary rugae in males and females

Gender	**N**	**Mean**	**SD**	**Mean Difference**	**95%Cl of the Mean difference**		**P value**
					Lower	Upper	
Male	68	7.85	1.91	-0.46	-1.06	0.14	>0.05
Female	68	8.31	1.62				

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