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ORIGINAL RESEARCH ARTICLE

Comparison of the Effects of Different Decontamination Methods on Staphylococcus Aureus Biofilm

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Abstract

Purpose: The current in-vitro study aims to compare the effectiveness of various mechanical decontamination modalities in the elimination of Staphylococcus aureus biofilm from titanium surfaces using qualitative and quantitative techniques.
Materials and Methods: A total of 78 titanium discs were inoculated with Staphylococcus aureus and randomly allocated into control and three experimental groups consisting of plastic curettes (PC), ultrasonic-driven plastic tips (UPT), and ultrasonic-driven stainless-steel tips (UST). Following decontamination procedures, colony-forming units and viable biomass were analyzed to identify the biofilm removal efficacy of the treatments and the viability of bacteria remaining on the surface. Biofilm structure was assessed by confocal laser scanning microscopy and scanning electron microscopy. Analysis of variance and post hoc Tukey tests were applied for comparisons.
Results: Reductions in both colony counts and variable biomass following the decontamination procedure were significant in all treatment groups (p=0.000). Although the highest reduction in colony count was determined in the UST and the lowest in the PC group, the difference was not statistically significant between treatment groups (p = 0.246). Nonetheless, the reduction in viable biomass in the UST group was greater than in the UPT and PC groups (p=0.005, p=0.000, respectively).
Conclusions: Ultrasonic-driven instruments are more effective than plastic curettes in removing the biofilm that colonizes the titanium surfaces in the initial stages. Stainless steel tips provide better elimination of microbial biofilm compared to plastic instruments, but they alter the surface topography of roughed titanium surfaces more than plastic curettes.

Keywords: Biofilm; Colony forming units; Confocal Laser Scanning Microscopy; Decontamination; Peri-Implantitis

Introduction

Peri-implantitis is a site-specific lesion characterized by loss of surrounding bone and clinical inflammation of the peri-implant mucosa, potentially leading to implant loss if appropriate treatment is not provided.[1,2] Early eradication of the microbial biofilm formed by pathogens such as Staphylococcus aureus (S. aureus), which colonize the peri-implant tissues, is crucial for implant survival.[3,4]

Although it has been suggested that the bacterial biofilm on implant and dental surfaces is similar, recent data show that the microbiota in peri-implantitis is a polymicrobial anaerobic infection and has a more complex structure than that in periodontitis.[5] Many studies have shown that microorganisms such as Staphylococcus aureus, Enterobacteriaceae, Candida albicans, and Pseudomonas aeruginosa, which are not commonly found in the oral flora, can be present in the peri-implant flora. These microorganisms are rarely associated with periodontal disease but can successfully adhere to titanium surfaces.[5,6] The strong affinity of S. aureus for titanium surfaces and its ability to adhere to extracellular matrix components accumulated on biomaterial surfaces play a critical role in biofilm formation, leading to implant-associated infections.[7] S. aureus, one of the microorganisms involved in peri-implant diseases, can colonize the implant surfaces in the early stages after implant placement.[3] Additionally, it is known that individuals with failed titanium dental implants have low titers of antibodies against S. aureus.[6,7] Therefore, the complete removal of early colonizers like S. aureus from dental implant surfaces could determine long-term implant success.

Various mechanical techniques for biofilm removal have been proposed in the literature.[8] Ultrasonic instruments and curettes made of various materials are frequently utilized for this purpose.[9] Among the mechanical methods used in daily practice, ultrasonic instruments are probably the most commonly used for biofilm removal on both implant and dental surfaces due to the ease of use provided by the micro-movements of the ultrasonic tips.[10,11] However, the results from studies on the effectiveness of biofilm removal using ultrasonic tips have been controversial. While some studies reported that ultrasonic tips outperformed other mechanical techniques, regardless of the tip material (peek or steel)[12,13], others have shown contradictory results.[14,15] On the other hand, curettes made of plastic material have been introduced, considering the potential hazard that ultrasonic tips can cause to the implant surface.[16,17] However, questions remain regarding the efficacy of plastic curettes in the decontamination of implant surfaces when compared to other mechanical methods.[18–21]

Different techniques have been used to measure the remaining biofilm on titanium implant surfaces after biofilm removal methods in the literature. The use of other methods based on the principle of staining live-dead cells and imaging them with microscopes, along with traditional methods such as enumeration of viable cells by colony forming units (CFU), where only quantitative information about living cells is obtained, offers new perspectives in the evaluating results. This is because qualitative information, as well as quantitative information, is obtained from the stained cells.[22]

Clinicians face different challenges in selecting the best treatment for patients with peri-implant diseases, as there is no consensus on which mechanical technique is most effective in the elimination of peri-implantitis-causing biofilm on implant surfaces.[8] In this context, the present study aims to compare the effectiveness of various mechanical decontamination modalities in the removal of Staphylococcus aureus biofilm from titanium implant surfaces, using qualitative and quantitative methods. The null hypothesis is that the evaluated mechanical techniques will yield comparable outcomes in terms of the biofilm elimination potential.

Material and Methods

The study was conducted using 78 titanium discs (Ø 6 mm and a thickness of 4 mm) produced from dental implant material whose surface was roughened with biphasic calcium phosphate (Bioinfinity, Istanbul, Türkiye). Gamma irradiation was used by the manufacturer to sterilize the titanium disc specimens.

Biofilm formation

All sterile discs were covered with Staphylococcus aureus (S. aureus) biofilm.[23] Reference strain S. aureus ATCC 29213 was preferred to establish a bacterial biofilm layer on disc surfaces. The S. aureus ATCC 29213 was cultured at 37 °C for 24 h using brain heart infusion broth (BHI, Merck, Germany). Cells were then diluted in BHI until an optical density at 600 nm of 0.1 was reached using a spectrophotometer (UV-1800 Shimadzu, Japan). The bottom and side surfaces of the titanium discs were carefully covered with parafilm to ensure that the biofilm formation occurred only on the upper surface of the discs. Then, the parafilm-covered discs were placed into the wells of a 24-well flat bottom plate, and 1 mL of the bacterial culture was transferred to each well. The plates were incubated statically (37 °C, 48h) to establish an intact biofilm layer on the titanium discs.

At the 24th hour of incubation, the culture medium in the wells was carefully removed with a pipette, and 1 mL of sterile BHI broth was added to the wells. The discs were taken out of the wells following the incubation and were gently cleaned by washing them three times with 2 mL phosphate-buffered saline (pH 7.4) to eradicate any planktonic or loosely adherent bacteria that were not embedded in the biofilm.[24,25]

Experimental design

The total number of bacteria-coated titanium discs used in all stages of the study was 78 (n=42 for CFU analysis, n=28 for confocal microscopy and n=8 for scanning electron microscopy). The study comprised three experimental groups, each subjected to different disinfection methods, as follows: 1) Ultrasonic-driven steel tip: An ultrasonic device with a stainless-steel tip (Air-Flow Master Piezon with PS instrument, EMS, Nyon, Switzerland) was used at the 80% power and maximum water cooling.[26] 2) Ultrasonic-driven plastic tip: The scaling was performed using a thermoplastic scaler tip (Air-Flow Master Piezon® with PI instrument, EMS, Nyon, Switzerland) made of polyether ether ketone (PEEK) material with the same settings (power 80%, water 100%) recommended by the manufacturer. 3) Plastic curette: The surface of the previously contaminated discs was decontaminated using a hand-instrument made from high-grade resin (ImplacareTM II; Hu-Friedy®; Chicago, IL, USA).

Bacteria-coated titanium discs receiving no treatment served as controls. All titanium discs belonging to the experimental groups were decontaminated by the same experienced operator. During decontamination procedures, the angulation and working distance of the instruments were adjusted by the operator to ensure optimal access to the disc surface. The working tip of the instruments was contacted the disc surface without pressure. Instrumentation time was limited to 2 min for each decontamination procedure and controlled using a stopwatch. Following instrumentation, remnants were cleaned from the treated surfaces by gentle rinsing with distilled water for 20 s.[13] During the procedure, sterile instruments and materials were used to prevent contamination of the titanium surfaces with microorganisms other than S. aureus.

Analysis by Colony Forming Unit (CFU) counting

A total of 42 bacteria-coated discs were used for CFU analyses and 14 bacteria-coated titanium discs were allocated to each experimental group with 7 designated for treatment and 7 for control.[27] Due to the complexity of the applied procedure (CFU counting process), separate control groups were created for each experimental group, and each was compared with its own control.

The quantity of S. aureus on treated surfaces was calculated in CFU per titanium disc, allowing for a quantitative evaluation of the remaining biofilm. Enumeration of S. aureus ATCC 29213 in the control (untreated) and treated samples was performed using the surface spread technique. For this purpose, titanium discs were transported to Falcon tubes containing 10 mL of 0.5% (w/v) Tween20 PBS. Subsequently, the tubes were vortexed for 1 minute and sonicated (35 kHz, Sonorex, Germany) for 5 minutes at 25°C to disrupt the biofilm. After sonication, the tubes were vortexed for another minute, and decimal serial dilutions were prepared using sterile saline solution (0.85%, w/v). Then, 100 µl of each dilution was spread onto Tryptic Soy Agar plates, and incubated (48 h at 37°C).[28]

The reduction in colony count (CFU/surface) was calculated using the following equation: R= (C−T)

Where C is the number of colonies in control samples (no treatment), T is the number of colonies after the treatment and R is the log reduction in colony count (CFU/surface).

Analysis by Confocal Laser Scanning Microscopy (CLSM)

A total of 28 bacteria-coated titanium discs were immunostained for confocal microscopy, and randomly divided into a control group and three experimental groups that received different disinfection modalities. Titanium discs were placed in wells of flat bottom plates and stained with the LIVE/DEAD BacLight Bacterial Viability and Counting Kit (Invitrogen, Merelbeke, Belgium), subsequently left under light protection for 15 min. Confocal laser scanning microscopy (Leica Lasertechnik, Heidelberg, Germany) was used to examine three randomly selected fields on each specimen. Excitation wavelengths were set as 488 and 532 nm, and 10/1.0 magnification optical lenses were preferred for observing the specimens. The

Table 1. Mean reduction values in colony counts and viable biomass according to the decontamination procedures

Group	Colony Count in Control Groups (CFU/Surface)	Log Reduction in Colony Count (CFU/Surface)	p	Viable Biomass in Control Group	Reduction in Viable Biomass
Ultrasonic-driven steel tip (UST)	5,33±0,14	1,39±0,42	**0.000a***	18,01±4,62	15,82±0,9A
Ultrasonic-driven plastic tip (UPT)	6,14±0,24	1,14±0,54	**0.000a***		7,57±5,85B
Plastic curette (PC)	6,36±0,18	1,02±0,12	**0.000a***		1,35±4,35C
		0.246b			**0.000b***

a: Independent samples test, b: Analysis of variance (ANOVA), * p<0,05. A shows the statistically significant differences between the reduction in viable biomass in the ultrasonic-driven steel tip group and the reductions observed in the ultrasonic-driven plastic tip and plastic curette groups, Tukey's test (p=0.005 for UST- UPT groups, p=0.000 for UST-PC groups); B shows the statistically significant differences between the reduction in viable biomass in the ultrasonic-driven plastic tip group and the reductions observed in the ultrasonic-driven steel tip and plastic curette groups, Tukey's test (p=0.005 for UPT- UST groups, p=0.035 for UPT-PC groups); C shows the statistically significant differences between the reduction in viable biomass in the plastic curette group and the reductions observed in the ultrasonic-driven plastic tip and ultrasonic-driven steel tip groups, Tukey's test (p=0.035 for PC-UPT groups, p=0.000 for PC-UST groups).

properties of the total and viable biomass (m3/m2) were measured using the COMSTAT software.

Analysis by Scanning Electron Microscopy (SEM)

Two discs from each group were randomly allocated following the instrumentation for SEM evaluation. Biofilm on the titanium surface was fixed for one hour with glutaraldehyde (2.5%) and dehydrated with multiple ethanol washes (10%, 25%, 50%, 75%, and 90% for 20 m, and 100% for one hour). Following the dehydration of the biofilm was accomplished, titanium disc specimens were kept in the incubator at 37 °C overnight. Gold coating was applied to the specimens, which were carefully examined using an SEM (Apreo S, ThermoFisher Scientific, Norway) at 10 kV and magnifications of 1000, 2500, 5000 and 10.000x. Representative micrographs of S. aureus biofilm remaining attached to titanium surfaces were taken, and descriptive analysis of these images was conducted.

Statistical analysis

In the power analysis conducted before the study (80% power and probability of error α = 0.05), the sample size for each study group was determined as 12 titanium discs. IBM SPSS Statistics software (Version 23.0, SPSS Inc., Chicago, IL, USA) was used to analyze data. Shapiro-Wilk test was performed to determine the distribution of the data. Normally distributed data was submitted for analysis of variance and post hoc Tukey tests to assess dissimilarities among the study groups. The Pearson correlation coefficient was used analyze the relationship between colony counts and viable biomass values. Descriptive statistics were given as mean ± standard deviation. The level of .05 was accepted as the limit of statistical significance.

Results

Mean reductions in viable log10 counts and viable biomass according to the treatment procedures were presented in Table 1.

Reductions in S. aureus colony counts following the decontamination procedure were significant in all treatment groups (p=0.000). The highest log reduction in colony count was determined in the ultrasonic-driven steel tip (1,39 ±0,42 log CFU/surface) and the lowest was in the plastic curette group (1,02 ±0,12 log CFU/surface, Table 1). However, no statistically significant difference was noted among the decontamination modalities (p=0.246).

Viable biomass values confirmed by COMSTAT quantification showed a significant decrease on all treated discs (p=0.000). Consistent with the log reduction in the colony counts, the highest decrease in the viable biomass was detected in the ultrasonic-driven steel tip group (15,82 ± 0,9), while the lowest decrease was in the plastic curette group (1,35 ± 4,35), (Table 1). According to the variance analysis, there was a significant difference in the reduction of viable biomass between the groups (p=0.000). The reduction in viable biomass in the ultrasonic-driven steel tip group was higher than in the ultrasonic-driven plastic tip and plastic curette groups (p=0.005, p=0.000, respectively).

Figure 1 revealed the presence of the remaining S. aureus biofilm attached to the titanium surface. CLSM images of control discs confirmed the predominance of live bacteria on untreated disc surfaces. The quantity of live bacteria was lowest in the ultrasonic-driven steel tip group and highest in the plastic curette group. In all treatment groups, the quantity of live bacteria dominated the dead bacteria (Figure 1).

In SEM micrographs, S. aureus colonies were more pronounced in untreated control discs and plastic curette-treated discs. However, although ultrasonic-driven procedures were more efficient in microbial biofilm removal, they altered the surface topography of the discs. It has been noted that the initial roughened surface of the discs is damaged in all treatment groups. Moreover, plastic remnants were detected on the surfaces treated with plastic instruments (Figure 2).

Discussion

Current treatment modalities are focused on surface decontamination methods to eliminate the biofilm attached to the titanium surface since the main causative factor of peri-implantitis is a pathological biofilm.[26] Hand instruments and ultrasonic devices are widely used due to their ease of daily practice and lower costs compared to other mechanical methods.[29] This in vitro study provides a comparative evaluation of the effect of three frequently preferred decontamination methods in daily practice on the removal of S. aureus biofilm from previously contaminated titanium disc surfaces.

In the present study, significant reductions were observed in both colony count and viable biomass of S. aureus in all treatment groups compared to the control. In agreement with our findings, Kawashima et al.[10] reported that both the steel tip and the plastic-coated tip significantly removed microbial biofilm from the implant surface.

Among the three decontamination modalities investigated, ultrasonic-driven steel tips were found to be more effective than ultrasonic-driven PEEK tips and plastic curettes. Our viable biomass results revealed that this observed difference was statistically significant. These findings are consistent with studies indicating plastic curettes as less efficient in removing the biofilm layer compared to other mechanical decontamination modalities.[20,30] Besides these studies, Schmage et al.[31] demonstrated that two types of ultrasonic scalers with steel and a plastic-coated tip had better biofilm removal scores than plastic curettes. Unlike our results with viable biomass,

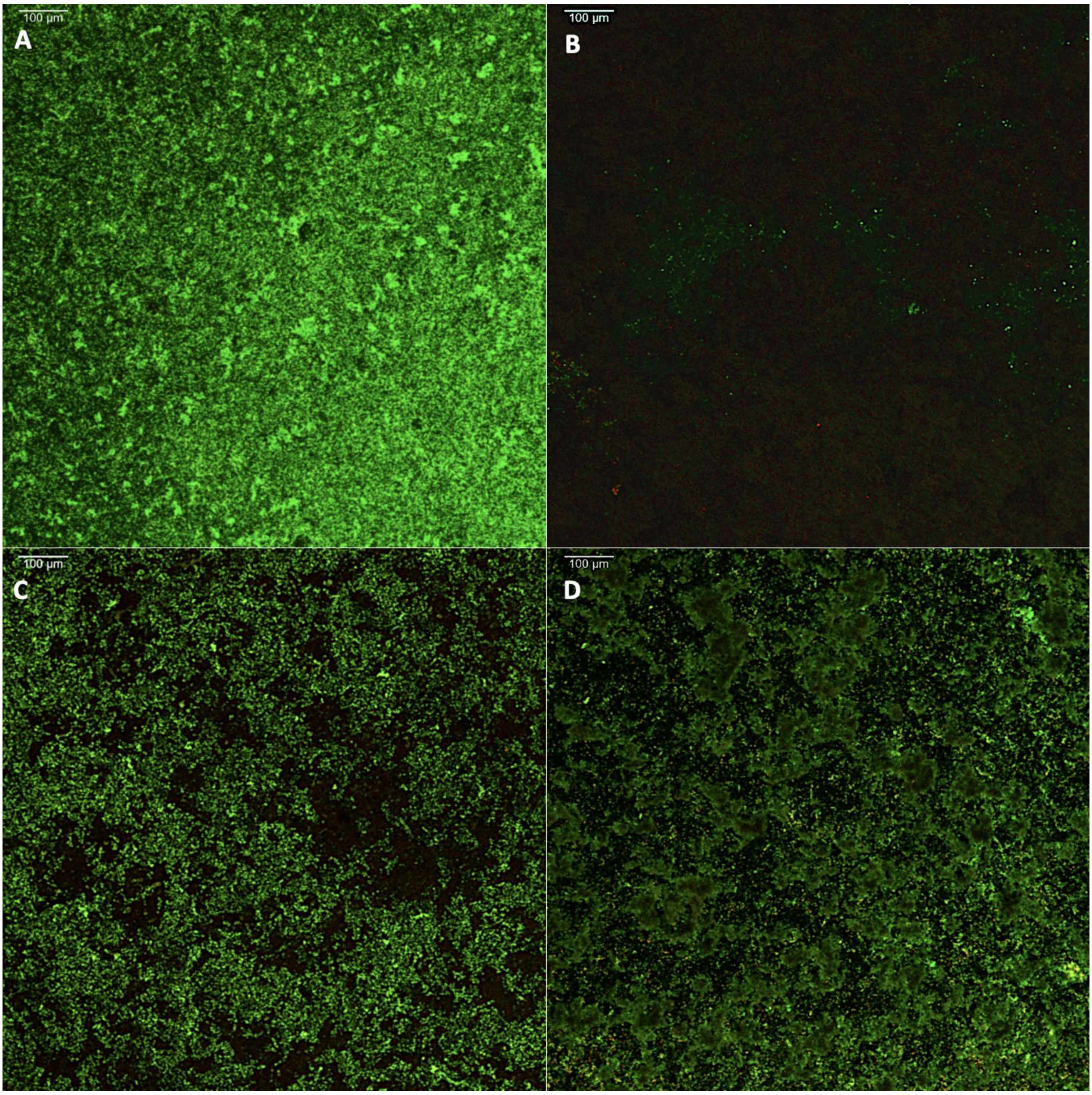

Figure 1. Representative CSLM images of S. aureus biofilm on the surfaces of control and treatment discs: (A) Control, (B) Ultrasonic-driven steel tip, (C) Ultrasonic-driven plastic tip, (D) Plastic curette (Viable bacteria = green; dead bacteria = red).

Luengo et al.[14] did not observe any difference in decontamination effectiveness between ultrasonic-driven steel tips and PEEK tips, both macroscopically and microscopically. They attributed this to the inability of the ultrasonic tips to reach the valley parts of the implant threads and perform effective decontamination. The discrepancy in our study results may be ascribed to using flat-surfaced titanium discs rather than the original threaded implant surface.

On the other hand, no significant difference was detected among the treatment groups according to our colony count results. Similarly, in a study conducted by Renvert et al.[32], the effectiveness of ultrasonic systems compared to manual curettes was investigated and no significant difference was reported. Another study comparing ultrasonic instruments and plastic curettes also demonstrated no significant difference in results obtained with either method.[33] Furthermore, Kawashima et al.[10] stated no significant difference in biofilm removal from titanium implant surfaces between plastic-coated tipped and steel-tipped ultrasonic devices. All these studies, including ours, overlook the nature of the oral cavity where the implant is placed. Considering the pH balance, temperature, and humidity of the oral environment, the contribution of saliva to bacterial biofilm formation, and the challenges of removing biofilm from implant surfaces, statistical differences between these decontamination techniques can be expected in further clinical studies.

SEM images of the present study reveal that the ultrasonic-driven steel tip nearly eliminates the S. aureus biofilm from the surface but alters the surface structure severely. Similarly, in a study that evaluated SEM images, Schmidt et al.[34] presented that treatment groups containing stainless steel instruments caused more detrimental changes on the implant surface than other treatment groups. Additionally, in their study, which is very similar to ours and includes SEM images, Beak et al.[35] observed that conventional steel tips caused more damage to titanium surfaces compared to plastic-coated tips. When ultrasonic devices are used, the oscillation of the steel ultrasonic tip effectively removes the biofilm on the

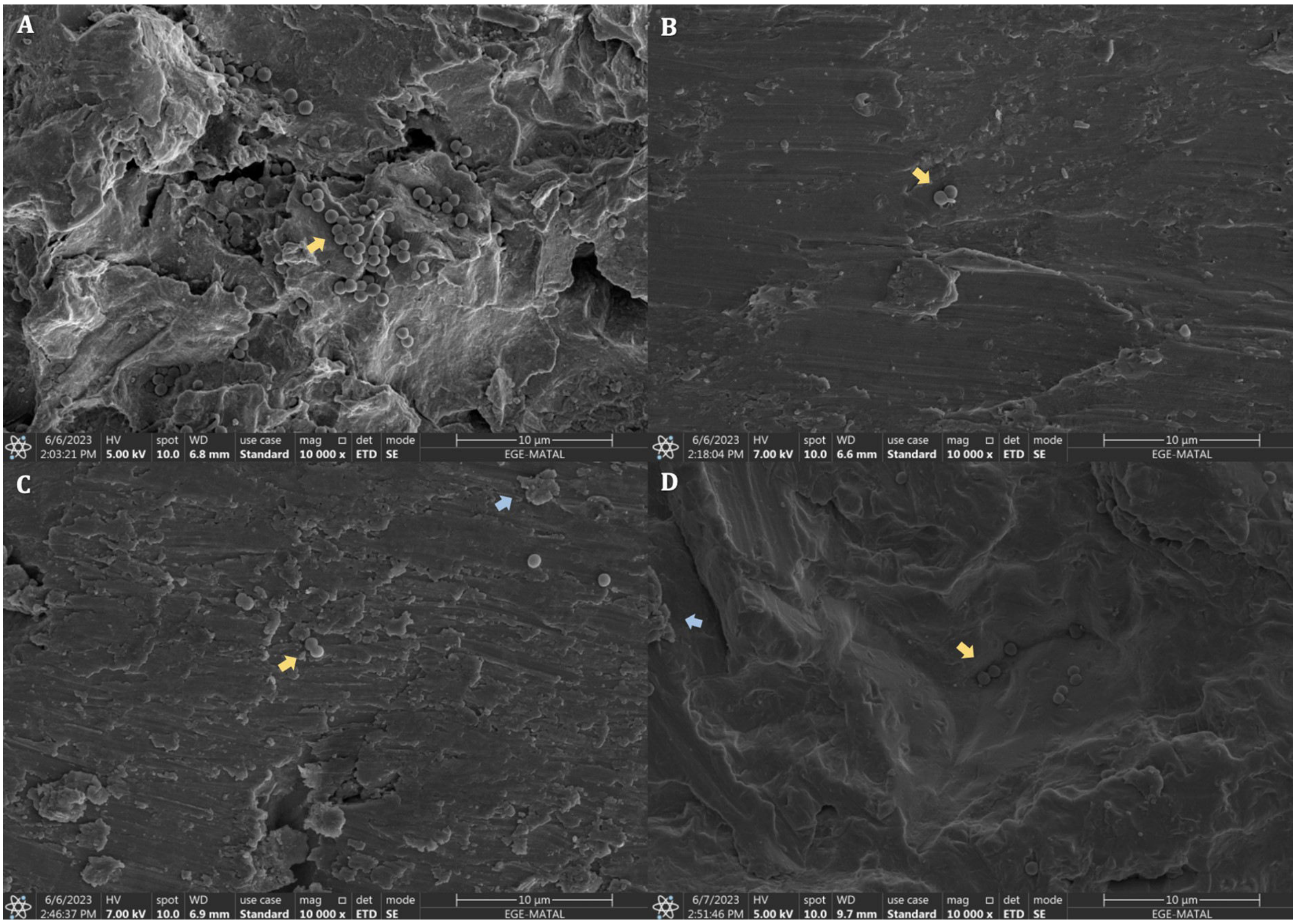

Figure 2. Representative SEM images of the S. aureus biofilm on the disc surfaces following decontamination procedures at a magnification of × 10000: (A) Control, (B) Ultrasonic-driven steel tip, (C) Ultrasonic-driven plastic tip, (D) Plastic curette. S. aureus biofilm (yellow arrow), and plastic remnants (blue arrow) remaining on the treated surfaces are indicated by arrows.

implant surface, yet this effect may come at the expense of damaging surface integrity.[15,26] Alternative tips for ultrasonic-driven devices, such as plastic coating tips, have been demonstrated to leave remnants of coating material on the implant surface.[36,37] Consistently to the mentioned studies, we observed that ultrasonic-driven plastic tips altered the surface integrity and left plastic remnants on the surface.

A plastic curette could be preferred when the main goal of treatment is to maintain surface integrity; but its capability to effectively eliminate microbial biofilm from implant surfaces has been widely questioned.[37] SEM images from our study indicate that the detrimental effect of plastic curettes on surface integrity was insignificant compared to ultrasonic tips. Consistent with the other findings of this study, we observed that the plastic curette was insufficient in removing biofilm compared to other decontamination modalities and left plastic remnants on the surface of the titanium discs. Similarly, Hakki et al.[38] detected plastic residues on the plastic curette-treated implant surfaces. In another similar study, plastic remnants were detected on all titanium surfaces following treatments performed with different plastic instruments. Still, the amount of remnants was highest on plastic curettes.[39]

The present study has several limitations. One limitation is that titanium discs were tested instead of screw-shaped implants to ensure standardization in assessing bacterial elimination. Although roughened titanium discs have the same microstructure as the original implant surfaces, decontamination of the implants is much more complicated cause of the presence of valleys between the threads. This screw-shaped design of titanium implants may hinder instruments from accessing the diseased surface and limit decontamination procedures. Another limitation is that an in vitro S. aureus biofilm is preferred over a microbial biofilm with a complex structure that may be more resistant to instrumentation. The findings of this study revealed the incapability of all tested treatment procedures to total removal of S. aureus biofilm, so it can also be estimated that it would be ineffective in eliminating more pathological biofilm.

Within the limitations, mechanical decontamination procedures evaluated in this study presented some beneficial effects in the removal of S. aureus biofilm from titanium surfaces. However, none of these methods were sufficient to eliminate the biofilm. These findings indicate that instrumentation of S. aureus-infected titanium surfaces with mechanical procedures alone may not be sufficient to eradicate the intact biofilm. This is consistent with studies reporting that the combined use of mechanical and chemical methods or other newly developed instruments like lasers can increase the disinfection effect.[18,33] Additionally, alterations in the surface topography and surface chemistry of the implant have a significant efficacy on bacterial biofilm formation.[40] Therefore, further investigations on surface properties and bacterial elimination methods are required before a definitive treatment recommendation can be provided.

Conclusion

All investigated procedures resulted in reductions in the quantity and viable biomass of S. aureus biofilm on titanium surfaces, but none of them achieved complete elimination of the biofilm. To establish a gold standard method capable of completely eradicating

S. aureus biofilm, attention should be directed toward combination procedures that integrate various techniques designed to minimize damage to the titanium surface while inducing chemical disruption of the biofilm.

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Data Collection : E.A.A. , U.B.
Data Analysis : A.K.
Data interpretation and Literature review : All Authors
Draft of the manuscript : E.A.A.
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Conflict of Interest

The author declare no conflict of interest.

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References

1. Alcoforado GA, Rams TE, Feik D, Slots J. Microbial aspects of failing osseointegrated dental implants in humans. J Parodontol. 1991;10(1):11–18.
2. Berglundh T, Jepsen S, Stadlinger B, Terheyden H. Peri-implantitis and its prevention. Clin Oral Implants Res. 2019;30(2):150–155. doi:10.1111/clr.13401.
3. Fürst MM, Salvi GE, Lang NP, Persson GR. Bacterial colonization immediately after installation on oral titanium implants. Clin Oral Implants Res. 2007;18(4):501–508. doi:10.1111/j.1600-0501.2007.01381.x.
4. Mombelli A, Lang NP. Microbial aspects of implant dentistry. Periodontol 2000. 1994;4:74–80. doi:10.1111/j.1600-0757.1994.tb00007.x.
5. Persson GR, Renvert S. Cluster of bacteria associated with peri-implantitis. Clin Implant Dent Relat Res. 2014;16(6):783–793. doi:10.1111/cid.12052.
6. Albertini M, López-Cerero L, O'Sullivan MG, Chereguini CF, Ballesta S, Ríos V, et al. Assessment of periodontal and opportunistic flora in patients with peri-implantitis. Clin Oral Implants Res. 2015;26(8):937–941. doi:10.1111/clr.12387.
7. Salvi GE, Furst MM, Lang NP, Persson GR. One-year bacterial colonization patterns of Staphylococcus aureus and other bacteria at implants and adjacent teeth. Clin Oral Implants Res. 2008;19(3):242–248. doi:10.1111/j.1600-0501.2007.01470.x.
8. Cosgarea R, Roccuzzo A, Jepsen K, Sculean A, Jepsen S, Salvi GE. Efficacy of mechanical/physical approaches for implant surface decontamination in non-surgical submarginal instrumentation of peri-implantitis. A systematic review. J Clin Periodontol. 2023;50 Suppl 26:188–211. doi:10.1111/jcpe.13762.
9. Meyle J. Mechanical, chemical and laser treatments of the implant surface in the presence of marginal bone loss around implants. Eur J Oral Implantol. 2012;5 Suppl:71–81.
10. Kawashima H, Sato S, Kishida M, Ito K. A comparison of root surface instrumentation using two piezoelectric ultrasonic scalers and a hand scaler in vivo. J Periodontal Res. 2007;42(1):90–95. doi:10.1111/j.1600-0765.2006.00924.x.
11. Sahrmann P, Winkler S, Gubler A, Attin T. Assessment of implant surface and instrument insert changes due to instrumentation with different tips for ultrasonic-driven debridement. BMC Oral Health. 2021;21(1):25. doi:10.1186/s12903-020-01384-0.
12. Keim D, Nickles K, Dannewitz B, Ratka C, Eickholz P, Petsos H. In vitro efficacy of three different implant surface decontamination methods in three different defect configurations. Clin Oral Implants Res. 2019;30(6):550–558. doi:10.1111/clr.13441.
13. Sahrmann P, Ronay V, Hofer D, Attin T, Jung RE, Schmidlin PR. In vitro cleaning potential of three different implant debridement methods. Clin Oral Implants Res. 2015;26(3):314–319. doi:10.1111/clr.12322.
14. Luengo F, Sanz-Esporrín J, Noguerol F, Sanz-Martín I, Sanz-Sánchez I, Sanz M. In vitro effect of different implant decontamination methods in three intraosseous defect configurations. Clin Oral Implants Res. 2022;33(11):1087–1097. doi:10.1111/clr.13991.
15. Sanz-Martín I, Paeng K, Park H, Cha JK, Jung UW, Sanz M. Significance of implant design on the efficacy of different peri-implantitis decontamination protocols. Clin Oral Investig. 2021;25(6):3589–3597. doi:10.1007/s00784-020-03681-y.
16. Park JB, Jang YJ, Koh M, Choi BK, Kim KK, Ko Y. In vitro analysis of the efficacy of ultrasonic scalers and a toothbrush for removing bacteria from resorbable blast material titanium disks. J Periodontol. 2013;84(8):1191–1198. doi:10.1902/jop.2012.120369.
17. Park JB, Lee SH, Kim N, Park S, Jin SH, Choi BK, et al. Instrumentation With Ultrasonic Scalers Facilitates Cleaning of the Sandblasted and Acid-Etched Titanium Implants. J Oral Implantol. 2015;41(4):419–428. doi:10.1563/aaid-joi-d-13-00078.
18. Schwarz F, Sculean A, Rothamel D, Schwenzer K, Georg T, Becker J. Clinical evaluation of an Er:YAG laser for nonsurgical treatment of peri-implantitis: a pilot study. Clin Oral Implants Res. 2005;16(1):44–52. doi:10.1111/j.1600-0501.2004.01051.x.
19. Toma S, Behets C, Brecx MC, Lasserre JF. In Vitro Comparison of the Efficacy of Peri-Implantitis Treatments on the Removal and Recolonization of Streptococcus gordonii Biofilm on Titanium Disks. Materials (Basel). 2018;11(12). doi:10.3390/ma11122484.
20. Toma S, Brecx MC, Lasserre JF. Clinical Evaluation of Three Surgical Modalities in the Treatment of Peri-Implantitis: A Randomized Controlled Clinical Trial. J Clin Med. 2019;8(7). doi:10.3390/jcm8070966.
21. Toma S, Lasserre J, Brecx MC, Nyssen-Behets C. In vitro evaluation of peri-implantitis treatment modalities on Saos-2osteoblasts. Clin Oral Implants Res. 2016;27(9):1085–1092. doi:10.1111/clr.12686.
22. Al-Hashedi AA, Laurenti M, Benhamou V, Tamimi F. Decontamination of titanium implants using physical methods. Clin Oral Implants Res. 2017;28(8):1013–1021. doi:10.1111/clr.12914.
23. Pérez-Tanoira R, Fernández-Arias M, Potel C, Carballo-Fernández R, Pérez-Castro S, Boutinguiza M, et al. Silver Nanoparticles Produced by Laser Ablation and Re-Irradiation Are Effective Preventing Peri-Implantitis Multispecies Biofilm Formation. Int J Mol Sci. 2022;23(19). doi:10.3390/ijms231912027.
24. Giannelli M, Landini G, Materassi F, Chellini F, Antonelli A, Tani A, et al. Effects of photodynamic laser and violet-blue led irradiation on Staphylococcus aureus biofilm and Escherichia

coli lipopolysaccharide attached to moderately rough titanium surface: in vitro study. Lasers Med Sci. 2017;32(4):857–864. doi:10.1007/s10103-017-2185-y.

25. Hiltunen AK, Savijoki K, Nyman TA, Miettinen I, Ihalainen P, Peltonen J, et al. Structural and Functional Dynamics of Staphylococcus aureus Biofilms and Biofilm Matrix Proteins on Different Clinical Materials. Microorganisms. 2019;7(12). doi:10.3390/microorganisms7120584.
26. Cha JK, Paeng K, Jung UW, Choi SH, Sanz M, Sanz-Martín I. The effect of five mechanical instrumentation protocols on implant surface topography and roughness: A scanning electron microscope and confocal laser scanning microscope analysis. Clin Oral Implants Res. 2019;30(6):578–587. doi:10.1111/clr.13446.
27. Kurt A, Cilingir A, Bilmenoglu C, Topcuoglu N, Kulekci G. Effect of different polishing techniques for composite resin materials on surface properties and bacterial biofilm formation. J Dent. 2019;90:103–199. doi:10.1016/j.jdent.2019.103199.
28. Reigada I, Pérez-Tanoira R, Patel JZ, Savijoki K, Yli-Kauhaluoma J, Kinnari TJ, et al. Strategies to Prevent Biofilm Infections on Biomaterials: Effect of Novel Naturally-Derived Biofilm Inhibitors on a Competitive Colonization Model of Titanium by Staphylococcus aureus and SaOS-2 Cells. Microorganisms. 2020;8(3). doi:10.3390/microorganisms8030345.
29. Romanos GE, Weitz D. Therapy of peri-implant diseases. Where is the evidence? J Evid Based Dent Pract. 2012;12(3 Suppl):204–208. doi:10.1016/s1532-3382(12)70038-6.
30. Louropoulou A, Slot DE, Van der Weijden F. The effects of mechanical instruments on contaminated titanium dental implant surfaces: a systematic review. Clin Oral Implants Res. 2014;25(10):1149–1160. doi:10.1111/clr.12224.
31. Schmage P, Thielemann J, Nergiz I, Scorziello TM, Pfeiffer P. Effects of 10 cleaning instruments on four different implant surfaces. Int J Oral Maxillofac Implants. 2012;27(2):308–317.
32. Renvert S, Samuelsson E, Lindahl C, Persson GR. Mechanical non-surgical treatment of peri-implantitis: a double-blind randomized longitudinal clinical study. I: clinical results. J Clin Periodontol. 2009;36(7):604–609. doi:10.1111/j.1600-051X.2009.01421.x.
33. Karring ES, Stavropoulos A, Ellegaard B, Karring T. Treatment of peri-implantitis by the Vector system. Clin Oral Implants Res. 2005;16(3):288–293. doi:10.1111/j.1600-0501.2005.01141.x.
34. Schmidt KE, Auschill TM, Heumann C, Frankenberger R, Eick S, Sculean A, et al. Influence of different instrumentation modalities on the surface characteristics and biofilm formation on dental implant neck, in vitro. Clin Oral Implants Res. 2017;28(4):483–490. doi:10.1111/clr.12823.
35. Baek SH, Shon WJ, Bae KS, Kum KY, Lee WC, Park YS. Evaluation of the safety and efficiency of novel metallic ultrasonic scaler tip on titanium surfaces. Clin Oral Implants Res. 2012;23(11):1269–1274. doi:10.1111/j.1600-0501.2011.02302.x.
36. Mann M, Parmar D, Walmsley AD, Lea SC. Effect of plastic-covered ultrasonic scalers on titanium implant surfaces. Clin Oral Implants Res. 2012;23(1):76–82. doi:10.1111/j.1600-0501.2011.02186.x.
37. Rühling A, Kocher T, Kreusch J, Plagmann HC. Treatment of subgingival implant surfaces with Teflon-coated sonic and ultrasonic scaler tips and various implant curettes. An in vitro study. Clin Oral Implants Res. 1994;5(1):19–29. doi:10.1034/j.1600-0501.1994.050103.x.
38. Hakki SS, Tatar G, Dundar N, Demiralp B. The effect of different cleaning methods on the surface and temperature of failed titanium implants: an in vitro study. Lasers Med Sci. 2017;32(3):563–571. doi:10.1007/s10103-017-2149-2.
39. Yang SM, Park JB, Ko Y. Use of confocal microscopy for quantification of plastic remnants on rough titanium after instrumentation and evaluation of efficacy of removal. Int J Oral Maxillofac Implants. 2015;30(3):519–525. doi:10.11607/jomi.3500.
40. Teughels W, Van Assche N, Sliepen I, Quirynen M. Effect of material characteristics and/or surface topography on biofilm development. Clin Oral Implants Res. 2006;17 Suppl 2:68–81. doi:10.1111/j.1600-0501.2006.01353.x.

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ORIGINAL RESEARCH ARTICLE

Clinical Impact of Local Anesthesia on Sedation Stability and Propofol Dosage in Pediatric Dental Sedation

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Abstract

Background: Local anesthesia (LA) is often preferred for stabilization of vital signs, depth of anesthesia and pain control in dental restorations but the efficacy of LA administration during deep sedation is controversial.
Aim: To retrospectively investigate the effects of LA on heart rate, blood pressure, oxygen saturation, depth of anesthesia and total dose of anesthetic drugs given in pediatric patients sedated for dental procedures.
Materials and Methods: Records of 50 healthy children were divided into two groups: Patients who received infiltration LA at the beginning of sedation (Early LA) or who received LA at the end of sedation after completion of restorations (Late LA). Demographic data, hemodynamic data, Bispectral Index (BIS) scores, Ramsey Sedation Scale scores, total propofol dose administered were compared. Since the difference between two quantitative dependent variables did not meet the assumptions of normal distribution, Wilcoxon Signed Rank test was used. Generalized Estimation Models were used to look at the effect of quantitative variables with repeated measures (BIS and Ramsey) on groups.
Results: There was no statistically significant difference between the groups in terms vital signs, depth of anesthesia (BIS (p=0.190) and Ramsey score (p=0.887)), and total propofol dose adjusted for BMI (p=0.59).
Conclusions: The presence of LA during deep dental sedation has no significant impact on vital signs, depth of anesthesia and total amount of propofol used compared to the absence of LA. LA does not contribute to stabilization of dental sedation, but close monitoring of deep sedation prevents drug overdose.

Keywords: Dental Sedation; Local Anesthesia; Monitoring; Pediatric Anesthesia; Propofol

Introduction

Anxiety and fear are challenging for dentists in the treatment of pediatric patients.[1] When cooperation with the child cannot be achieved with behavioral management methods, pharmacological methods such as oral sedatives, nitrous oxide inhalation, deep sedation and general anesthesia are used.[2–4] Intravenous anesthesia combined with local anesthesia is an preferable method during general anesthesia in terms of safety and effectiveness in controlling anxiety and pain in patients.[5] During dental restorations under general anesthesia, local anesthesia is often preferred for bleeding and postoperative pain control.[6] In addition, local anesthesia is effective for stabilization of vital signs and anesthesia depth during general anesthesia or sedation, control of pain and bleeding after the procedure, and enhancement of recovery.[5–10] Although some dentists believe that LA is ineffective for pain, delays wound healing and causes prolonged numbness, we acknowledge it is an integral part of procedural sedation for postoperative pain and bleeding control.[11,12]

The optimal timing of local anesthesia administration during pediatric dental sedation is still a controversial topic. Depending on personal preference, some dentists administer local anesthesia at the very beginning of the procedure, while others leave it until after the completion of restorative procedures, just before the extractions. We hypothesized that infiltration local anesthetic administration during the induction period of procedural sedation stabilize vital signs, enhances the depth of anesthesia, and reduces the need for sedative medication.

In this retrospective study, we aimed to compare the effects of the presence or absence of LA on hemodynamic parameters, depth of anesthesia, and total anesthetic dose used during deep dental sedation for restorative dental procedures.

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Material and Methods

Study Design and Setting

This retrospective cohort study evaluates the retrospective data of 50 patients who underwent dental treatment using deep sedation at Ankara University, Faculty of Dentistry, Department of Pediatric Dentistry between December 2021 and December 2022. All the patients in this study were anesthetized in the faculty of dentistry of a tertiary university hospital. The findings of this study are based on pre-recorded data on monitor readings and administered medications with patient characteristics during deep sedation procedures.

Ethical Approval and Clinical Trials Registration

After obtaining the institutional ethical committee approval (approval number: 36290600/55) records of the 50 patients who had dental treatments under sedation in the department of pediatric dentistry between 2021-2022 were included in this retrospective study. This study was performed in line with the principles of the Declaration of Helsinki and registered to ClinicalTrials.gov (NCT06218173). The parents of the patients whose records were used had previously provided written informed consent for deep sedation anesthesia for restorative dental procedures.

Sample Size Determination and Patient Selection

A power analysis was performed to determine the appropriate sample size. According to the results of a preliminary study with 12 patients, the sample calculation was made based on the effect size. When the effect size of the relationship between the study variables was 0.2 a sample size of 44 was determined at an alpha of 0.05 and a power of 0.95. In this case, the records of 2 groups of patients were accessed: 28 patients who received LA at the time of anesthesia induction (EarlyLA) and 22 patients who received LA after the end of anesthesia (LateLA).

Pediatric dental patients who were previously sedated and fulfilled the following inclusion criteria were included in this investigation. Inclusion criteria were patients with American Society of Anesthesiologists (ASA) physical status classification I-II and aged between 2 and 8 years. Exclusion criteria were ASA status III-V, age older than 8 years, any history of allergy to anesthetic drugs, renal disease interfering with drug metabolism.

Anesthesia and Dental Interventions

Patient records were divided into two groups: patients undergoing infiltration anesthesia (4% articaine HCl with 1:100.000 epinephrine) at the beginning of sedation (Early LA Group, n:28) and administered infiltration anesthesia after the completion of restorative treatments and just before the extractions (Late LA Group, n:22). The utilization of local anesthesia in pediatric dental sedation was a discretionary decision made by individual practitioners. Within our clinic, some pediatric dentists choose to administer LA at the beginning of the sedation, while others choose to administer at the end, just before the extractions. Since bleeding blocks the exposure of the surgical site, teeth extractions are routinely performed as the last step of sedation protocol in our clinical practice. After induction of anesthesia in the early la group and stabilization of the sedation level to the target BIS level with maintenance anesthesia, the patient was prepared for dental restorations. At this stage, local anesthesia was administered by the dentist just before starting dental treatments. On the other side, in the Late LA group, local anesthesia was administered at the end of sedation, corresponding to the discontinuation of anesthetic drugs and just before extractions. Since the local anesthetic in the Late LA group was administered after the propofol infusion was discontinued, it was considered that it did not affect the total dose of sedative drug used. Infiltration anesthesia was performed with 4% articaine HCl with 1:100,000 epinephrine solution. Articaine is an amid type local anesthetic, which has a rapid onset and potency and widely used in dentistry.[13] Articaine was the local anesthetic utilized in this study and dosing never exceeded 7mg/kg in all patients.

Patients were monitored for oxygen saturation, respiratory rate, electrocardiography, heart rate, blood pressure (Dräger, Infinity Vista XL monitor, Germany), capnography (Microstream EtCO2; Medtronic Capnostream35, USA), and Bispectral Index (BIS) (Aspect XP Bispectral Index Monitor (Medtronic, Minneapolis, Minnesota, USA). Anesthesia induction was achieved by inhalation of 50% oxygen + 50% nitrous oxide + 1-8% sevoflurane gas mixture via mask ventilation. After intravenous access was established, sevoflurane and nitrous oxide were discontinued. A bolus dose of 0.1 mg/kg lidocaine and 1mg/kg propofol were administered. Depth of anesthesia was monitored by BIS, which is a technique that uses the electroencephalogram (EEG) to assess patients' levels of consciousness while under anesthesia. This system allows accurate adjustment of sedation levels by assigning a numerical value ranging from 0 to 100, with higher scores indicating higher levels of consciousness.[14,15] After induction of anesthesia, propofol infusion was started in all patients using a TCI system based on the Schneider model. (BBraun Perfusor SpaceTM TCI; BBraun, Melsungen, Germany). The primary plasma target concentration was 2 μg/ml, the expected brain propofol concentration was calculated and displayed on the TCI pump monitor. Propofol was titrated to the desired BIS value by the anesthesiologist. To reach the deep sedation level, the goal was to reach a BIS value of 50-60, characterized by unresponsiveness to painful stimuli and absence of reflex activity. The sedation score was also assessed and recorded according to the Ramsey sedation scale from 1 to 6, with a score of 1 meaning fully awake and a score of 6 meaning unresponsive to any stimulus.[16] After a stable depth of sedation was reached, patients were placed in the head and chin lift position and a nasal cannula was inserted for supplemental oxygen (2-4 L/min). The airway was not instrumented. According to BIS levels, deep sedation and spontaneous ventilation was also confirmed. Chin lift or chin thrust maneuvers were performed if any saturation drop occurred. The standard analgesia protocol applied in our clinic was paracetamol administration at a dose of 10 mg/kg. Once consciousness was restored after the dental procedure, patients were transferred to the post-anesthesia care unit (PACU), where they were closely monitored until they met the AAPD's established discharge criteria.

All anesthesia interventions, follow-up and recovery were performed in accordance with the guidelines of AAP/AAPD.[3] All interventions during the procedure were performed by an experienced anesthesiologist. Patients were observed by an independent observing anesthesiologist for hemodynamic parameters, complications, and medical record. Restorative procedures (fissure sealants, glass ionomer restorations, compomer and composite resin restorations, pulpotomy and pulpectomy, stainless steel crowns, strip crowns and extractions) were performed by the pediatric dentists in all patients.

Hemodynamic data including systolic and diastolic blood pressure, heart rate and blood oxygen saturation were retrieved form the files. The total amount of anesthetic drug administered, recovery time, complications were also recorded.

Patient demographics, blood pressure, heart rate, oxygen saturation, BIS values and sedation depth scores according to Ramsey Sedation Scale were compared between the two groups. The total amount of general anesthetic drug (propofol) given was compared according to body mass index (BMI).

Table 1. Identifiers by Groups

Variables		Group: EarlyLA:28	Group: LateLA:22	p value
Age (years)	Mean.±SD	5.11±0.85	4.55±1.10	0.095[b]
	Median (Min.-Max.)	5.00 (4.00-7.00)	5 (2-6)	
Sex, n(%)	Male	16 (59.3)	10 (45.5)	0.336[c]
	Female	12 (40.7)	12 (54.5)	
BMI	Mean±SD	16.04±1.64	17.87±3.38	0.016[a]
	Median (Min.-Max.)	15.70 (13.61-22.16)	17.57 (12.46-24.41)	
Total Propofol (mg)	Mean SD	217.44±72.50	215±75.95	0.597[b]
	Median (Min.-Max.)	201 (140-380)	202.5 (131-392)	

SD: Standard Deviation, Min.: Minimum, Max.: Maximum, a: Student-t test, b: Mann-Whitney U test, c: Chi-square test

Statistical Analysis

SPSS 11.5 program was used in the analysis of the data. Mean ± standard deviation and median (minimum-maximum) were used as descriptors for quantitative variables, and the number of patients (percentage) for qualitative variables. The difference between the categories of the qualitative variable, which has two categories in terms of quantitative variables, was examined using the Mann-Whitney U test, since the assumptions of normal distribution were not met. Chi-square test was used to examine the relationship between two qualitative variables. When the difference between two quantitative dependent variables was wanted to be examined, the Wilcoxon Signed Rank test was used because the assumptions of normal distribution were not met. Generalized Estimation Equation (GEE) Models were used to look at the effect of the LA application timing of groups on the quantitative variable with repeated measurements. The statistical significance level was taken as 0.05.

Results

The 28 patients included in the study received local anesthesia just after the induction of anesthesia for restorative procedures (Early LA group), while 22 patients received local anesthesia only immediately prior to tooth extraction following restorations (Late LA group). Patients were aged between 2 and 7 years and 52% were male. There was no significant difference between the two groups in terms of age and gender. Table 1. shows the relationship between age, gender, body mass index (BMI) and the total amount of propofol used between the groups. There were no significant differences between the two groups in terms of the total amount of propofol used (p=0.59). The total amount of general anesthetic drug given was compared adjusting to body mass index.

Table 2. shows the differences between the BIS values according to the groups and the times (minutes) when the measurements were made. Generalized Estimating Equation (GEE) models were used to examine the effect LA application timing on the BIS variable with repeated measurements, and no statistically significant differences were found between the two groups in terms of BIS measurements (p=0.190). The difference between the mean BIS values of the Early LA group and Late LA group was 1.25.

GEE models were used to examine the effect of LA application timing of groups on the Ramsey scores variable with repeated measurements, and no statistically significant differences were found between the two groups in terms of Ramsey score measurements (p=0.887). The difference between the mean Ramsey Scores of Early LA and Late LA groups was 0.02. The descriptors of the Early LA and Late LA groups and the differences between these groups before the procedure, at other times, and between the groups are given in Table 3. There was no significant difference between the groups in these measurements. No complications were observed in the recordings. The lowest oxygen saturation was 99% in the EarlyLA group and 98.2% in the LateLA group. All non-severe oxygen saturation drops were corrected by chin elevation or airway repositioning.

Discussion

This study aimed to examine the effects of timing of local anesthesia administration for restorative procedures during dental treatments under sedation on hemodynamic data, depth of anesthesia and total anesthetic drug dose. Findings of this retrospective study revealed that there was no difference between the groups that received LA at the beginning of the sedation and received LA following the sedation in terms of hemodynamic parameters, depth of sedation and total propofol requirements.

The effect of local anesthesia on hemodynamic data in children undergoing dental treatment under general anesthesia has been investigated in many studies.[5–9,17] Most of these studies show that local anesthesia application under general anesthesia reduces the fluctuations in vital signs by blocking pain pathways. However, our study may contribute to the literature in terms of both focusing on pediatric patients under deep sedation and showing that the effect of local anesthesia does not strengthen sedation contrary to the information in the literature. For instance, a study by El Batawi et al.[8] and reported that the use of local anesthesia in painful dental treatments under general anesthesia helped stabilize heart and respiratory rates. In the same study, it was stated that tooth extraction and pulp treatments had the most impact on hemodynamic data.[8] According to a study by Watts et al.[9] during traumatic interventions under general anesthesia such as closure treatment, pulpotomy, and pulpectomy, the depth of anesthesia decreases due to pain, and the need for additional sedative drugs or LA emerges. They concluded that patients who were not given intraoperative local anesthesia were more likely to have vital sign fluctuations requiring anesthetist intervention. However, in this study, unlike our study, the depth of anesthesia was provided by anesthesia interventions including intermittent bolus propofol administration when needed.[9] The difference in vital signs between patients with and without LA may also be due to a fluctuating anesthetic course maintained by bolus drug administration which are likely to alter heart rate and blood pressure as well. According to the Wilson at al.[10] exclusive administration of anesthetic agents does not sufficiently restrain physiological responses such as changes in blood pressure, heart rate, or irregular heartbeats triggered by painful surgical stimuli. Research has demonstrated that employing bupivacaine alongside general anesthesia during the perioperative period can diminish these reactions to surgical stimuli.[10] In our study, hemodynamic parameters such as heart rate, SpO2, systolic and diastolic blood pressure measurements remained constant and there was no statistically significant difference between the two groups when compared Figures:1-4. The reason why there were no difference in hemodynamic parameters in our study may be the continuous monitoring of the depth of anesthesia with BIS monitoring and prevention of fluctuations in vital signs with deep and stable sedation throughout the procedures. This is because anesthetic maintenance in this study was adjusted to consistently achieve the targeted BIS

Table 2. Identifiers for the EarlyLA and LateLA groups for the BIS

Variables	EarlyLA:28			LateLA:22			
minute	Mean.±SD	Median (Min.-Max.)	P value[a]	Mean.±SD	Median (Min.-Max.)	P value[a]	P value[b]
3.	58.15±6.76	61 (36-65)	–	56,41±8,08	58 (44-68)	–	0.449e
5.	57.93±8.20	60 (31-69)	0.664c	55.73±10.11	56 (35-72)	0.832c	0.586e
10.	55.96±8.14	58 (38-66)	**0.034c**	55.41±8.97	55 (30-68)	0.757c	0.793e
15.	53.03±8.15	52 (35-65)	**0.007c**	53.64±9.67	55 (25-64)	0.156c	0.672e
20.	52.11±10.59	52 (30-66)	**0.008c**	54.18±7.93	54 (40-71)	0.389c	0.451 d
30.	50.59±9.80	46 (38-65)	**0.006c**	47.05±8.90	48 (30-62)	**0.001c**	0.432e
40.	51.78±10.44	56 (32-65)	**0.013c**	44.60±7.35	44 (32-59)	**<0.001c**	0.021e
50.	50.88±11.98	45.50 (36-75)	**0.041c**	49.71±8.19	52 (40-65)	0.035c	0.747d
60.	51.92±9.16	50 (41-65)	0.130c	54.00±12.09	52 (37-69)	0.255c	0.658d
70.	50±11.21	51 (36-62)	**0.026c**	-	-	-	-
80.	45±4.62	45 (41-49)	0.063c	-	-	-	-

a: Comparison between 3 and other times, b: Comparison between EarlyLA and LateLA groups, c: Wilcoxon Signed Rank test, d: Student-t test, e: Mann-Whitney U test

Table 3. EarlyLA and LateLA group descriptors for Ramsey Sedation Score

Variables	EarlyLA:28			LateLA:22			
(time-minute)	Mean.±SD	Median (Min.-Max.)	P value[a]	Mean.±SD	Median (Min.-Max.)	P value[a]	P value[b]/
Preoperative	1±.0	1 (1.0-1.0)		1.0±0.0	1 (1.0-1.0)		1.000d
3.	5.59±0.50	6 (5-6)	**<0.001c**	5.86±0.35	6 (5-6)	**<0.001c**	**0.039d**
5.	5.81±0.40	6 (5-6)	**<0.001c**	5.64±0.49	6 (5-6)	**<0.001c**	0.164d
10.	5.78±0.42	6 (5-6)	**<0.001c**	5.82±0.39	6 (5-6)	**<0.001c**	0.730d
15.	5.93±0.27	6 (5-6)	**<0.001c**	5.82±0.39	6 (5-6)	**<0.001c**	0.257d
20.	5.93±0.27	6 (5-6)	**<0.001c**	5.64±0,49	6 (5-6)	**<0.001c**	**0.013d**
30.	5.78±0.42	6 (5-6)	**<0.001c**	6±0.00	6 (5-6)	**<0.001c**	**0.019d**
40.	5.48±0.66	6 (5-6)	**<0.001c**	5.80±0.41	6 (5-6)	**<0.001c**	0.085d
50.	5.50±0.52	6 (5-6)	**<0.001c**	5.83±0.38	6 (5-6)	**<0.001c**	**0.041d**
60.	5.58±0.51	6 (5-6)	**<0.001c**	5.44±0.53	6 (5-6)	**<0.001c**	0.538d
70.	6±0.0	6	**<0.001c**				-
80.	6±0,0	(5-6)	**<0.001c**				-

a: Comparison between 3 and other times, b: Comparison between EarlyLA and LateLA groups, c: Wilcoxon Signed Rank test, d: Mann-Whitney U test value using target-controlled propofol infusion. A stable anesthesia as in this present study, will not require any additional drug administration and will not lead to vital sign fluctuations due to anesthetic agents. This may have also masked the effect of painful procedures in reducing the depth of anesthesia. In this study, no difference was found between the groups in BIS values and Ramsey Scores, which are parameters indicating the depth of sedation. (p=0.190 for BIS; 0.887 for Ramsay). However, what is noteworthy here is that the total dose of sedative agents used for BIS values providing similar depth of anesthesia was not different between the two groups.

In a survey study conducted in 2014, 92% of the dentists participating in the study reported that they preferred the use of local anesthesia to stabilize vital signs and maintain the depth of anesthesia while performing treatments under general anesthesia.[6] The use, drug choice, application method and time of LA may be according to the clinical habits of most dentists. In our clinic, some pediatric dentists apply LA at the beginning of sedation just before starting intraoral procedures, while others use it at the end of sedation, just before the tooth extraction. However, our study shows that vital signs were similar the other group in the absence of LA during sedation. In this case, consolidation of anesthesia and stabilization of vital signs are not related to the presence of local anesthesia, but rather can be attributed to close BIS monitoring and target-controlled propofol titration.

There are limited studies in the literature investigating the effect of LA application on anesthetic requirement during dental sedation. However, the findings of a study investigating the effect of infiltrative local anesthesia and abdominal wall nerve blockade on the need for anesthetic drugs in pediatric patients undergoing inguinal hernia repair are remarkable. Infiltration anesthesia did not reduce the need for intravenous anesthesia at the level of abdominal nerve blockade, but BIS values were similar throughout the surgery.[18] Likewise, in our study, infiltration anesthesia did not decrease the need for propofol. Although dental infiltration anesthesia is different from the infiltration anesthesia mentioned in abdominal surgery, it is significant that these findings demonstrate the difference in analgesic potency between direct nerve block and infiltration anesthesia. On the other hand, intraligamental LA injection provides more effective postoperative analgesia than infiltration anesthesia as shown in the results of a study by Leong et al.[19] This finding may also be much related to the fact that infiltration anesthesia did not contribute to the depth of anesthesia or reduced the need for propofol under sedation in this study. In this respect, these findings of above studies may support the findings of our study.

In general, the goal after procedural sedation is to avoid any possibility of re-sedation and safely discharge the patient directly home in the same condition as before the sedation. In this context, the concern in pediatric anesthesia is to provide effective anesthesia with the minimal dose of medication possible without residual effects. One of the aims of this study was to investigate the total doses of propofol required for both groups. In this study LA presence resulted in no difference in the requirement of propofol in groups. As Lin et al.[20] demonstrated, BIS-guided TCI propofol sedation technique provides the targeted depth of sedation with less drug consumption.[20] Another conclusion of this study that is consistent with literature that deep sedation can be achieved effectively with TCI propofol under BIS monitoring.[14] On the other hand, it is known that the pharmacodynamics of propofol may be different in underweight and overweight children; therefore, TCI mediated propofol anesthesia is recommended to eliminate this effect.[21] Rogerson et al.[22] showed that overweight and obese children require lower doses of propofol for deep sedation than children of normal body weight.[22] In our study, BMI was found to be higher in Late LA group. To reveal the effect of BMI, the total amount of propofol used was calculated by eliminating BMI and there was no statistically significant difference between the two groups (0.597). This study also demonstrated that deep sedation can be achieved with a similar dose of propofol under the BIS monitor and through target control propofol infusion, regardless of local anesthetic contribution.

Local anesthesia at the beginning of sedation did not contribute to stabilization of vital signs, depth of anesthesia and total dose of propofol administered compared to LA at the end of sedation.

Pediatric deep dental sedation via target-controlled propofol infusion using BIS monitoring resulted in similar amounts of propofol consumption regardless of the presence of local anesthesia. It is concluded that close Bispectral Index monitoring and target controlled propofol infusion rather than timing of local anesthetic administration are the parameters that influence the quality of pediatric deep dental sedation and total drug consumption.

Readers of this study should not conclude that there is no need for local anesthesia under sedation. Local anesthesia has been shown to have many benefits in terms of pain and bleeding control in dental restorations. In this context, the type of drug and drug combinations, dose titration and analgesic potency for postoperative pain management of local anesthesia under sedation may be the subject of future studies.

This study had a couple of limitations. Contrary to the findings in the existing literature, our results showed that the application of local anesthesia at the beginning of sedation did not provide any benefit in terms of stability of vital signs, depth of anesthesia and drug requirement. This may be due to the limited sample size of this retrospective study. In addition, the number of restorative procedures and the total amount of local anesthetic used for each patient in both groups are not known. The lack of standardization in this regard is another limitation of this study. Therefore, our study design aims to provide a randomized controlled trial to fully conclude that local anesthetic application does not affect the depth of hypnosis during propofol anesthesia for pediatric dentistry.

Conclusion

Overall, this retrospective study on 50 healthy subjects showed that local anesthesia during sedation is not effective in strengthening the depth of sedation and stabilizing vital signs. Furthermore, the application of local anesthesia at the induction of deep sedation did not reduce the total dose of propofol needed. In contrast, target-controlled propofol infusion and bispectral index monitoring allow titrating the minimal dose of propofol required to achieve effective depth of sedation rather than supplementing sedation with local anesthesia.

Clinical Implication

The presence of LA during deep dental sedation does not contribute to the depth of sedation, hemodynamic stabilization, and the total dose of propofol required. Pediatric dentists using local anesthesia to enhance sedation may inadvertently increase unnecessary doses and associated complications. According to the results of this retrospective study LA has no benefits to deepen sedation. This study also emphasizes that TCI-propofol and BIS monitoring are essential for ensuring sedation depth and stability.

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Author Contributions

Design : All Authors
Data Collection : C.V. , B.B.U.
Data Analysis and Led the Writing: M.H.K. , B.B.U.

Conflict of Interest

The authors have no conflicts of interest to declare.

Ethics Approval

After obtaining the institutional ethical committee approval (approval number: 36290600/55) records of the 50 patients who had dental treatments under sedation in the department of pediatric dentistry between 2021-2022 were included in this retrospective study. This study was performed in line with the principles of the Declaration of Helsinki and registered to ClinicalTrials.gov (NCT06218173).

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References

1. Klingberg G, Broberg AG. Dental fear/anxiety and dental behaviour management problems in children and adolescents: a review of prevalence and concomitant psychological factors. Int J Paediatr Dent. 2007;17(6):391–406. doi:10.1111/j.1365-263X.2007.00872.x.
2. Ahmed SS, Hicks SR, Slaven JE, Nitu ME. Deep Sedation for Pediatric Dental Procedures: Is this a Safe and Effective Option? J Clin Pediatr Dent. 2016;40(2):156–160. doi:10.17796/1053-4628-40.2.156.
3. Coté CJ, Wilson S. Guidelines for Monitoring and Management of Pediatric Patients Before, During, and After Sedation for Diagnostic and Therapeutic Procedures. Pediatrics. 2019;143(6). doi:10.1542/peds.2019-1000.
4. Zouaidi K, Olson G, Lee HH, Kalenderian E, Walji MF. An Observational Retrospective Study of Adverse Events and Behavioral Outcomes During Pediatric Dental Sedation. Pediatr Dent. 2022;44(3):174–180.
5. Parekh S, Gardener C, Ashley PF, Walsh T. Intraoperative local anaesthesia for reduction of postoperative pain following general anaesthesia for dental treatment in children and adolescents. Cochrane Database Syst Rev. 2014;2014(12):Cd009742. doi:10.1002/14651858.CD009742.pub2.
6. Townsend JA, Hagan JL, Smiley M. Use of local anesthesia during dental rehabilitation with general anesthesia: a survey of dentist anesthesiologists. Anesth Prog. 2014;61(1):11–17. doi:10.2344/0003-3006-61.1.11.
7. Anand P, Wilson R, Sheehy EC. Intraligamental analgesia for post-operative pain control in children having dental extractions under general anaesthesia. Eur J Paediatr Dent. 2005;6(1):10–15.
8. El Batawi HY. Lidocaine use for pain management during paediatric dental rehabilitation under general anaesthesia. Eur Arch Paediatr Dent. 2013;14(6):381–387. doi:10.1007/s40368-013-0027-6.
9. Watts AK, Thikkurissy S, Smiley M, McTigue DJ, Smith T. Local anesthesia affects physiologic parameters and reduces anesthesiologist intervention in children undergoing general anesthesia for dental rehabilitation. Pediatr Dent. 2009;31(5):414–419.
10. Wilson IH, Richmond MN, Strike PW. Regional analgesia with bupivacaine in dental anaesthesia. Br J Anaesth. 1986;58(4):401–405. doi:10.1093/bja/58.4.401.
11. Coulthard P, Rolfe S, Mackie IC, Gazal G, Morton M, Jackson-Leech D. Intraoperative local anaesthesia for paediatric postoperative oral surgery pain–a randomized controlled trial. Int J Oral Maxillofac Surg. 2006;35(12):1114–1119. doi:10.1016/j.ijom.2006.07.007.
12. Moness Ali AM, Hammuda AA. Local Anesthesia Effects on Postoperative Pain After Pediatric Oral Rehabilitation Under General Anesthesia. Pediatr Dent. 2019;41(3):181–185.
13. Luo W, Zheng K, Kuang H, Li Z, Wang J, Mei J. The potential of articaine as new generation of local anesthesia in dental clinics: A review. Medicine (Baltimore). 2022;101(48):e32089. doi:10.1097/md.0000000000032089.
14. Chen SC, Chen CY, Shen SJ, Tsai YF, Ko YC, Chuang LC, et al. Application of Bispectral Index System (BIS) Monitor to Ambulatory Pediatric Dental Patients under Intravenous Deep Sedation. Diagnostics (Basel). 2023;13(10):1789. doi:10.3390/diagnostics13101789.
15. Powers KS, Nazarian EB, Tapyrik SA, Kohli SM, Yin H, van der Jagt EW, et al. Bispectral index as a guide for titration of propofol during procedural sedation among children. Pediatrics. 2005;115(6):1666–1674. doi:10.1542/peds.2004-1979.
16. Ramsay MA, Savege TM, Simpson BR, Goodwin R. Controlled sedation with alphaxalone-alphadolone. Br Med J. 1974;2(5920):656–659. doi:10.1136/bmj.2.5920.656.
17. Townsend JA, Ganzberg S, Thikkurissy S. The effect of local anesthetic on quality of recovery characteristics following dental rehabilitation under general anesthesia in children. Anesth Prog. 2009;56(4):115–122. doi:10.2344/0003-3006-56.4.115.
18. Han D, Pan S. Comparison of Analgesic Efficacy of Local Anesthetic Infiltration and Ultrasound-guided Abdominal Wall Nerve Block in Children Undergoing Ambulatory Inguinal Hernia Repair. J Perianesth Nurs. 2022;37(5):699–705. doi:10.1016/j.jopan.2021.12.006.
19. Leong KJ, Roberts GJ, Ashley PF. Perioperative local anaesthetic in young paediatric patients undergoing extractions under outpatient 'short-case' general anaesthesia. A double-blind randomised controlled trial. Br Dent J. 2007;203(6):E11–335. doi:10.1038/bdj.2007.724.
20. Lin YJ, Wang YC, Huang HH, Huang CH, Liao MX, Lin PL. Target-controlled propofol infusion with or without bispectral index monitoring of sedation during advanced gastrointestinal endoscopy. J Gastroenterol Hepatol. 2020;35(7):1189–1195. doi:10.1111/jgh.14943.
21. Morse JD, Cortinez LI, Anderson BJ. Considerations for Intravenous Anesthesia Dose in Obese Children: Understanding PKPD. J Clin Med. 2023;12(4):1642. doi:10.3390/jcm12041642.
22. Rogerson CM, Abulebda K, Hobson MJ. Association of BMI With Propofol Dosing and Adverse Events in Children With Cancer Undergoing Procedural Sedation. Hosp Pediatr. 2017;7(9):542–546. doi:10.1542/hpeds.2016-0191.

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ORIGINAL RESEARCH ARTICLE

Evaluation of YouTube^{TM} as an Information Source for Indirect Restorations: Cross-Sectional Evaluation

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Abstract

Purpose: To evaluate the usefulness and quality of popular videos about indirect restorations shared by different uploaders on YouTube and to evaluate the demographic characteristics of the videos.
Materials and Methods: The most commonly used terms related directly to indirect posterior restorations were determined as "inlay" and "onlay" in this topic. Of the 400 videos (200 for each topic), 40 videos were selected for analysis. Evaluations were made for each video in terms of the following: (1) number of views, (2) number of comments, (3) days since up-load, (4) number of 'likes', (5) Viewing rate; [(number of views/number of days since upload) * 100%], (6) Viewer interaction, (7) Usefulness Index score, (8) 5-point global quality scale (GQS) criteria.
Results: No statistically significant difference was found among usefulness scores and video sources. (p=0.754). Based on the usefulness score, 20% were classified as good, 40% as poor, and 40% as moderate. No statistically significant difference was found among primary purpose of videos and video sources. (p=0.754). The greatest number of videos (42.5%) was uploaded by dentists (n=17). When the primary purpose is evaluated for the videos uploaded by dentists, the highest numerical value was determined as education for health professionals (52.9%) (n=9).
Conclusions: The contents of YouTube videos regarding the indications and production stages of inlay and onlay restorations need to be revised according to our evaluation criteria. The number of educational videos providing detailed content and information to patients should be increased.

Keywords: Indirect restoration; Inlay; Onlay; Video analysis; YouTube

Introduction

Conservative restorative dentistry offers a broad range of techniques and systems for the minimally invasive treatment of posterior teeth. Composite materials placed by direct or indirect methods are considered one of the best alternatives to restorative treatments, which are tooth-coloured and non-metallic.[1] Light-cured resin composite material is placed in the prepared cavity for indirect restorations. Being compatible with the modern concept of minimally invasive conservative restorative dentistry and allowing maximum preservation of tooth structure are the most important advantages of this technique. Another advantage they have is being performed in only one treatment appointment with low costs compared to other treatment options. Direct restorations also have disadvantages, such as low wear resistance and being associated with polymerization shrinkage.[2,3]

Metal, composite and/or ceramic restorative materials can be used in indirect restorations. Shape and function can be controlled better with indirect inlay/onlay restorations, especially in case of larger defects in posterior teeth.[4] The indirect technique allows the restoration to be produced outside the oral cavity by removing the caries tissue and taking an impression of the tooth prepared with the determined parameters. In the indirect technique, some disadvantages direct composite resin restorations have, for example, polymerization shrinkage, can be solved.[5] In addition, indirect restorations are post-cured with light or heat to provide better physical and mechanical properties. Ideal occlusal morphology and proximal contact are created, and natural compatibility with opposing tooth structure is provided.[6,7] However, this technique takes more time than the direct technique, requiring extra costs and an appointment. This may exceed the patient's wishes and budget.[8]

According to the shape and size of the cavities that need to be restored in the posterior region, indirect restorations after caries removal and cavity preparation are completed are named as follows: inlay restorations (cavity that does not require any tubercle cover), onlay restorations (cavities closed with one or more tubercles) and overlay restorations. (a custom onlay topology with full tubercle coverage).[9] When used effectively, the internet provides a helpful platform for patients who want to learn about health-related issues.[10] In dentistry, besides getting information from the clinician, the internet is also one of the critical information sources. Along with Google™ and Facebook™, YouTube™ is greatly preferred by individuals to find information.[11] YouTube, a free video-sharing site with different content, started in 2005 as an online platform where non-professional users upload and share videos.[12] Health professionals or laypersons can upload health-related videos on YouTube. However, as these videos are not moderated, they may also contain inaccurate information.[13] Numerous studies have evaluated YouTube videos on dental procedures, including teeth whitening, wisdom tooth surgery, dental implants, denture care and orthodontics.[12–18]

Although different topics related to dentistry and medicine have been evaluated in YouTube videos[15,19–24], limited studies evaluate information on indirect restorations. Hence, this research aims to evaluate information in YouTube videos related to indirect restorations regarding the quality of information included with a usability score system and global quality scale (GQS). It also aims to examine the demographic characteristics of these videos, such as how many times they were viewed, how many likes and comments they received, how long ago they were uploaded, how long the videos took, the number of subscribers and the audience interaction. According to video demographic data, our first null hypothesis is that there will be no difference between usefulness scores and GQS scores. The second null hypothesis is that there will be no difference between video sources and usefulness scores regarding video demographics and GQS scores.

Material and Methods

On 12 November 2022 at 11:00 AM, a Google Trends search was performed to specify the keywords. Search criteria are set to the last five years and 'Worldwide'. The most commonly used terms related directly to indirect posterior restorations were determined as "inlay" and "onlay" in this topic. Since this study was conducted on public internet data, it does not require ethics committee approval.

The "Sort by relevance" filter was the search filter used in the present study following the purpose of the study. After clearing the computer history and cookies, the search was started. By using the URLs (universal resource locators) of the videos, playlists were made of the 200 videos for each keyword and 400 videos in the prepared playlists were watched. Videos that were not in English, those which lasted longer than 30 minutes, those which did not have sound, duplicates, videos that were irrelevant to the study and advertisements were not included. Two researchers (ID and MKÖ) independently analyzed the content of all selected videos. In case of any disagreement, the answers were debated until a consensus was eventually reached. Videos were grouped into four regarding their sources: (1) dentist, (2) health institution, (3) commercial company, and (4) individual users. The purposes of the videos are grouped under five headings: training for healthcare professionals, information for patients, sharing personal experience, general information, and product promotion.

Evaluations were made for each video in terms of the following: (1) number of views, (2) number of comments, (3) days since up- load, (4) number of 'likes', (5) Viewing rate; [(number of views/number of days since upload) * 100%], (6) Viewer interaction, which was found by using the formula of interaction index; [(number of likes/total number of views) * 100%], (7) Usefulness Index score, (8) 5-point global quality scale (GQS) criteria. The video content was evaluated with a usefulness score calculated using a 7-point scoring system (Table 1). By using the scale above, the content of videos was evaluated as poor (0 and 1 points), moderate (2 to 4 points), or good (5 to 7 points). Video quality was also evaluated with a 5-point global quality scale (GQS) criteria (Table 2). In order to assess rating reliability and consistency, 20 videos

Table 1. Usefulness score components and rate of observation in videos

Score Component	Point
Defination	1
Indications / Contraindications	1
Cavity preparation	1
Material Selection	1
Advantage / Disadvantage	1
Impression	1
Cementation	1
Total score	7

for each keyword were selected and re-rated by the authors one month after the first evaluation. The videos were scored (from 1 to 5) in terms of flow, quality, and educational usefulness for patients seeking information online by using the -point Global Quality Score (GQS) index (Table 2) as a second method of evaluation. Interaction index and viewing rate formulas: Interaction of YouTube users with the videos was calculated using Interaction index=(number of likes / total number of views)×100% and viewing rate=(number of views/number of days since upload)×100

The data of the present study was analyzed with IBM SPSS V23 software. The normality distribution of the data was tested using the Shapiro-Wilk test. While Kruskal Wallis test was used for comparing non-normally distributed data according to groups of three or more, Dunn's test was used for multiple comparisons. The chi-square test was used to compare categorical data in terms of groups. The relationship between non-normally distributed data was examined with Spearman's rho correlation coefficient. $p<0.050$ significance level was used in analyses.

Results

As a result of the exclusion criteria, the initial sample of 400 videos was decreased to 40. Regarding the usefulness score, 40% of these 40 videos were poor, 40% were moderate, and 20% were good. Except for the variables of days since upload and interaction index, video sources were not found to be statistically significantly different in terms of GQS score or video demographics.(Table 3)

The primary purpose of videos and video sources was not statistically significantly different ($p=0.754$). The greatest number of videos (42.5%) was uploaded for education for health professionals. (Table 4)

Usefulness scores and video sources were not found to be statistically significantly different (p=0,754). Videos which had poor and moderate content were significantly higher in number than the videos with good content. It was found that the good content group had significantly higher GQS scores when compared with the content groups of poor and moderate (P<001) (Table 5).

Compared to the Usefulness group, median values of other parameters were not statistically significantly different ($p>0.050$) (Table 6).

No statistically significant difference was found between the usefulness group regarding the primary purpose ($p=0.804$) (Table 7).

Discussion

YouTube is being increasingly used as a source of information since it can be accessed free and easily. It would be safe to say that YouTube is the first platform that comes to mind when individuals want to have about general and dental health, as in all subjects, due to the gradually increasing popularity of the internet and social media. Although it has various advantages, it has a critical disadvantage that the information it presents cannot be verified in terms of reliability.[25] Since the videos published are not subject to any control mechanism, the accuracy of the transmitted information depends

Table 2. Global quality scale (GQS) criteria

GQS Description	GQS Score
Poor quality; very unlikely to be of any use to patients	1
Poor quality but some information present; of very limited use to patients	2
Suboptimal flow, some information covered but important topics missing; somewhat useful to patients	3
Good quality and flow, most important topics covered, useful to patients	4
Excellent quality and flow; highly useful to patients	5

Table 3. Comparison of video sources according to video demographics and GQS score (P<.05)

	Dentist	Health Instution	Commercial Company	Individual User	p*
Number of views	7503 (117 - 109891)	4876,5 (314 - 92844)	11673,5 (3696 - 70998)	4917 (275 - 68629)	0,863
Number of comments	12 (0 - 115)	2 (0 - 123)	1,5 (0 - 7)	1 (0 - 10)	0,188
Days since upload	719 (245 - 3496)[a]	1568,5 (410 - 4845)[ab]	4132,5 (1958 - 4998)[b]	1796 (45 - 4274)[ab]	0,032
Viewing Rate	20,3 (0,5 - 489,8)	3,8 (0 - 67,9)	0,6 (0,2 - 2)	7,9 (0 - 46,7)	0,065
Usefulness Index Score	3 (1 - 6)	3 (1 - 6)	1 (0 - 3)	3 (3 - 5)	0,099
GQS Score	2 (1 - 4)	2,5 (1 - 4)	1,5 (1 - 2)	3 (1 - 4)	0,336
Number of Likes	134 (4 - 1200)	45,5 (0 - 1000)	15,5 (10 - 100)	21 (1 - 307)	0,304
Interaction Index	1,7 (0,1 - 4,8)[a]	1,2 (0 - 4,6)[ab]	0,3 (0,1 - 0,4)[b]	0,7 (0 - 4,7)[ab]	0,029

*Kruskall Wallis test, a-b: There is no difference between groups with the same letter (Dunn test), median (minimum – maximum)

Table 4. Comparison of Video Sources and Primary Purpose

	Video Sources					
Primary purpose	dentist(n=17)	health instution(n=14)	commercial company(n=4)	individual user(n=5)	Total(n=40)	P
education for health professionals	9 (52,9)	4 (28,6)	1 (25)	3 (60)	17 (42,5)	0,754
information for patients	4 (23,5)	5 (35,7)	1 (25)	1 (20)	11 (27,5)	
presentation of product	0 (0)	1 (7,1)	1 (25)	0 (0)	2 (5)	
providing general information	2 (11,8)	2 (14,3)	0 (0)	0 (0)	4 (10)	
sharing personal experience	2 (11,8)	2 (14,3)	1 (25)	1 (20)	6 (15)	

Table 5. Comparison of usefulness scores by video sources

	Video Sources					
Usefullnes scores	dentist(n=17)	health instution(n=14)	commercial company(n=4)	individual user(n=5)	Total(n=40)	P
Poor	8 (47,1)	5 (35,7)	3 (75)	0 (0)	16 (40)	0,158
Moderate	7 (41,2)	4 (28,6)	1 (25)	4 (80)	16 (40)	
Good	2 (11,8)	5 (35,7)	0 (0)	1 (20)	8 (20)	

Table 6. Comparison of usefulness scores according to video demographics and GQS score

	Usefullnes group						p
	Poor		Moderate		Good		
	mean ± s.deviation	Median (min-max)	mean ± s.deviation	Median (min-max)	mean ± s.deviation	Median (min-max)	
Number of views	23421,75 ± 30445,74	10155 (690 - 109891)	19586,31± 27450,8	4844 (224-75437)	23747,75± 35654,49	4733,5 (117-92844)	0,726
Days since upload	1945,44± 1483,25	1562,5 (245 - 4731)	1876,44± 1600,47	1204 (521 - 4998)	1700,38 ± 1399,61	1327 (45 - 3541)	0,934
Interaction Index	1,06 ± 0,78	1,1 (0 - 2,67)	1,95 ± 1,76	1,25 (0,02 - 4,76)	2,01 ± 1,48	1,79 (0,36 - 4,6)	0,314
Viewing Rate	53,78 ± 123,83	3,96 (0 - 489,8)	18,28±30,84	5,5 (0,02 - 116,01)	21,2 ± 24,05	14,46 (0,46-67,74)	0,787
Like	326,38±459,9	63 (0 - 1200)	196,94 ± 312,98	78,5 (1-1000)	211,63 ± 221,69	177 (4-593)	0,834
GQS Score	1,5±0,63	1 (1 - 3)[b]	2,31±0,79	2,5 (1 - 3)[b]	3,75 ± 0,46	4 (3 - 4)[a]	<0,001
Number of comments	23,94±42,41	2 (0 - 123)	12,25±20,79	6,5 (0 - 83)	6,25 ± 7,36	2,5 (0 - 15)	0,835

Table 7. Comparison of usefulness scores according to the primary purpose

	Primary Purpose						p
	education for health Professional	information for patients	presentation of product	providing general information	sharing personal experience	Total	
Poor	5 (29,4)	5 (45,5)	1 (50)	2 (50)	3 (50)	16 (40)	0,804
Moderate	8 (47,1)	4 (36,4)	0 (0)	1 (25)	3 (50)	16 (40)	
Good	4 (23,5)	2 (18,2)	1 (50)	1 (25)	0 (0)	8 (20)	

on the uploaders' responsibility. This can result in both accurate and useful information as well as false information. The primary aim of the present study is to evaluate the quality of information provided by YouTube videos on indirect restorations.

Previous studies evaluated the first 60 to 202 videos found in search results.[12,15,20,22] Therefore, this study evaluated the first 200 videos that appeared as a result of the search for each keyword.

A successful functional and esthetic result can be achieved if certain clinical protocols are followed for posterior adhesive indirect restorations, such as careful consideration of indications and contraindications, preparation according to the clinical situation, selection of the correct restoration materials, restoration production with the correct tooth dimensions, and an appropriate cementation procedure. It can also make a difference in patient comfort by increasing clinical success.[9] As a result of this situation, a 7-point scoring system was developed to decide the usefulness score of each video, which includes all stages from the definition to the cementation of inlay-onlay restorations.

Usefulness scores and video sources were not found to be statistically significantly different (p=0.754). Poor and moderate content videos were significantly higher in number than good content videos. When the 40 selected videos were evaluated, 20% were classified as good, 40% as poor, and 40% as moderate. When we look at the upload source from the videos evaluated according to the exclusion criteria, dentists (n=17) took the first place and health institutions (n=14) took the second place. Considering the specificity of the topic, it can be estimated that dental professionals shared a great majority of the videos. It could be said that the reason for this is that the content of most videos in our study did not focus on indications/contraindications, material selection and impression, which may have led to poor scores.

The usefulness group, according to the primary purpose, was not found to be statistically significantly different (p=0.804). It was found that the purpose of most videos was education for health professionals (42.5%) (n=17). These videos are primarily aimed at education for dentists or dental students. A significantly higher number of moderate usefulness scores were found in 47.1% of these videos. This may be because the videos for dentists should have an explanation above a certain standard.

The primary purpose of videos and video sources were not found to be statistically significantly different (p=0.754). Most videos (42.5%) were uploaded by dentists (n=17). When the primary purpose is evaluated for the videos uploaded by dentists, the highest numerical value was determined as education for health professionals (52.9%) (n=9). According to the previous literature[26–28], multiple factors affect the success of inlay-onlay restorations, from indication to cementation. When dentists' videos about indirect restorations contain detailed information, they can become instructional videos for dentists or dental students who do not routinely perform the procedure rather than providing information to patients. A previous study found a similar situation, showing that ordinary people were less interested in high-level instructional videos.[29] Previous studies have used subjectively constructed scoring methods and GQS to evaluate the informational content of videos on YouTube.[12,30–34]

The GQS score is a 5-point scale that indicates the flow and quality of the video. It was found that the videos with good content had significantly higher GQS scores than those with poor and moderate content (P<001). The median values of other parameters were not statistically significantly different compared to the Usefulness scores (p>0.050). The fact that the videos with high GQS scores among the videos we examined are at a good level compared to the Usefulness scores can be interpreted as parallel to the increase in the richness of the content as the video quality increases.

In a previous study, researchers noted that although academic institutions and journals have recently created their own educational YouTube channels, health authorities and organizations have posted few highly educational and/or appropriate medical videos.[16] Among medical videos, only 27% were found to be highly educational.[29,35] Hegarty et al.[21] stated that to prevent misinformation, healthcare professionals should provide more information to social media resources, such as Google and YouTube. Bavbek and Balos stated that universities and educational institutions that provide information to the community without expecting anything in return could overcome the lack of reliable information in this field.[36] Our second null hypothesis, that there would be no differences among video sources in terms of video demographics and GQS scores and that there would be no difference among usefulness scores in terms of video sources, was also partially rejected. Except for days since the up-load and interaction index, video sources were not found to be statistically significantly different when GQS score or video demographics were considered.

Last but not least, another crucial issue is that today, sharing content such as patient education continues to be released without regulation or oversight. Because of this, patients and/or users should be educated about choosing the correct information and be guided as to which criteria they should look for. As a result, these scoring systems have taken their place in the scientific literature for professionals. Understandable and accessible criteria for users should be determined and disseminated. Providing and controlling knowledge—especially for health-related content —should be the duty of governments or educational institutions. Even if these organizations cannot control data, they should educate and inform the public on choosing reliable information sources.

There were some limitations in this study. Firstly, this study evaluated videos only in the English language. Further studies should be conducted to evaluate the videos in other languages to comprehend the phenomena country-by-country. Furthermore, this study investigated a limited timeline on the internet. Because the internet is a dynamic source, constantly evolving, such studies regarding the same topics should be conducted in the future.

Conclusion

It has been concluded that the contents of YouTube videos regarding the indications and production stages of inlay and onlay restorations need to be revised according to our evaluation criteria. The number of educational videos providing detailed content and information to patients should be increased.

Author Contributions

Study Design : I.D.
Literature Review : I.D , M.K.O.
Data Collection and Processing : I.D. , M.K.O.
Statistics : I.D.
Preparation of the Manuscript : I.D. , M.K.O.

Conflict of Interest

The authors declare no conflict of interest.

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References

1. Spreafico RC, Krejci I, Dietschi D. Clinical performance and marginal adaptation of class II direct and semidirect composite

restorations over 3.5 years in vivo. J Dent. 2005;33(6):499–507. doi:10.1016/j.jdent.2004.11.009.
2. Barnes DM, Blank LW, Thompson VP, Ginell JC. [Clinical investigation of a posterior composite materials after 5 and 8 years]. Quintessenz. 1991;42(7):1067–1080.
3. Feilzer AJ, De Gee AJ, Davidson CL. Setting stress in composite resin in relation to configuration of the restoration. J Dent Res. 1987;66(11):1636–1639. doi:10.1177/00220345870660110601.
4. Collares K, Corrêa MB, Laske M, Kramer E, Reiss B, Moraes RR, et al. A practice-based research network on the survival of ceramic inlay/onlay restorations. Dent Mater. 2016;32(5):687–694. doi:10.1016/j.dental.2016.02.006.
5. Wassell RW, Walls AW, McCabe JF. Direct composite inlays versus conventional composite restorations: three-year clinical results. Br Dent J. 1995;179(9):343–349. doi:10.1038/sj.bdj.4808919.
6. Barone A, Derchi G, Rossi A, Marconcini S, Covani U. Longitudinal clinical evaluation of bonded composite inlays: a 3-year study. Quintessence Int. 2008;39(1):65–71.
7. Duquia Rde C, Osinaga PW, Demarco FF, de VHL, Conceição EN. Cervical microleakage in MOD restorations: in vitro comparison of indirect and direct composite. Oper Dent. 2006;31(6):682–687. doi:10.2341/05-132.
8. Angeletaki F, Gkogkos A, Papazoglou E, Kloukos D. Direct versus indirect inlay/onlay composite restorations in posterior teeth. A systematic review and meta-analysis. J Dent. 2016;53:12–21. doi:10.1016/j.jdent.2016.07.011.
9. Ferraris F. Posterior indirect adhesive restorations (PIAR): preparation designs and adhesthetics clinical protocol. Int J Esthet Dent. 2017;12(4):482–502.
10. AlGhamdi KM, Moussa NA. Internet use by the public to search for health-related information. Int J Med Inform. 2012;81(6):363–373. doi:10.1016/j.ijmedinf.2011.12.004.
11. Stellefson M, Chaney B, Ochipa K, Chaney D, Haider Z, Hanik B, et al. YouTube as a source of chronic obstructive pulmonary disease patient education: a social media content analysis. Chron Respir Dis. 2014;11(2):61–71. doi:10.1177/1479972314525058.
12. Yagci F. Evaluation of YouTube as an information source for denture care. J Prosthet Dent. 2023;129(4):623–629. doi:10.1016/j.prosdent.2021.06.045.
13. Abukaraky A, Hamdan AA, Ameera MN, Nasief M, Hassona Y. Quality of YouTube TM videos on dental implants. Med Oral Patol Oral Cir Bucal. 2018;23(4):e463–e468. doi:10.4317/medoral.22447.
14. Dias da Silva MA, Pereira AC, Walmsley AD. Who is providing dental education content via YouTube? Br Dent J. 2019;226(6):437–440. doi:10.1038/s41415-019-0046-8.
15. Kılınç DD, Sayar G. Assessment of Reliability of YouTube Videos on Orthodontics. Turk J Orthod. 2019;32(3):145–150. doi:10.5152/TurkJOrthod.2019.18064.
16. Knösel M, Jung K, Bleckmann A. YouTube, dentistry, and dental education. J Dent Educ. 2011;75(12):1558–68.
17. Ozdal Zincir O, Bozkurt AP, Gas S. Potential Patient Education of YouTube Videos Related to Wisdom Tooth Surgical Removal. J Craniofac Surg. 2019;30(5):e481–e484. doi:10.1097/scs.0000000000005573.
18. Simsek H, Buyuk SK, Cetinkaya E, Tural M, Koseoglu MS. "How I whiten my teeth": YouTube™ as a patient information resource for teeth whitening. BMC Oral Health. 2020;20(1):183. doi:10.1186/s12903-020-01172-w.
19. Abdoli S, Hessler D, Vora A, Smither B, Stuckey H. Descriptions of diabetes burnout from individuals with Type 1 diabetes: an analysis of YouTube videos. Diabet Med. 2020;37(8):1344–1351. doi:10.1111/dme.14047.
20. Hassona Y, Taimeh D, Marahleh A, Scully C. YouTube as a source of information on mouth (oral) cancer. Oral Dis. 2016;22(3):202–208. doi:10.1111/odi.12434.
21. Hegarty E, Campbell C, Grammatopoulos E, DiBiase AT, Sherriff M, Cobourne MT. YouTube™ as an information resource for orthognathic surgery. J Orthod. 2017;44(2):90–96. doi:10.1080/14653125.2017.1319010.
22. Ho A, McGrath C, Mattheos N. Social media patient testimonials in implant dentistry: information or misinformation? Clin Oral Implants Res. 2017;28(7):791–800. doi:10.1111/clr.12883.
23. Lena Y, Dindaroğlu F. Lingual orthodontic treatment: A YouTube™ video analysis. Angle Orthod. 2018;88(2):208–214. doi:10.2319/090717-602.1.
24. Ustdal G, Guney AU. YouTube as a source of information about orthodontic clear aligners. Angle Orthod. 2020;90(3):419–424. doi:10.2319/072419-491.1.
25. Ozdede M, Peker I. Analysis of Dentistry YouTube Videos Related To COVID-19. Braz Dent J. 2020;31(4):392–398. doi:10.1590/0103-6440202003767.
26. D'Arcangelo C, Vanini L, Casinelli M, Frascaria M, De Angelis F, Vadini M, et al. Adhesive Cementation of Indirect Composite Inlays and Onlays: A Literature Review. Compend Contin Educ Dent. 2015;36(8):570–7; quiz 578.
27. Dietschi D, Spreafico R. Evidence-based concepts and procedures for bonded inlays and onlays. Part I. Historical perspectives and clinical rationale for a biosubstitutive approach. Int J Esthet Dent. 2015;10(2):210–227.
28. Rocca GT, Krejci I. Bonded indirect restorations for posterior teeth: from cavity preparation to provisionalization. Quintessence Int. 2007;38(5):371–379.
29. Desai T, Shariff A, Dhingra V, Minhas D, Eure M, Kats M. Is content really king? An objective analysis of the public's response to medical videos on YouTube. PLoS One. 2013;8(12):e82469. doi:10.1371/journal.pone.0082469.
30. ElKarmi R, Hassona Y, Taimeh D, Scully C. YouTube as a source for parents' education on early childhood caries. Int J Paediatr Dent. 2017;27(6):437–443. doi:10.1111/ipd.12277.
31. Erdem MN, Karaca S. Evaluating the Accuracy and Quality of the Information in Kyphosis Videos Shared on YouTube. Spine (Phila Pa 1976). 2018;43(22):E1334–e1339. doi:10.1097/brs.0000000000002691.
32. Nason K, Donnelly A, Duncan HF. YouTube as a patient-information source for root canal treatment. Int Endod J. 2016;49(12):1194–1200. doi:10.1111/iej.12575.
33. Özbay Y, Çırakoğlu NY. YouTube as an information source for instrument separation in root canal treatment. Restor Dent Endod. 2021;46(1):e8. doi:10.5395/rde.2021.46.e8.
34. Singh AG, Singh S, Singh PP. YouTube for information on rheumatoid arthritis–a wakeup call? J Rheumatol. 2012;39(5):899–903. doi:10.3899/jrheum.111114.
35. Steinberg PL, Wason S, Stern JM, Deters L, Kowal B, Seigne J. YouTube as source of prostate cancer information. Urology. 2010;75(3):619–622. doi:10.1016/j.urology.2008.07.059.
36. Bavbek NC, Tuncer BB. Information on the Internet Regarding Orthognathic Surgery in Turkey: Is It an Adequate Guide for Potential Patients? Turk J Orthod. 2017;30(3):78–83. doi:10.5152/TurkJOrthod.2017.17027.

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ORIGINAL RESEARCH ARTICLE

The Effect of Different Polishing Procedures and Re-polishing on the Color Stability of Single-shade Composite Resin

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Abstract

Purpose: The aim of this study is to evaluate the effect of different polishing systems on the color stability of single-shade resin composite after coffee immersion, brushing cycles and re-polishing.
Materials and Methods: A total of 40 disc-shaped single-shade resin composite (Omnichroma, Tokuyama, Japan) specimens were prepared using a standard mold. One-step polisher (OneGloss, Shofu, USA), two-step polisher (Clearfil Twist Dia, Kuraray, Japan), multi-step polisher (OptiDisc, Kerr, USA) polishing systems were applied to each group (n=10) in accordance with the manufacturer's instructions. No polishing procedure was applied to the Control group. Representing 6-months and 1-year of clinical use, specimens were exposure in coffee solution (6-12 days) and subjected to brushing cycles (5000-10000 cycles). The specimens were then re-polished by applying the same polishing procedures as initially applied. Color measurements were repeated in all time periods and color change (ΔE00) values were calculated with the CIEDE2000 formulation. Kruskal-Wallis analysis was used for between group comparison, and Mann-Whitney U test was used as a post-hoc test (α=0.05).
Results: At simulated 6-months and 1 year periods, the ΔE00 values of the Control group and one-step polisher (OneGloss) group were statistically similar and significantly higher than the those of the other groups ($p<0.05$). There was no statistically significant difference between all groups in ΔE00 values after re-polishing.
Conclusions: Two-step and multi-step polisher resulted in lower discoloration of single-shade resin composite compared to one-step polisher. Although re-polishing lowered the ΔE00 values, no polishing system was able to cut down the color change of single-shade resin composite below the acceptable threshold.

Keywords: Brushing; Color; Coffee; Re-polishing; Single-shade Composite

Introduction

Innovative esthetic restorative materials are quickly developing to suit patients esthetic aspirations and adjust seamlessly with tooth shade. Within the scope of these developments, a new generation of smart chromatic single-shade resin composites has been introduced to the market, simplifying shade selection procedure without compromising shade matching potential of the composite restoration. One of these materials, Omnichroma (Tokuyama, Japan), was introduced to the market with the claim that it provides shade matching without added pigment and has become one of the most preferred single-shade resin composites by dentists.[1] In some studies, it has been reported that although single-shade resin composites initially exhibit good shade matching performance, they are subjected to more discoloration than resin composites with multi-shade systems.[2,3]

Resin composites must possess color stability and the capacity to resist surface stains to retain their visual appeal. Despite advances in resin composite manufacture, discoloration remains one of the major reasons for the replacement of resin composite restorations.[4] Discoloration of restorations can be caused by extrinsic staining agents or intrinsic discoloration. Intrinsic discoloration factors are mainly related to the composition of the resin composites, such as matrix, type, and amount of filler; photo-initiator system; and polymerization degree. Plaque accumulation, surface discoloration, and minor penetration of staining agents are examples of extrinsic factors that can cause discoloration in the superficial layers of resin composites.[5]

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According to reports, coffee, tea, and other beverages commonly consumed as part of dietary habits cause staining and discoloration of resin composites. Several studies have reported that coffee is the beverage that has the most severe effect on the coloration of resin composites.[6–8] The coffee-induced discoloration is a result of both adsorption and absorption of coloring pigments. Coffee has the ability to release low-polarity yellow pigments that can penetrate the organic phase in resin composites and cause discoloration.[6] Considering that coffee is the most consumed beverage in the world and its consumption is increasing, it is important to understand its effect on the color stability of single-shade resin composite.

Brushing is recommended in the daily routine to partially or completely remove superficial stains caused by beverages and to maintain the color stability of dental resin composite restorations.[9,10] Another method commonly used to remove superficial surface discoloration in composite restorations is re-polishing. Re-polishing is a minimally invasive treatment alternative to improve the esthetics and longevity of resin composite restorations that have not been significantly damaged.[11] Polishing procedures are effective in both preventing and removing the discoloration of resin composites. Various methods and instruments are commercially available for finishing and polishing resin composite restorations. The effectiveness of aluminum oxide-coated abrasive discs is well known in the literature and is recommended as the gold standard.[12] However, the use of these discs is multi-step, and in recent years, one-step or two-step polishing procedures have become quite common in order to effectively reduce the time dentists spend at the chairside for polishing.

Spectrophotometers are considered the most reliable and reproducible measurement devices for determining the color changes of resin composites.[13] Spectrophotometers measure L*, a* and b* in the CIELAB color system and ΔE is calculated using the changes in the color parameters. The Commission Internationale de l'Eclairage (CIE) has developed the CIEDE2000 formula, which considers all variables equally to more accurately determine perceptible and acceptable color change. According to this formula, the 50:50% perceptibility threshold for color change is ΔE=0.8 and the 50:50% acceptability threshold is ΔE=1.8.[14]

Although the shade of resin composite restorations is initially compatible, color incompatibility may occur in the restorations under different external factors and oral conditions. To the authors' knowledge, although there are studies in the literature evaluating the color stability of single-shade resin composites after coffee immersion, the methods of these studies did not include brushing procedures.[15,16] The aim of this study was to evaluate the effect of different polishing procedures and re-polishing on the color stability of single-shade resin composite after coffee immersion and brushing cycles.

The null hypotheses to be tested in the present study were: H01) Regardless of time, there would be no difference in the effect of different polishing systems on the color stability of single-shade resin composite after simulated coffee solution immersion and brushing cycles. H02) Re-polishing procedure would not revert the color change, regardless of the polishing system used.

Material and Methods

In the present study, 3 different polishing systems, one-step polisher (OneGloss, Shofu Dental, USA), two-step polisher (Clearfil Twist Dia, Kuraray, Japan) and multi-step polisher (OptiDisc, Kerr, USA), were tested on a single-shade resin composite (Omnichroma, Tokuyama Dental, Japan) (Table 1). G*power program (G * Power 3.1 Software, Germany) was used to determine the specimen size. According to the results of the analysis a total number of 40 specimenss, at least 10 for each subgroup, was determined at 85% power and 0.05 significance level. Flow diagram of the study is shown in Figure 1.

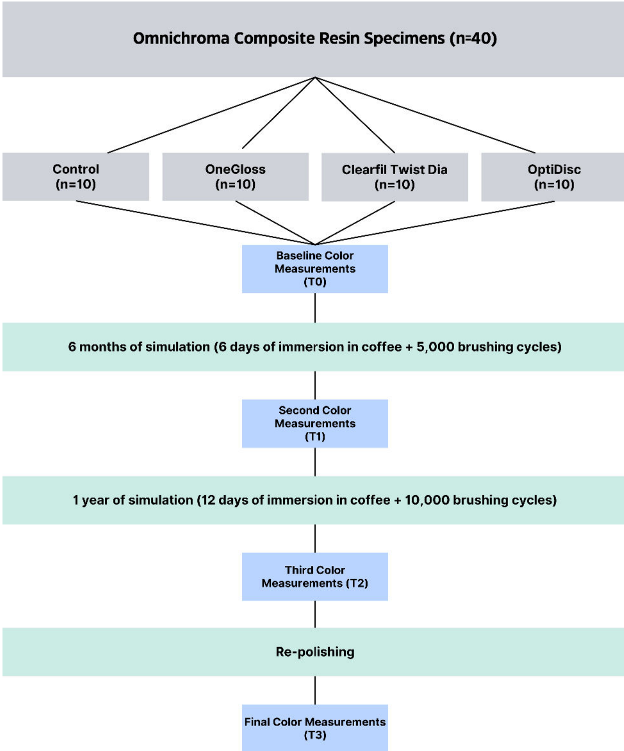

Figure 1. Flow diagram of the experimental design

Preparation of Specimens

A total of 40 disc-shaped single-shade resin composite specimens were prepared using a standard mold (10 mm diameter x 2 mm depth). After the resin composite was placed in the mold, a mylar strip and a 1-mm-thick glass slide were placed on the upper surface of the specimens. Light pressure was applied to ensure that the excess resin composite material overflows and to obtain a standard surface. The glass slide and mylar strip were removed, and the excess resin composite was removed with a metal spatula. After repositioning the mylar strip and glass slide, the specimens were photopolymerized with an LED light device (SmartLite Focus, Dentsply Sirona, USA) in contact with the glass slide for 10 s, after which the glass slide was removed and polymerized for an additional 10 s. After polymerization, the specimens were removed from the mold and stored in distilled water at 37°C in an incubator for 24 h.

Polishing Procedures

Resin composite specimens were randomly divided into 4 groups: Control, One-step polisher (OneGloss), two-step polisher (Clearfil Twist Dia), multi-step polisher (OptiDisc). Except for the control group, the specimens' top surfaces were roughened for 20 s at 250 rpm using 600-grit silicon carbide (SiC) paper in a polisher (Metaserv 250 Twin, Buehler, Germany) under a water stream to standardize the top surface. After each polishing step, the specimens were rinsed with water spray and air-dried. The rpm at which polishing materials were used was determined according to manufacturer instructions, all procedures were carried out in this study by the same operator to reduce variability.

- Control: No polishing procedure was applied.
- One-step polisher (OneGloss): Disc-shaped polishing rubber (IC REF 0183) was applied to the or 20 s at 10,000 rpm under water spray cooling.
- Two-step polisher (Clearfil Twist Dia): Pre-polishing spiral

(dark blue) and high gloss polishing (light blue) were applied for 20 s each at 8,000 rpm under water spray cooling.
- Multi-step polisher (OptiDisc): Polishing discs of 12.6 mm diameter, coarse, medium, fine and super fine, respectively, were applied at 10,000 rpm for 20 s each.

Staining and Brushing Procedures

The specimens were kept in the coffee solution in 1,5 ml Eppendorf tubes prepared for 6 and 12 days, exposure simulating 6 months and 1 year of clinical use. To prepare the coffee solution, soluble granulated coffee (Nescafe Gold, Nestle, France) was chosen. It was prepared using 1 g of coffee for every 100 ml. When the solution reached 37°C, each specimen was placed in separate Eppendorf tubes containing coffee solution and kept in an incubator at 37°C to mimic oral conditions, and the solution was renewed every day.

After staining procedures, 5,000 cycles simulating 6 months brushing, and 10,000 cycles simulating 1 year brushing[17?] were applied to the specimens in a circular motion, under a load of 250 g, with a movement diameter of 16 mm and a movement speed of 40 mm /s. During the brushing simulation, Sensodyne Promine Repair+ (GlaxoSmithKline, USA) toothpaste diluted 1/3 by volume was used with a Colgate Extra Clean toothbrush (Colgate-Palmolive Co., USA).

Re-polishing Procedures

Resin composite specimen groups were re-polished using the initial polishing systems and the same procedures after 6 and 12 days coffee exposure and 5,000 and 10,000 brushing cycles.

Color Measurements

The color values of the resin composite specimens were measured with a contact spectrophotometer (VITA Easyshade V, VITA Zahnfabrik, Germany) using the white calibration plate of the instrument before each measurement. To ensure precise measurements, the probe tip was positioned perpendicular and in direct contact with the surfaces of the specimens. The measurements were repeated three times at the center of the resin composite discs, and the mean L*a*b values were obtained. The color values of the specimens were measured at baseline (T0), after 6 days of coffee immersion followed by 5,000 brushing cycles (T1), after 12 days of coffee immersion followed by 10,000 brushing cycles (T2), and after re-polishing (T3). Using the CIEDE2000 formula, the color change value (ΔE) was calculated based on the mean L*a*b* values of the measurements (KL=KC=KH=1).

Statistical Analysis

Statistical analyses were performed with IBM SPSS Statistics (Version 26.0, IBM Corp., USA). The normality of the distribution of the data was analyzed by Kolmogorov Smirnov and Shapiro-Wilk tests. Kruskal-Wallis analysis was used for between-group comparison, and Mann-Whitney U test was used as a post-hoc test for significant differences. Wilcoxon Signed Rank test was applied for comparison of time periods. (α=0.05).

Results

Within the scope of the study, the color change values of resin composite polished with 3 different polishing systems were compared at simulated 6-months and 1 year coffee exposure, and after re-polishing. Comparisons between groups, mean color change values, and standard deviations are shown in the Table 2 and Table 3.

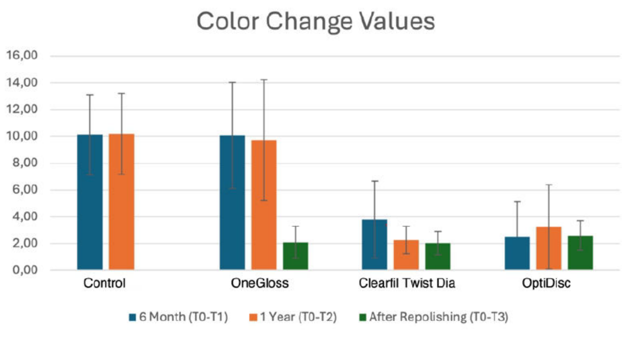

Figure 2. Bar chart of the mean color change value ($\Delta E00$) of the groups at different time points and after re-polishing.

A statistically significant difference was found between the groups in the color change values after simulated 6-month coffee exposure and brushing (p<0.05). As a result of the post hoc test, the color change values of the Control and one-step polisher (OneGloss) groups were statistically similar (p>0.05), and significantly higher than the other polishing system groups. There was also no significant difference between two-step polisher (Clearfil Twist Dia) and multi-step polisher (OptiDisc) groups (p>0.05). The highest color change value was measured in the Control group and the lowest color change value was measured in the multi-step polisher (OptiDisc) group.

Similar to the 6-month exposure simulation results, a statistically significant difference was found between the groups in the color change values after aging, which exposure simulates the 1 year (p<0.05). 1 year time period color change values are statistically similar in the Control and one-step polisher (OneGloss) groups (p>0.05), and significantly higher than in other polishing system groups (p<0.05). No significant difference was found between the two-step polisher (Clearfil Twist Dia) and multi-step polisher (OptiDisc) groups (p>0.05). The highest color change value was measured in the Control group, and the lowest color change value was measured in the multi-step polisher (OptiDisc) group. Although there was a decrease in the color change values of the re-polished resin composites, there was no statistically significant difference between the polisher groups (p>0.05).

There was no statistically significant difference between the color change values in the comparison between the time periods in the Control, two-step polisher (Clearfil Twist Dia) and multi-step polisher (OptiDisc) groups (p>0.05). In the one-step polisher (OneGloss) group, there is no statistically significant difference between 6-months and 1-year exposure simulation color change values (p>0.05), but there is a statistically significant difference between 6 months exposure simulation and re-polishing and 1 year exposure simulation and re-polishing color change values (p<0.05). Resin composite specimens in the one-step polisher (OneGloss) group had significantly reduced color change values after re-polishing. The bar graph of the mean color change value of the groups is shown in Figure 2.

Discussion

Resin composite restorations should be able to esthetically mimic natural teeth regarding their optical properties such as color, gloss, and translucency and should retain these properties in the long term. However, even if the color matching of the restorations is initially acceptable with the teeth, they may change color over time due to exposure to different intrinsic and extrinsic staining agents. In the present study, the effect of different polishing systems on the color stability of single-shade resin composites was evaluated after immersion in coffee solution, brushing cycles, and re-polishing.

Table 1. Materials used in study

Materials	Composition	Type	Manufacturer	Lot Number
Omnichroma	UDMA, TEGDMA, Uniform-sized supra-nano-spherical filler (260 nm spherical SiO_2-ZrO_2), Composite filler (260 nm spherical SiO_2-ZrO_2), Filler loading 79% by wt (68% by vol)	Single-shade composite resin	Tokuyama Dental, Japan	567483
OneGloss	Highly concentrated aluminum oxide with silicone as binder	One-step polisher	Shofu Dental, USA	0719318
Clearfil Twist Dia	Diamond impregnated spiral	Two-step polisher	Kuraray Noritake Dental İnc., Japan	455213
OptiDisc	Polyethylene synthetic polymers aluminum oxide	Multi-step polisher	Kerr Corporation, USA	7120288

TEGDMA: Triethylene glycol dimethacrylate, UDMA: Urethane dimethacrylate

Table 2. Multiple comparisons of mean color difference (△E00) between different polishing systems after simulated coffee immersion and brushing, at different time points and after re-polishing.

		n	Median (Min-Max)[a]	Mean Rank	p
6 Month (T0-T1)	Control	10	10.9 (3.85-13.34)a	28.6	0.001
	One-step polisher(OneGloss)	10	12.02 (2.67-13.65)a	29.4	
	Two-step polisher(Clearfil Twist Dia)	10	2.33 (1.14-8.66)b	14.25	
	Multi-step polisher(OptiDisc)	10	1.26 (0.22-8.64)b	9.75	
1 Year (T0-T2)	Control	10	11.59 (5.60-13.05)a	29.3	0.001
	One-step polisher(OneGloss)	10	11.33 (1.41-13.57)a	28.8	
	Two-step polisher(Clearfil Twist Dia)	10	1.94 (1.18-4.21)b	12.3	
	Multi-step polisher(OptiDisc)	10	1.70 (0.52-9.62)b	11.6	
After Re-polishing (T0-T3)	Control	0	-		0.405
	One-step polisher(OneGloss)	10	1.50 (0.95-4.31)	13.5	
	Two-step polisher(Clearfil Twist Dia)	10	2.37 (0.64-2.96)	14.5	
	Multi-step polisher(OptiDisc)	10	2.61 (0.98-4.28)	18.5	

a,b exponential letters are used for comparison of groups at the same mean color change values. There is no difference between the groups with the same letter.

Table 3. Multiple comparisons of mean color difference (△E00) between different polishing systems after simulated coffee immersion and brushing, according to the different time points.

	6 Month (T0-T1) Median (Min-Max)	**1 Year (T0-T2) Median (Min-Max)**	**After Re-polishing(T0-T3) Median (Min-Max)**	**p**
Control	10.9 (3.85-13.34) a	11.59 (5.60-13.05) a	-	-
One-step polisher (OneGloss)	12.02 (2.67-13.65) a	11.33 (1.41-13.57) a	1.50 (0.95-4.31) b	0.013
Two-step polisher (Clearfil Twist Dia)	2.33 (1.14-8.66) a	1.94 (1.18-4.21) a	2.37(0.64-2.96) a	-
Multi-step polisher (OptiDisc)	1.26 (0.22-8.64) a	1.70 (0.52-9.62) a	2.61 (0.98-4.28) a	-

a,b exponential letters are used for comparison of groups at the same mean color change values. There is no difference between the vertical columns with the same letter.

The effect of different polishing systems on the color change of single-shade resin composite was found to be different after exposure simulations at 6 months and 1 year periods, so hypothesis H01 was rejected. Although re-polishing had no significant effect on color change in two-step polisher (Clearfil Twist Dia) and multi-step polisher (OptiDisc) groups, a significant change in color change was observed after re-polishing with one-step polisher (OneGloss). Therefore, hypothesis H02 was rejected.

Coffee consumption is widespread and increasingly becoming a part of dietary habits around the world. In the study of Guler et al.[18], it was stated that a cup of coffee is consumed in approximately 15 min, and the average daily coffee consumption per person is 3.2 cups. Based on these data, the present study immersed resin composite specimens in coffee solution for 6 days, simulating 6 months of clinical use, and for 12 days, simulating 1 year of clinical use. Also, it has been reported that tooth brushing, as part of oral hygiene, reduces staining by removing extrinsic pigments that stain restorative materials.[9,10] A study by Sexson et al.[19] found that a person performs an average of 15 cycles of brushing per brushing session. This finding means that a total of 10,000 cycles are completed over the course of a year while maintaining oral hygiene by brushing twice a day. Therefore, in addition to staining the resin composite samples, 5,000 cycles simulating 6 months of tooth brushing and 10,000 cycles simulating 1 year of tooth brushing were performed on the brushing simulation device. In the present study, no significant difference was found between the 6-months and 1-year coffee and brushing exposure simulation in all groups tested ($p>0.05$).

The formation of a resin-rich layer on the top surface of the resin composite as a result of polymerization under a mylar strip has an impact on the color stability of the resin composite. More discoloration has been reported in composite resins finished with mylar strips only as a result of the resin-rich layer compared to surfaces polished with a polishing system.[20,21] Although polishing results in a rougher surface compared to resin composites finished with mylar strips, it reduces the hydrophilicity of the restoration by reducing the amount of organic matrix on the surface.[22] This means that the coloring pigments are less absorbed. In the present study, the resin composite specimens in the control group did not receive any polishing procedures and were cured against a mylar strip. The Control group showed the highest color change at 6-months and 1-year of coffee and brushing exposure simulation. In addition, resin composite specimens polished with one-step polisher (OneGloss), exhibited a similar color change to the Control group ($p>0.05$).

It has been reported that the surface quality of resin composite is affected by finishing and polishing procedures, which may be associated with the early discoloration of resin composites.[23–25] In the present study, resin composite specimens polished with diamond abrasive two-step polisher (Clearfil Twist Dia) and aluminum oxide-coated abrasive disc multi-step polisher (OptiDisc) exhibited significantly less discoloration than one-step polisher (OneGloss). The one-step polisher (OneGloss) had the highest abrasive particle size (80 μm) among the materials compared in the study. The abrasive type, hardness, and distribution of the tested polishing systems varied significantly and may have had an effect on the color stability of the resin composite. In a similar previous study comparing the color change of Omnichroma polished with three-step (Enamel Plus Shiny), two-step (Super-Snap X-treme) and one-step (OneGloss) polishers and stained with coffee, it was reported that there was a difference between the polishing materials and that the group with the least color change was the three-step (Enamel Plus Shiny), and the group with the most color change was the one-step (OneGloss) polisher. However, unlike the present study, no brushing procedure was included in this study.[15]

Re-polishing can partially or completely remove discoloration or absorbed stains on the top surface of colored resin composite restorations.[8,26] In few studies examining the depth of discoloration, it was reported that restoration discoloration occurs in a superficial layer of less than 20 μm and that it is possible to remove this layer by re-polishing.[27,28] In a study examining the effect of re-polishing Omnichroma resin composite after immersion in coffee on color change, researchers reported that re-polishing with different polishing systems affected the results and that polishing systems containing diamond particles were more effective in stain removal than aluminum oxide particles and silicon-carbide abrasive particles.[29] In this study, the re-polishing procedure applied to remove stains after the coffee immersion and brushing cycles was significantly effective in reducing the color change values for specimens polished with the one-step polisher (OneGloss) group only. In addition, the color change values of the single-shade resin composite were above the acceptable $\Delta E=1.8$ in all periods and groups. The results of our research align with previous studies that have shown the efficacy of re-polishing resin composites after staining with different solutions in decreasing the ΔE values to some extent.[8,30–32]

In addition, the polishability and surface quality of resin composites are affected by various variables depending on the type of resin composite , such as filler particle size, filler load and type, resin amount, and particle shape.[33] The inorganic filler composition of the single-shade resin composite Omnichroma, utilized in this investigation, contains fillers consisting of silicon dioxide (SiO2) and zirconium dioxide (ZrO2) with a uniform supra-nano spherical particle size of 260 nm, and contains TEGDMA and UDMA monomers in the resin matrix composition. It has been reported that the TEGDMA monomer in the matrix structure of resins composites shows more color change than other monomers.[34,35] Several studies comparing the color changes of resin composites have concluded that Omnichroma, a single-shade resin composite, undergoes a more pronounced color change than other resin composites.[2,3,36] The color change values measured in the present study were higher than the acceptable $\Delta E=1.8$ at all time periods. Therefore, the monomer structure and inorganic components of Omnichroma may have affected color stability regardless of the polishing systems tested.

One of the limitations of the present study is that the color stability evaluation was performed under in vitro conditions. Although beverage consumption and brushing are simulated, variables such as chewing movements in the oral cavity, the temperature of food and beverages, and saliva will also be important for color stability. Furthermore, although all procedures were performed by a single operator, the absence of a pressure stabilization system may have affected the results. In addition, the polishing systems tested in the present study were tested on a single type of resin composite. In the future, the color stability of resin composite types and commercial brands with different monomer and resin matrix structures should be compared in long-term clinical studies.

Conclusion

Within the limitations of this current in vitro study, it was concluded that: The color change value of the single-shade resin composite was significantly higher in the group polished with a one-step polisher as a result of coffee exposure and brushing simulations. Although the two-step polisher and the multi-step polisher performed better than the one-step polisher, the measured color change was above the acceptable threshold. Although the color change values decreased quantitatively after re-polishing, this decrease was significant only in the group re-polished with one-step polisher.

Author Contributions

Methodology and Conceptualization : All Authors
Data Analysis and İnterpretation : S.O.

Writing - Original Draft : S.O.
Review and Editing : All Authors

Conflict of Interest

The authors do not have any financial interest in the companies whose materials are included in this article.

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References

1. Dental T. Omnichroma technical report. Tokuyama. 2019;9:2020.
2. El-Rashidy AA, Abdelraouf RM, Habib NA. Effect of two artificial aging protocols on color and gloss of single-shade versus multi-shade resin composites. BMC Oral Health. 2022;22(1):321. doi:10.1186/s12903-022-02351-7.
3. Ersöz B, Karaoğlanoğlu S, Oktay E, Aydin N. Resistance of Single-shade Composites to Discoloration. Oper Dent. 2022;47(6):686–692. doi:10.2341/21-156-L.
4. Parpaiola AR, Guimarães PS, França FMG, Basting RT. Small cross-sectional survey of composite restoration attributes associated with choices for replacement. Braz Oral Res. 2009;23:346–351. doi:10.1590/s1806-83242009000300020.
5. Arocha MA, Mayoral JR, Lefever D, Mercade M, Basilio J, Roig M. Color stability of siloranes versus methacrylate-based composites after immersion in staining solutions. Clin Oral Investig. 2013;17:1481–1487. doi:10.1007/s00784-012-0837-7.
6. Bagheri R, Burrow M, Tyas M. Influence of food-simulating solutions and surface finish on susceptibility to staining of aesthetic restorative materials. J Dent. 2005;33(5):389–398. doi:10.1016/j.jdent.2004.10.018.
7. Reddy PS, Tejaswi KS, Shetty S, Annapoorna B, Pujari SC, Thippeswamy H. Effects of commonly consumed beverages on surface roughness and color stability of the nano, microhybrid and hybrid composite resins: an in vitro study. J Contemp Dent Pract. 2013;14(4):718. doi:10.5005/jp-journals-10024-1390.
8. TURKUN LS, Turkun M. Effect of bleaching and repolishing procedures on coffee and tea stain removal from three anterior composite veneering materials. J Esthet Restor Dent. 2004;16(5):290–301. doi:10.1111/j.1708-8240.2004.tb00056.x.
9. Bezgin T, Özer L, Tulga Öz F, Özkan P. Effect of toothbrushing on color changes of esthetic restorative materials. J Esthet Restor Dent. 2015;27:S65–S73. doi:10.1111/jerd.12136.
10. Mozzaquatro LR, Rodrigues CS, Kaizer MR, Lago M, Mallmann A, Jacques LB. The effect of brushing and aging on the staining and smoothness of resin composites. J Esthet Restor Dent. 2017;29(2):E44–E55. doi:10.1111/jerd.12293.
11. deOliveira ALBM, Botta AC, Campos JADB, Garcia PPNS. Effects of immersion media and repolishing on color stability and superficial morphology of nanofilled composite resin. Microsc Microanal. 2014;20(4):1234–1239. doi:10.1017/S1431927614001299.
12. Marghalani HY. Effect of finishing/polishing systems on the surface roughness of novel posterior composites. J Esthet Restor Dent. 2010;22(2):127–138. doi:10.1111/j.1708-8240.2010.00324.x.
13. Agrawal V, Kapoor S. Color and shade management in esthetic dentistry. Univers Res J Dent. 2013;3(3):120–127. doi:10.4103/2249-9725.123975.
14. Paravina RD, Ghinea R, Herrera LJ, Bona AD, Igiel C, Linninger M, et al. Color difference thresholds in dentistry. J Esthet Restor Dent. 2015;27:S1–S9. doi:10.1111/jerd.12149.
15. Abo-Eldahab G, Kamel M. Color stability of nanofilled and suprananofilled resin composites with different polishing techniques after immersion in coffee solution. Egypt Dent J. 2023;69(1):827–836. doi:10.21608/edj.2022.175150.2350.
16. AYDIN N, KARAOĞLANOĞLU S, OKTAY EA, ERSÖZ B. Investigation of single shade composite resin surface roughness and color stability. J Dent Fac Ataturk Univ. 2021;31(2):207–214. doi:10.17567/ataunidfd.895734.
17. Goldstein GR, Lerner T. The effect of toothbrushing on a hybrid composite resin. J Prosthet Dent. 1991;66(4):498–500. doi:10.1016/0022-3913(91)90511-t.
18. Guler AU, Yilmaz F, Kulunk T, Guler E, Kurt S. Effects of different drinks on stainability of resin composite provisional restorative materials. J Prosthet Dent. 2005;94(2):118–124. doi:10.1016/j.prosdent.2005.05.004.
19. Sexson JC, Phillips RW. Studies on the effects of abrasives on acrylic resins. J Prosthet Dent. 1951;1(4):454–471. doi:10.1016/0022-3913(51)90031-5.
20. Allccahuaman-Avalos R, Medina-Sanchez R, Castro-Ramirez L, Ladera-Castaneda M, Cervantes-Ganoza L, Martinez-Campos R, et al. In vitro color stability evaluation of three polished and unpolished nanohybrid resin composites immersed in a 0.12 Polymers. 2023;15(6):1339. doi:10.3390/polym15061339.
21. Gönülol N, Yılmaz F. The effects of finishing and polishing techniques on surface roughness and color stability of nanocomposites. J Dent. 2012;40:e64–e70. doi:10.1016/j.jdent.2012.07.005.
22. Costa GdFAd, Fernandes ACBdCJ, Carvalho LAd, de Andrade AC, de Assuncao IV, Borges BCD. Effect of additional polishing methods on the physical surface properties of different nanocomposites: SEM and AFM study. Microsc Res Tech. 2018;81(12):1467–1473. doi:10.1002/jemt.23147.
23. Marufu C, Kisumbi BK, Osiro OA, Otieno FO. Effect of finishing protocols and staining solutions on color stability of dental resin composites. Clin Exp Dent Res. 2022;8(2):561–570. doi:10.1002/cre2.555.
24. Schmitt VL, Puppin-Rontani RM, Naufel FS, Nahsan FPS, Alexandre Coelho Sinhoreti M, Baseggio W. Effect of the polishing procedures on color stability and surface roughness of composite resins. Int Sch Res Notices. 2011;2011. doi:10.5402/2011/617672.
25. Shintani H, Satou J, Satou N, Hayashihara H, Inoue T. Effects of various finishing methods on staining and accumulation of Streptococcus mutans HS-6 on composite resins. Dent Mater J. 1985;1(6):225–227. doi:10.1016/S0109-5641(85)80046-4.
26. Elhamid MA, Mosallam R. Effect of bleaching versus repolishing on colour and surface topography of stained resin composite. Aust Dent J. 2010;55(4):390–398. doi:10.1111/j.1834-7819.2010.01259.x.
27. ANFE TEDA, Agra CM, Vieira GF. Evaluation of the possibility of removing staining by repolishing composite resins submitted to artificial aging. J Esthet Restor Dent. 2011;23(4):260–267. doi:10.1111/j.1708-8240.2011.00435.x.
28. Um CM, Ruyter I. Staining of resin-based veneering materials with coffee and tea. Quintessence Int. 1991;22(5):377–386.
29. Aksoy Vaizoğlu G, Ulusoy N, Güleç Alagöz L. Effect of coffee and polishing systems on the color change of a conventional resin composite repaired by universal resin composites: an in vitro study. Materials. 2023;16(17):6066. doi:10.3390/ma16176066.
30. Garoushi S, Lassila L, Hatem M, Shembesh M, Baady L, Salim Z, et al. Influence of staining solutions and whitening procedures on discoloration of hybrid composite resins. Acta Odontol Scand. 2013;71(1):144–150. doi:10.3109/00016357.2011.654253.
31. Mundim FM, Garcia LdFR, Pires-de Souza FdCP. Effect of stain-

ing solutions and repolishing on color stability of direct composites. J Appl Oral Sci. 2010;18:249–254. doi:10.1590/s1678-77572010000300009.
32. Uctasli M, Garoushi S, Uctasli M, Vallittu P, Lassila L. A comparative assessment of color stability among various commercial resin composites. BMC Oral Health. 2023;23(1):789. doi:10.1186/s12903-023-03515-9.
33. Amaya-Pajares SP, Koi K, Watanabe H, da Costa JB, Ferracane JL. Development and maintenance of surface gloss of dental composites after polishing and brushing: Review of the literature. J Esthet Restor Dent. 2022;34(1):15–41. doi:10.1111/jerd.12875.
34. Jeong TS, Kang HS, Kim SK, Kim S, Kim HI, Kwon YH. The effect of resin shades on microhardness, polymerization shrinkage, and color change of dental composite resins. Dent Mater J. 2009;28(4):438–445. doi:10.4012/dmj.28.438.
35. Sideridou I, Tserki V, Papanastasiou G. Study of water sorption, solubility and modulus of elasticity of light-cured dimethacrylate-based dental resins. Biomaterials. 2003;24(4):655–665. doi:10.1016/s0142-9612(02)00380-0.
36. Rohym S, Tawfeek HEM, Kamh R. Effect of coffee on color stability and surface roughness of newly introduced single shade resin composite materials. BMC oral health. 2023;23(1):236. doi:10.1186/s12903-023-02942-y.

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ORIGINAL RESEARCH ARTICLE

Radiographic Examination of Alveolar Ridge Resorption Concerning Age in Kennedy Class II Edentulism

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Abstract

Purpose: After the loss of teeth, the alveolar bone begins to resorb due to the disappearance of the stimulus being applied by the teeth to the alveolar bone. This situation is termed residual ridge resorption. This study aims to determine the amount of alveolar bone resorption that occurred in the maxilla and mandible of patients having Kennedy Class II edentulousness and the distribution of it according to age groups.

Materials and Methods: The study was carried out on the panoramic radiographs of 122 individuals (60 mandibles, 62 maxilla). Vertical measurements were made at 10 sites (central incisors, first premolars, and molars at the left and right of both jaws). The difference in the measurements according to the group and demographic variables was analyzed with the independent groups independent-t and one-way ANOVA tests. Also, dentate and edentulous measurements according to the group and demographic characteristics in the group interaction were analyzed with the repeated ANOVA test.

Results: When the edentulous regions were considered, the vertical height values of the mandible were lower than the maxilla. Also, a statistically significant difference was detected in the maxillary premolar region of the edentulous regions. According to gender, women's vertical height results were found to be lower than men and the vertical heights of the 6-12 months group were higher than the 12-24 months group.

Conclusions: According to these results, we think that the patient should be directed to implant rehabilitation to prevent bone loss, especially in edentulous patients in the maxillary premolar region.

Keywords: Alveolar Bone Loss; Alveolar Resorption; Anatomy; Panoramic Radiography

Introduction

There is a relationship between tooth eruption and the development of alveolar structures. The subsequent development and eruption of deciduous and permanent dentition have a stimulating effect on the growth and development of alveolar structures. The part of the alveolar bone that supports the teeth is called the "alveolar ridge," and apart from various pathological conditions such as periodontitis and osteoporosis, the alveolar crest continues to exist as long as teeth are present. After the loss of teeth, the alveolar bone begins to resorb due to the disappearance of the stimulus applied by the teeth to the alveolar bone. This resorption is very rapid in the first year, with the fastest phase occurring in the first 3 months. This chronic, progressive, irreversible, and cumulative phenomenon is termed "residual ridge resorption (RRR)" and continues for life.[1–5]

RRR is a multifactorial process. These factors include anatomical (amount and quality of the bone), metabolic (physiological capacity of the bone), functional (forces on the bone), prosthetic (duration of prosthesis use, number of prostheses used, quality of prostheses), and systemic factors (advanced age, gender, diseases such as hyperparathyroidism, thyroid dysfunction, asthma, osteoporosis, diabetes).[6–9] According to various studies, the average annual rate of vertical resorption in the anterior maxilla has been determined to be approximately 0.1 mm (ranging from 0 to 0.7 mm), varying both among individuals and within the same individual at different times.[1,10,11] This rate of resorption is influenced by anatomical, biological, psychosocial, metabolic, functional, and prosthetic factors.[10,12] Cawood and Howell[13] propose that alveolar ridge resorption follows a predictable pattern, beginning with horizontal bone loss and subsequently progressing to vertical re-

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sorption. They further suggest that bone resorption occurs in the alveolar process of the jaw rather than in the palatine process.[10]

Panoramic radiographs, which are frequently used, especially for initial imaging, allow many morphometric measurements that assess the quality and quantity of bone.[14–18] This imaging technique is available for the evaluation of RRR and has been used by several investigators. Wical and Swoope[19] developed a method for the evaluation of RRR using panoramic radiography. According to this method, the reference point was the mental foramen, and it naturally included only the mandible. Packota et al.[15] introduced a technique that also evaluates the maxilla. In this technique, Wical and Swoope's method was used for the mandible. Later, Xie et al.[18] developed a technique, which we also used in our study, to make RRR assessment more accurate and sensitive in both the maxilla and mandible. Additionally, in most studies, age group classification was not evaluated, and this situation was stated as a limitation. Therefore, clear information about the effect of age on resorption was not reported in the literature.[8,20,21] We hypothesized that by dividing the age groups specified as limitations in other studies, and by determining which regions have more resorption in which age range, the time intervals important for patient orientation in prosthesis or implant rehabilitation for edentulous areas can be determined. For this reason, we investigated the amount of alveolar bone resorption seen in the maxilla and mandible and its distribution according to age groups in patients who were determined to be Kennedy Class II on panoramic radiographs.

Material and Methods

Participants

This clinical study was retrospectively conducted on 122 patients aged between 40 and 74 years who were admitted to the Department of Oral and Maxillofacial Radiology. The study was approved by the Local Ethics Committee (2020/243). The study protocol was carried out in accordance with the principles of the Declaration of Helsinki.

Inclusion criteria for panoramic radiographs;

- Anatomic landmarks such as the inferior points of the orbit and zygomatic process, the posterior and inferior border of the mandible, and the alveolar crest must be evident,
- No distortion in the maxilla and mandible images,
- Maxillary and mandibular crests should not be in contact,
- Images must be diagnostically sufficient, with no artifacts observed.

Individuals with systemic disorders affecting bone metabolism, such as hyperparathyroidism, osteoporosis, hypo- or hyperthyroidism, diabetes, chronic renal failure, malignancy, and those using drugs that affect bone metabolism, were excluded from the study. Since the prolongation of the edentulous period would cause changes in the bone structure and reduce the reliability of the measurements, the edentulous period was examined in two groups to standardize the measurements. One group consisted of patients with panoramic films taken between 6 and 12 months after becoming edentulous. The other group consisted of patients with a period of edentulism between 12 and 24 months. Each patient's dentate side was measured as a control group. Patients with bone destruction due to periodontal disease or any pathology in the control region were excluded from the study.

According to the power analysis performed while determining the groups, with alpha and power set at 0.05 and 0.90, respectively, there should be a minimum of 20 individuals in each group. Individuals with more than one missing tooth on the dentate sides were excluded from the groups. The absence of a third molar tooth was not considered missing.

Based on the limitations of previous studies in the literature, we formed a total of 6 groups in our study: mandible and maxilla over 3 age groups. Since our study involved Kennedy Class II patients, each patient's dentate side was measured as a control group. These groups are;

- Group 1: Mandible Kennedy Class II (ages 40-49): 20 individuals (8 men and 12 women) with a mean age of 42.3.
- Group 2: Maxilla Kennedy Class II (ages 40-49): 22 individuals (7 men and 15 women) with a mean age of 42.9.
- Group 3: Mandible Kennedy Class II (ages 50-59): 20 individuals (8 men and 12 women) with a mean age of 51.9.
- Group 4: Maxilla Kennedy Class II (ages 50-59): 20 individuals (10 men and 10 women) with a mean age of 51.7.
- Group 5: Mandible Kennedy Class II (ages 60-74): 20 individuals (9 men and 11 women) with a mean age of 65.6.
- Group 6: Maxilla Kennedy Class II (ages 60-74): 20 individuals (14 men and 6 women) with a mean age of 65.7.

Procedures

The radiographs used in the study were taken on the same panoramic machine, the Instrumentarium OP 200D (Instrumentarium Dental, Tuusula, Finland). The images were saved in Tagged Image File Format (TIFF), and reference drawings and measurements were made using ImageJ software version 1.52v (https://imagej.nih.gov/ij/). Measurements were made by one observer, and 20% of the measurements, randomly chosen from all groups, were repeated and recorded by the same observer one month later.

First, a line passing through the inferior borders of the two orbits (HO) in the maxilla and a second line joining the inferior borders of the zygomatic processes (HZ) were drawn. Next, a third line was drawn tangent to the body of the mandible and the mandibular angle (D1). A fourth line, parallel to D1, was drawn 10 mm above it (D2) in the mandible. The measurements were performed and recorded separately for the points determined based on these lines as dentate (control side) and edentulous areas. To determine the possible locations of the premolars and molars in the edentulous region, the distance from the midline to the outermost border of the ramus of the mandible was first measured on the D2 line in the mandible in the dentate regions. Then, on this line, the distance from the midline to the distal of the 1st premolar and the distance to the distal of the 1st molar was determined. (For this, the line that determines the horizontal length of the mandible (D2) was extended perpendicularly from the distal surfaces of the 1st premolar and 1st molar, and the points where they intersected the line were determined as the locations of the 1st premolar and 1st molar). Calculations from the dentate region showed that the 1st premolars are located at a point corresponding to approximately 35% of the horizontal length of the mandible from the midline, and the 1st molars at 53%. This ratio is consistent with the 34% and 53% ratios found by Xie et al.[18] Therefore, in the measurements to be performed in edentulous areas, the positions of the 1st premolar and 1st molar teeth were determined as percentages according to the above ratios.

The measurement points were determined as follows: the maxillary and mandibular midlines (in the maxilla, A1; in the mandible, C1); the distal surfaces of the first premolars (FP) on the left and right (in the maxilla, A2; in the mandible, C2); the distal surfaces of the first molars on the left and right (in the maxilla, A3; in the mandible, C3); and the distance between the zygoma and the orbit at the midlines (B) (Fig.1-Fig.2).

Statistical analysis

The data analysis was conducted using the SPSS 25 software, with a 95% confidence level. The kurtosis and skewness values ob-

Table 1. Demographic Properties of the study

		Mandible	Maxilla
		N (%)	N (%)
Age groups	40-50	20 (33.3)	22 (36.6)
	50-60	20 (33.3)	20 (33.2)
	60>	20 (33.3)	20 (32.2)
Gender	Men	25 (41.7)	31 (51.7)
	Women	35 (58.3)	29 (48.3)
Duration of Edentuloussness	6-12 months	11 (18.3)	9 (14.5)
	12-24 months	49 (81.6)	53 (75.5)

Table 2. Vertical Height Values According to Regions of Measurement

	Mandible	Maxilla	p
Edentulous premolar region	37.56±4.96	46.59±5.23	**0.000***
Edentulous molar region	28.91±4.83	42.06±5.66	**0.000***
Dentate anterior region	39.29±5.39	48.63±5.69	**0.000***
Dentate premolar region	39.03±4.65	49.21±5.03	**0.000***
Dentate molar region	32.8±4.77	46.55±4.99	**0.000***

* p < 0.001

tained from the measurements in both groups were between 3 and -3.[22–25] Accordingly, the measurements were considered to meet the assumption of normality, and parametric methods were used in the analysis. Frequency (n) and percentage (%) were provided for categorical (qualitative) variables, while the mean ($\bar{x}$), standard deviation (SD), minimum (min), and maximum (max) were provided for numeric (quantitative) variables. The differences in measurements according to the group and demographic variables were analyzed using independent t-tests and one-way ANOVA tests. The differences between the control and edentulous measurements according to the group and demographic characteristics in group interaction were analyzed using the repeated measures ANOVA test. The intra-class correlation coefficient (ICC) was used to assess intra-observer agreement.

Results

Measurements were performed on 122 radiographs (62 maxilla, 60 mandible). The results of the demographic data are shown in Table 1.

The results according to the regions are presented in Table 2. When the edentulous regions were considered, a statistically significant difference was detected between the mandible and maxilla in both regions ($p < 0.05$). The vertical height values of the mandible were lower than those of the maxilla. Additionally, a statistically significant difference was found in the measurements of the regions used as control ($p < 0.05$), and as with the edentulous regions, the results for the mandible were lower than those for the maxilla. The results were obtained based on vertical measurement coefficients of variation in dentate regions as shown in Table 3. The coefficients of variation in dentate regions were calculated using the formula "Coefficient of Variation = (Standard Deviation X 100) / Mean." The results ranged from 9% to 13%.

The results by age group are presented in Table 4. A statistically significant difference was detected in the maxillary premolar region of the edentulous regions ($p < 0.05$), with this result being driven by the higher vertical values in the 40-49 age group. In the dentate group, a similar result was obtained in the molar region. In the mandible, no statistically significant differences were detected in either the edentulous or dentate groups ($p > 0.05$).

The comparison of the maxilla and mandible according to gender is presented in Table 5. There was a statistically significant difference only in the mandible between the edentulous and dentate regions ($p < 0.05$). This difference was driven by the women's values, as their vertical height results were found to be lower than those of men. In contrast, no statistically significant difference was detected in the maxilla ($p > 0.05$).

The results according to the duration of edentulism are presented in Table 6. In the mandible, a statistically significant difference was found between the 6-12 months group and the 12-24 months group ($p < 0.05$). The vertical heights of the 6-12 months group were higher than those of the 12-24 months group. In the maxillary anterior region, no statistically significant difference was present ($p > 0.05$).

The intra-observer agreement results of the measurements performed at one-month intervals were calculated using the intra-class correlation coefficient. According to the results of this evaluation, the correlation coefficient was determined to be 0.916.

Discussion

When reviewing the bone structure of the jaws, it is observed that while most of the bone structure of the mandible consists of cortical bone in the basal part, the cortical and trabecular portions of the mandible seem to behave differently with age. The cortical bone mass diminishes considerably over the years, but the trabecular portion shows marked individual variation in all age groups. Additionally, trabecular bone constitutes the majority of the bone structure in the maxilla.[26] As mentioned in the introduction, although residual ridge resorption (RRR) has been reported to be very rapid during the first year after extraction and continues gradually throughout the patient's life, some inter-individual variabilities affect the resorption rate. Factors such as nutrition, physiological factors, the period of edentulism, prosthesis usage and duration, gender, and systemic diseases have been suggested as reasons for these variabilities.[8,9,20,21,27] Furthermore, Pietrokovski et al.[28] stated that the mylohyoid muscle attached to the mylohyoid ridges, the buccinator muscles attached to the buccal bone, and the additional muscles surrounding the mandible limit chronic bone resorption in the edentulous jaws. Other studies have similarly stated that these muscles provide physiological stimulation of the edentulous region, thereby preventing bone resorption.[29–31] Muscles like the genioglossus, attached to the genial tubercles in the anterior mandible, serve as examples of this phenomenon. The process of alveolar resorption occurs more slowly with the stimulation provided by muscle attachment.[32] In line with this information, Kurt et al.32 reported bone apposition in the mandibular angle region where muscle attachment occurs in their study.

On the other hand, it is evident that the use of prostheses also transmits functional forces to the bone structure. Supporting this, some studies have revealed that bone resorption increases with the use of prostheses. This situation highlights the importance of tooth-supported fixed prostheses.[8,21] RRR removes the supporting bone tissue that allows total dentures to function, occurring more in the mandible than in the maxilla, sometimes within a short period, such as 3 months.[18,33] Tallgren[11] stated that in the first year after extraction, a decrease of 4-6 mm occurs in the anterior mandible and 2-4 mm in the maxilla. Atwood and Coy[34] reported that annual bone loss was 0.4 mm in the mandible and 0.1 mm in the maxilla in a follow-up study on edentulous patients over 2.5 years. They proposed that RRR is a biomechanical problem, suggesting that by eliminating direct occlusal contact, the functional forces acting on the edentulous ridge are reduced, subsequently inducing RRR. Although this "disuse atrophy theory" has been blamed for RRR, the mechanistic aspect of this theory has never been confirmed.[34] Indeed, the mechanism of disuse atrophy in RRR remains questionable, and whether the local alveolar crest becomes functionally unloaded needs to be seriously investigated in detail. After tooth extraction, it has been reported that the buccolingual width of the residual alveolar bone undergoes a more pronounced reduction compared to its height.[4] The height reduction rate, expressed as the percentage decrease in vertical linear distance between the base

Table 3. Vertical Measurement Coefficients of Variation According to Gender in Dentate Regions

	Mandible				Maxilla			
	Men	VC*(%)	Women	VC*(%)	Men	VC*(%)	Women	VC*(%)
Dentate anterior region	42.23±5.19	12	37.19±4.52	11	49.37±5.12	10	47.84±6.25	13
Dentate premolar region	41.89±4.9	11	36.98±3.2	9	49.33±4.23	8	49.09±5.85	11
Dentate molar region	36.47±4.41	12	30.18±2.97	9	46.21±4.34	9	46.91±5.65	12

VC*: Coefficient Of Variation

Table 4. Vertical Height Values According to Regions of Measurement and Age Groups

	Mandible				Maxilla			
	40-50	50-60	60>	p	40-50	50-60	60>	p
Edentulous premolar region	38.32±5.08	37.41±5.31	36.96±4.63	**0.684**	49.27±5.72	45.08±3.76	45.43±5.18	**0.017***
Edentulous molar region	30.32±4.79	27.98±4.78	28.44±4.85	**0.272**	43.52±6.76	41.05±4.32	41.61±5.63	**0.358**
Dentate anterior region	40.69±4.94	39.11±5.79	38.07±5.35	**0.308**	50.81±5.79	48.24±4.35	46.85±6.3	**0.081**
Dentate premolar region	39.7±4.62	38.47±5.07	38.91±4.4	**0.704**	51.19±5.7	48.79±3.65	47.65±5.1	**0.075**
Dentate molar region	33.42±4.68	31.54±4.51	33.43±5.11	**0.359**	48.87±5.35	45.39±3.92	45.38±4.96	**0.036***

* $p < 0.05$

Table 5. The Comparison of Maxilla and Mandible According to the Gender

	Mandible			Maxilla		
	Men	Women	p	Men	Women	p
Edentulous premolar region	40.03±5.27	35.8±3.93	**0.001***	46.79±4.81	46.38±5.74	**0.769**
Edentulous molar region	31.04±4.88	27.39±4.25	**0.003***	42.29±4.62	41.81±6.67	**0.746**
Dentate anterior region	42.23±5.19	37.19±4.52	**0.000****	49.37±5.12	47.84±6.25	**0.301**
Dentate premolar region	41.89±4.9	36.98±3.2	**0.000****	49.33±4.23	49.09±5.85	**0.856**
Dentate molar region	36.47±4.41	30.18±2.97	**0.000****	46.21±4.34	46.91±5.65	**0.587**

** $p < 0.001$ * $p < 0.05$

Table 6. The Comparison of Maxilla and Mandible According to Edentuloussnes Duration

	Mandible			Maxilla		
	6-12 months	12-24 months	p	6-12 months	12-24 months	p
Edentulous premolar region	42.06±5.29	36.22±4.48	**0.001***	43.8±6.18	46.29±4.07	**0.004***
Edentulous molar region	33.19±4.31	27.65±4.33	**0.002***	38.68±6.9	41.84±4.52	**0.004***
Dentate anterior region	43.88±4.65	38.02±5.26	**0.004***	47.04±5.51	48.35±5.52	**0.139**
Dentate premolar region	42.21±5	38.06±4.49	**0.027***	46.49±4.53	48.95±4.59	**0.005***
Dentate molar region	36.54±5.29	31.9±4.34	**0.013***	44.35±2.71	46.09±4.71	**0.002***

* $p < 0.05$

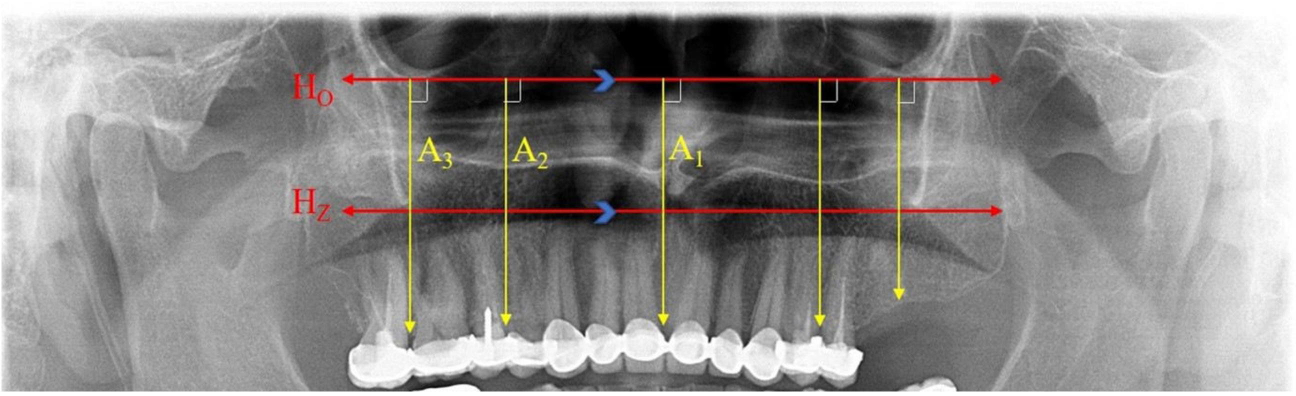

Figure 1. Reference lines and measured heights and sites in the maxilla. In the maxilla the A1 measurement was made in the midline, A2 and A3 measurement was made in the infraorbital and zygomatic vertical lines on both sides.

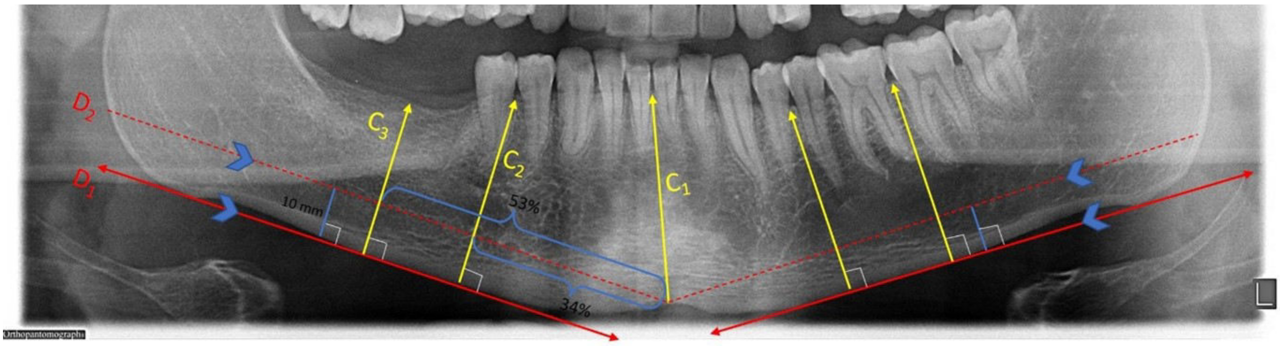

Figure 2. In the mandible a dotted line shows mandibular length; C2 and C3 distances were measured at 34% and 53% of the length; the tangent, the dotted line, and C2 and C3 measurements were made on both sides. The C1 measurement was recorded in the midline.

of the socket and the crest of the alveolar bone prior to extraction, was observed to be 15% at 3 months and between 11% and 22% at 6 months. Conversely, the reduction in buccolingual width, expressed as the percentage decrease in horizontal linear distance between the buccal and lingual borders of the alveolar bone before extraction, was reported to be 32% at 3 months and between 29% and 63% at 6 months.[35] Notably, the extent of height reduction varied depending on the specific region.[4,35] These clinical observations suggest that structural changes in the edentulous jawbone are predominantly unidirectional, primarily resulting from osteoclast-mediated resorption of the residual alveolar bone. Residual ridge reduction following tooth extraction has been studied extensively through the use of standardized lateral cephalographs[4,11] and panoramic radiographs[8,16], which have been employed to assess the structural changes occurring in the underlying jawbone.[4]

The first method for measuring residual ridge resorption on panoramic radiographs was developed by Wical and Swoope[19], and this method has been used in most studies. However, the mandibular ratio in this method can only indicate changes in bone height in the mental foramen region. A limitation of this method is that it cannot provide information on radiographs where the mental foramen cannot be clearly visualized, nor does it account for resorption occurring in other parts of the mandible or the maxilla.[8] Xie et al.[18], took the distance between the zygoma and orbit as the reference line in their study and improved the method we used in our study by altering only the measurement points and the ratio. They found a value varying between 9% and 10% in terms of maxillary ratio between toothed males and females, stating that this value is suitable for investigating vertical height changes. The values between 9% and 13% found in our study were close to these results. The differences are thought to be due to the selected groups or the magnification of the panoramic device. Using this method, we found that the edentulous maxilla and mandible had lower vertical heights than the toothed maxilla and mandible, consistent with the literature.[8,18,21,31] In our study, ridge resorption in the mandible was found to be higher than in the maxilla, with lower vertical heights measured in the mandible. The presence of trabecular bone and more bone marrow in the maxilla may delay bone loss, whereas the compact nature of the mandibular bone structure might contribute to rapid resorption when subjected to incoming forces.[18,31]

Although the results of our study align with similar studies in the literature.[8,18,21,26,31], it also had some particularities. For instance, the lack of division into age groups in the study by Ozan et al.[21], was noted as a limitation. Similarly, most studies did not classify age groups as restricted (under 65 and over 76).[8,20,21] In our study, patients were evaluated in three different age groups, which may provide clinically clearer information regarding which stages of these age groups experience more alveolar vertical loss and help guide patients toward dental or implant-supported prostheses. Indeed, in our results, a significantly lower vertical height was found with age progression in the maxillary premolar region of the edentulous regions when comparing age groups. No significant difference was found in other measurement regions in the maxilla and mandible. It has been reported in the literature that ridge resorption increases with age in edentulous areas. However, as a limitation, age ranges in the study by Ozan et al.[21] were not mentioned. Most existing studies in the literature used a wide age range to evaluate selected patients without dividing them into specific age ranges or groups. In contrast, in our study, individuals were grouped as 40-49, 50-59, and 60 and over. The age of 40 was selected as the initiation of investigation because it is accepted as the start of tooth loss. Therefore, we believe that by dividing the age groups specified as limitations in other studies and determining which regions have more resorption in which age ranges, we can identify the time intervals important for guiding patients in prosthesis or implant rehabilitation for edentulous areas. Narhi et al.[20] using the technique developed by Wical and Swoope[19], conducted a study on 96 individuals using total prostheses and found a significant relationship between the duration of toothlessness in women and RRR, but not in men, and stated that there was no relationship between patient age and resorption in both genders. Although we did not use the technique of Wical and Swoope[19], our study revealed that RRR gradually increased in the maxillary premolar edentulous region with each decade after the age of 40. Supporting this, RRR was shown to increase after menopause.[20] It has therefore been reported that RRR is higher in women than in men.[16,36] In our study, the vertical height in women was found to be significantly lower than in men in all regions of the mandible. This may be due to more common resorption in women than in men during the post-menopausal period due to bone destruction, as stated in the literature. There was no significant difference between both sexes in the maxilla. The width of the maxillary alveolar crest decreases more rapidly than its height. Prospective studies by Schroop et al.[37] evaluating changes in the extraction cavity over a 10-year period after single tooth extraction revealed that major changes occur within 12 months following extraction. Bone formation in the alveoli and a decrease in the vertical height of the alveolar bone crest occur simultaneously in the first three months, and bone formation continues in the second three months. The remodeling process continues for 6-12 months. Although the new level formed after the extraction cavity is filled with bone never rises to the level of the teeth located in the mesial and distal regions of the cavity, it was revealed through linear measurements that the bone level after 12 months coincides with the bone level after extraction.[38] For this reason, in our study, patients who had been edentulous for between 6-12 months and those who had been edentulous for between 12-24 months were classified. In these processes, the vertical height was found to be significantly lower in individuals who had been edentulous for between 6-12 months in all regions except the maxilla anterior toothed region compared to those who had been edentulous for between 12-24 months. We believe that the reason for this high value is the remodeling in the second six-month period in individuals who had been edentulous for 6-12 months, and the increase in osteoclastic activity due to the loss of stimulation in the edentulous area as time progresses. The lack of significant change in the maxillary anterior tooth region is due to the presence of teeth in the mouth, highlighting the importance of teeth in preventing the resorption of the alveolar bone structure. In our study, the changes in the Kennedy Class II classification with alveolar ridge resorption and prosthesis usage time in age and gender groups were revealed. The fact that there is no dramatic loss of alveolar bone due to the presence of teeth in this region once again underscores the importance of tooth-supported prostheses in patients.

As a limitation of the study, the edentulous period was restricted to two years, and the condition in other Kennedy classes and modifications was not evaluated. Further research that addresses these aspects could enhance the predictability of alveolar ridge resorption.

Conclusion

Firstly, teeth play a crucial role in preventing bone resorption, so prosthesis planning should take into account the resorption that will occur after tooth extraction. The literature reports that patients using removable and total prostheses experience more residual ridge resorption than those who do not use prostheses. This underscores the growing importance of implant-supported prostheses. The primary advantages of implants are that they function like natural teeth to prevent bone resorption and provide support to the superstructure prosthesis. Our study reveals that significant bone resorption occurs across the current age ranges, highlighting the need to minimize the duration of edentulism. Additionally, our findings show significant vertical bone loss in each decade in the maxillary premolar edentulous region, while no significant bone loss was observed in other edentulous regions over the decades. Based on these results, we recommend directing patients, particularly those who are edentulous in the maxillary premolar region, towards implant rehabilitation to prevent bone loss. Implant prostheses can be presented as an optimal solution in modern dentistry to meet the functional, phonetic, and aesthetic expectations of patients as they age.

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Conflict of Interest

The authors declare no conflict of interest.

Ethics Approval

The study was approved by the Local Ethics Committee (2020/243). The study protocol was carried out in accordance with the principles of the Declaration of Helsinki.

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References

1. Atwood DA. Some clinical factors related to rate of resorption of residual ridges. J Prosthet Dent. 1962;12(3):441–450. doi:10.1016/0022-3913(62)90125-7.
2. Bodic F, Hamel L, Lerouxel E, Baslé MF, Chappard D. Bone loss and teeth. Joint Bone Spine. 2005;72(3):215–221. doi:10.1016/j.jbspin.2004.03.007.
3. Kingsmill V. Post-extraction remodeling of the adult mandible. Crit Rev Oral Biol Med. 1999;10(3):384–404. doi:10.1177/10454411990100030801.
4. Kondo T, Kanayama K, Egusa H, Nishimura I. Current perspectives of residual ridge resorption: pathological activation

of oral barrier osteoclasts. J Prosthodont Res. 2023;67(1):12–22. doi:10.2186/jpr.JPR_D_21_00333.
5. Springe B, Slaidina A, Soboleva U, Lejnieks A. Bone mineral density and mandibular residual ridge resorption. Int J Prosthodont. 2014;27(3):270–276. doi:10.11607/ijp.3283.
6. Al AlSheikh H, AlZain S, Shaik JP, Bhogoju S, Warsy A, Parine NR. Two novel SNPs in genes involved in immune response and their association with mandibular residual ridge resorption. Saudi J Biol Sci. 2020;27(3):846–852. doi:10.1016/j.sjbs.2020.01.016.
7. Atwood DA. Some clinical factors related to rate of resorption of residual ridges. J Prosthet Dent. 2001;86(2):119–125. doi:10.1067/mpr.2001.117609.
8. Canger EM, Çelenk P. Radiographic evaluation of alveolar ridge heights of dentate and edentulous patients. Gerodontology. 2012;29(1):17–23. doi:10.1111/j.1741-2358.2010.00391.x.
9. Sawai DS, Joshi A, Mishra G, Mansoor MA, Kumar U, Suharwardy GA. Evaluation of Correlation between Residual Ridge Resorption and Diabetes Mellitus. J Pharm Bioallied Sci. 2024;16(Suppl 1):S915. doi:10.4103/jpbs.jpbs_1097_23.
10. Gerken U, Esser F, Möhlhenrich SC, Bartella AK, Hölzle F, Fischer H, et al. Objective computerised assessment of residual ridge resorption in the human maxilla and maxillary sinus pneumatisation. Clin Oral Invest. 2020;24:3223–3235. doi:10.1007/s00784-020-03196-6.
11. Tallgren A. The continuing reduction of the residual alveolar ridges in complete denture wearers: a mixed-longitudinal study covering 25 years. J Prosthet Dent. 1972;27(2):120–132. doi:10.1016/0022-3913(72)90188-6.
12. Reich KM, Huber CD, Lippnig WR, Ulm C, Watzek G, Tangl S. Atrophy of the residual alveolar ridge following tooth loss in an historical population. Oral Dis. 2011;17(1):33–44. doi:10.1111/j.1601-0825.2010.01699.x.
13. Cawood J, Howell R. A classification of the edentulous jaws. Int J Oral Maxillofac Surg. 1988;17(4):232–236. doi:10.1016/S0901-5027(88)80047-X.
14. Chu TMG, Liu SSY, Babler WJ. In: Craniofacial biology, orthodontics, and implants. Elsevier; 2014. p. 225–242. doi:10.1016/B978-0-12-416015-6.00011-3.
15. Packota G, Hoover J, Neufeld B. A study of the height of intact alveolar bone on panoramic radiographs of adult patients. J Prosthet Dent. 1988;60(4):504–509. doi:10.1016/0022-3913(88)90258-2.
16. Unal Erzurumlu Z, Celenk P. A radiological evaluation of the effects of edentulousness on the temporomandibular joint. J Oral Rehabil. 2020;47(3):319–324. doi:10.1111/joor.12910.
17. Wilding R, Levin I, Pepper R. The use of panoramic radiographs to measure alveolar bone areas. J Oral Rehabil. 1987;14(6):557–567. doi:10.1111/j.1365-2842.1987.tb00752.x.
18. Xie Q, Wolf J, Ainamo A. Quantitative assessment of vertical heights of maxillary and mandibular bones in panoramic radiographs of elderly dentate and edentulous subjects. Acta Odontol Scand. 1997;55(3):155–161. doi:10.3109/00016359709115409.
19. Wical KE, Swoope CC. Studies of residual ridge resorption. Part I. Use of panoramic radiographs for evaluation and classification of mandibular resorption. J Prosthet Dent. 1974;32(1):7–12. doi:10.1016/0022-3913(74)90093-6.
20. Närhi TO, Ettinger RL, Lam EW. Radiographic findings, ridge resorption, and subjective complaints of complete denture patients. Int J Prosthodont. 1997;10(2):183–189.
21. Ozan O, Orhan K, Aksoy S, Icen M, Bilecenoglu B, Sakul BU. The Effect of Removable Partial Dentures on Alveolar Bone Resorption: A Retrospective Study with Cone-Beam Computed Tomography. J Prosthodont. 2013;22(1):42–48. doi:10.1111/j.1532-849X.2012.00877.x.
22. DeCarlo LT. On the meaning and use of kurtosis. Psychological methods. 1997;2(3):292. doi:10.1037/1082-989X.2.3.292.
23. Groeneveld RA, Meeden G. Measuring skewness and kurtosis. Statistician. 1984;33(4):391–399. doi:10.2307/2987742.
24. Hopkins KD, Weeks DL. Tests for normality and measures of skewness and kurtosis: Their place in research reporting. Educ Psychol Meas. 1990;50(4):717–729. doi:10.1177/ 00131644 90504001.
25. Moors JJA. The meaning of kurtosis: Darlington reexamined. Statistician. 1986;40(4):283–284. doi:10.2307/2987742.
26. Klemetti E. A review of residual ridge resorption and bone density. J Prosthet Dent. 1996;75(5):512–514. doi:10.1016/S0022-3913(96)90455-2.
27. Alsaggaf A, Fenlon MR. A case control study to investigate the effects of denture wear on residual alveolar ridge resorption in edentulous patients. J Dent. 2020;98:103373. doi:10.1016/j.jdent.2020.103373.
28. Pietrokovski J, Harfin J, Levy F. The influence of age and denture wear on the size of edentulous structures. Gerodontology. 2003;20(2):100–105. doi:10.1111/j.1741-2358.2003.00100.x.
29. Alajbeg IZ, Valentic-Peruzovic M, Alajbeg I, Illes D, Celebic A. The influence of dental status on masticatory muscle activity in elderly patients. Int J Prosthodont. 2005;18(4):333–338.
30. Alajbeg IZ, Valentic-Peruzovic M, Alajbeg I, Cifrek M. The influence of age and dental status on elevator and depressor muscle activity. J Oral Rehabil. 2006;33(2):94–101. doi:10.1111/j.1365-2842.2006.01541.x.
31. Panchbhai AS. Quantitative estimation of vertical heights of maxillary and mandibular jawbones in elderly dentate and edentulous subjects. Spec Care Dentist. 2013;33(2):62–69. doi:10.1111/j.1754-4505.2012.00301.x.
32. Kurt MH, Yilmaz S, Evli C, Karahan S. Comparative evaluation of trabecular bone structures of bruxist and non-bruxist individuals with bone apposition in the mandible angle region by fractal analysis. J Oral Rehabil. 2023;50(5):360–369. doi:10.1111/joor.13435.
33. Wyatt CC. The effect of prosthodontic treatment on alveolar bone loss: a review of the literature. J Prosthet Dent. 1998;80(3):362–366. doi:10.1016/S0022-3913(98)70138-6.
34. Atwood DA, Coy WA. Clinical, cephalometric, and densitometric study of reduction of residual ridges. J Prosthet Dent. 1971;26(3):280–295. doi:10.1016/0022-3913(71)90070-9.
35. Tan WL, Wong TL, Wong MC, Lang NP. A systematic review of post-extractional alveolar hard and soft tissue dimensional changes in humans. Clin Oral Implants Res. 2012;23:1–21. doi:10.1111/j.1600-0501.2011.02375.x.
36. Huumonen S, Haikola B, Oikarinen K, Söderholm A, Remes-Lyly T, Sipilä K. Residual ridge resorption, lower denture stability and subjective complaints among edentulous individuals. J Oral Rehabil. 2012;39(5):384–390. doi:10.1111/j.1365-2842.2011.02284.x.
37. Schropp L, Wenzel A, Kostopoulos L, Karring T. Bone healing and soft tissue contour changes following single-tooth extraction: a clinical and radiographic 12-month prospective study. Int J Periodontics Restor Dent. 2003;23(4):313–323.
38. Tanaka M, Yamashita-Mikami E, Akazawa K, Yoshizawa M, Arai Y, Ejiri S. Trabecular bone microstructure and mineral density in human residual ridge at various intervals over a long period after tooth extraction. Clin Implant Dent Relat Res. 2018;20(3):375–383. doi:10.1111/cid.12591.

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ORIGINAL RESEARCH ARTICLE

Comparison of Adaptation and Microleakage of CAD/CAM Restorations to Inlay Cavities Prepared by Using Different Finishing Methods

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Abstract

Purpose: To compare the adaptation and microleakage of CAD/CAM inlay restorations using conventional or ultrasonic finishing equipment and their combinations.
Materials and Methods: Inlay cavities were prepared on 66 extracted human lower first molar teeth using one of the following finishing methods: Group I: straight fissure diamond bur; Group II: fissure diamond bur and ultrasonic tip; Group III: 6º tapered conical diamond bur; Group IV: 6º tapered conical diamond bur and ultrasonic tip. Inlay restorations milled from feldspathic ceramic blocks were cemented with resin cement. Adaptation and microleakage of the restorations were evaluated by micro-CT. The adaptation of the restorations was evaluated in four areas and at five determined points. The differences between the finishing methods were statistically evaluated at each measurement point.
Results: The adaptation of the restorations range from 1.07 and 330.71 µm. Statistical differences were observed in the marginal and internal adaptation of ceramic inlay restorations due to the finishing method used at some points of the ceramic and cavity interface. Group IV exhibited superior adaptation with significantly lower marginal gaps at points A, C, and E compared to Groups I, II, and III (($p<0.05$). However, the microleakage values between the finishing methods did not show a statistical difference ($p >0.05$).
Conclusions: According to the study findings, microleakage of inlay restorations was not affected by the finishing method. However, both marginal and internal adaptation were influenced by the finishing method, with Group IV (conical diamond burs + ultrasonic tip) demonstrating superior results.

Keywords: Ceramic Inlays; Inlay Preparation; Micro-CT; Microleakage; Ultrasonic Instruments

Introduction

Developments in dental bonding technology paved the way for the widespread use of indirect adhesive restorations for posterior teeth.[1] The most common indirect adhesive restorations used in the posterior area are inlays, onlays, and overlays.[1,2]

Inlay restorations are indirect restorations that involve occlusal and proximal tooth surfaces.[3] They are known as being more of a conservative restorations compared to complete coverage crowns.[4] The current materials used to fabricate CAD/CAM inlay restorations are glass ceramic and composite resin blocks.[1,4] Ceramic restorations provide high clinical success, good esthetics, and natural tooth morphology.[5] A higher success rate is reported for ceramic inlays than composite resin inlays.[4,6] They show better physical properties and lower polymerization shrinkage than composite resins.[7] Ceramic inlays are also known to demonstrate higher wear resistance and compressive force.[1,8,9]

Many variables affect the longevity of ceramic inlay restorations, such as the quality of the remaining tooth structure to which the restoration is bonded, oral hygiene, and applied load.[7] The clinician

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can control the tooth preparation design, choice of the restoration material, and bonding method used.[7] The factors associated with preparation design that could affect the longevity of the inlay/tooth complex are; cavity depth, preparation taper, cavity/isthmus width, and the morphology of internal line angles.[10]

Poor marginal adaptation of the restoration can result in microleakage, luting cement dissolution, the formation of secondary caries, and gingival inflammation.[4,11,12] Poor internal adaptation can reduce retention, increase cement thickness, alter occlusion, and lead to exchanged marginal adaptation.[4] With the developments in CAD/CAM systems, the internal and marginal adaptation of the milled restorations is improving.[7]

The preparation design of inlay restorations must be compatible with the specific properties of the ceramic material used.[10] The brittle structure of ceramics is a limiting factor; however, this limitation could be minimized through proper preparation design.[7] Avoiding internal stress concentration, providing adequate restoration thickness, and creating a passive insertion axis are essential for ceramic inlay tooth preparation.[3] The retention form is not needed for ceramic inlays as long as the restoration is bonded. The formation of bevels should be avoided since it reduces ceramic thickness.[3,7]

Additionally, the equipment used for the preparation process can affect the cavity geometry and the marginal and internal adaptation between the cavity and ceramic restoration. In inlay restorations where the preparation surface is very important, the choice of preparation instruments should also be made carefully. As an alternative to conventional preparation, different hand, rotary, and oscillating (ultrasonic) instruments have been developed to improve the preparation surface.[13] Rotary instruments work with rotational movements. Rotary instruments have a short working time, thus increasing patient comfort and efficiency for dentists. However, they cause the preparation surface to be rougher. On the other hand, ultrasonic instruments work with oscillatory movements and providing a smooth finishing line.[14]

Ultrasonic instruments are widely used in dentistry due to their operative ease, better efficiency, precise cutting ability, visualization, and success in accessing difficult areas at the margin of preparation.[15] There are studies indicating that preparation with ultrasonic instruments provides less surface roughness than rotary instruments.[16] Although there was a difference in surface roughness between rotary and ultrasonic preparation, some studies have also shown that this did not result in differences in microleakage or gaps between the restoration and tooth.[17]

The clinical significance of this research is that restoration fit is one of the most vital determinants of survival in the oral environment. Different cavity preparation techniques could influence the adaptation and microleakage of inlay restorations. This study aims to compare the effects of four different preparation finishing methods (straight diamond bur, straight fissure diamond bur, ultrasonic and ultrasonic tip, 6º tapered conical diamond bur, 6º tapered conical diamond bur, and ultrasonic tip) on the marginal and internal adaptation and microleakage of ceramic inlay restorations. The null hypotheses are: (H1) the use of a straight fissure diamond bur or a 6º tapered conical diamond bur would not bring about any difference in the restoration adaptation and microleakage of ceramic inlays, and (H2) finishing the proximal margins with an ultrasonic tip would not improve the adaptation and microleakage of the ceramic inlays.

Material and Methods

Preparation of the Specimens

A total of 66 extracted caries-free human lower first molar teeth were collected for this study. Based on calculations using a type I error rate (α) of 0.05, effect size (f) of 0.4, and test power (1-β) of 0.80, the sample size necessary to achieve a test power of 0.80 was determined to be 66. Teeth collection was approved by the Ethical Committee of Ankara University Faculty of Dentistry (22.07.2020 Date, 08/6 Issue). The utilization of extracted teeth in this study aimed to assess adhesive bonding under conditions that closely simulate real-world clinical scenarios. The teeth were randomly divided into four groups (n=14) and embedded in plaster up to the level of the collar for easy and precise inlay preparation.

The inlay cavities were prepared according to specific criteria for standardization. The following geometrical parameters for the inlay cavity were kept: 1.5 mm axial depth, 2 mm occlusal depth, 1 mm rounded shoulder margin in the axio-gingival angle, and a 12-degree tapered angle. To ensure standardization of the preparations, all inlay cavities were prepared by the same operator using different instruments for each group. The groups are as follows: The specimens in Group I underwent cavity preparation using a straight fissure diamond bur (Intensiv 8526). The specimens in Group II were prepared using a combination of fissure diamond bur (Intensiv 8526) and ultrasonic tip (SONICflex CAD-CAM mesial Nr. 34 Ref: 1.002.1984, Katenbach & Voigt GmbH (KaVo), Biberach, Germany). Group III specimens were prepared using 6º tapered conical diamond burs (Intensiv 3026SLC, Intensiv 3029SEC). Lastly, the specimens in Group IV were prepared using both 6º tapered conical diamond burs (Intensiv 3026SLC, Intensiv 3029SEC) and ultrasonic tips (SONICflex CAD-CAM mesial Nr. 34 Ref: 1.002.1984, Katenbach & Voigt GmbH (KaVo), Biberach, Germany).

The digital impressions of the inlay cavities were obtained with an intraoral scanner (Cerec Omnicam system, Sirona Dental Systems GmbH, Bensheim, Germany). Inlay restorations for each preparation were designed using the CAD program (Cerec CAD System Sirona Dental Systems GmbH, Bensheim, Germany). Both the scanning and designing procedures were performed by the same clinician. Sixty-six ceramic inlay restorations were milled from feldspathic ceramic blocks using the CEREC InLab MC XL (Sirona Dental Systems) and CEREC Blocs (Sirona Dental Systems GmbH, Bensheim, Germany). The fit of the inlay restorations before cementation was visually checked; reproduction was performed for incompatible restorations.

The ceramic inlay restorations were cemented onto the prepared teeth using resin cement (Panavia SA Cement Plus A2 Automix, Kuraray Noritake Dental Inc., Okayama, Japan, Lot: 1N0298). The cavity surfaces were etched with 37% phosphoric acid (i-GEL, i-dental, Šiauliai, Lithuania, Lot: 050154), while the cementation surfaces of the ceramic inlay restorations were treated with 4% buffered hydrofluoric acid gel (Porcelain Etchant Gel, Bisco Inc., USA). The restorations were then adapted using SONICflex CEM (KaVo, Biberach, Germany).

Micro-CT Analyses

For micro-CT analyses, a high-resolution scanning device, the Skyscan 1275 (Skycan, Kontich, Belgium), was used. The scanning parameters were set to a 0.2 rotation step, 125 kVp, 80 mA, and a 24 μm pixel size. To prevent radiological artifacts during scanning, a 1-mm thick aluminum filter was used. Each scanned specimen was reconstructed separately using NRecon software (version 1.6.4.8 Skycan, Kontich, Belgium). The software was also used to correct other radiological artifacts that may have occurred during the scanning. The two-dimensional axial projections of the reconstructed samples were obtained and then transferred to CTan software (version 1.14.4.1 Skycan, Kontich, Belgium) for quantitative analysis.

Linear Measurements

The Dataviewer software (version 1.5.6.2, Skycan, Kontich, Belgium) was used for two-dimensional measurements. Axially reconstructed images were examined in coronal planes using this software, and mid-coronal section images were obtained for the

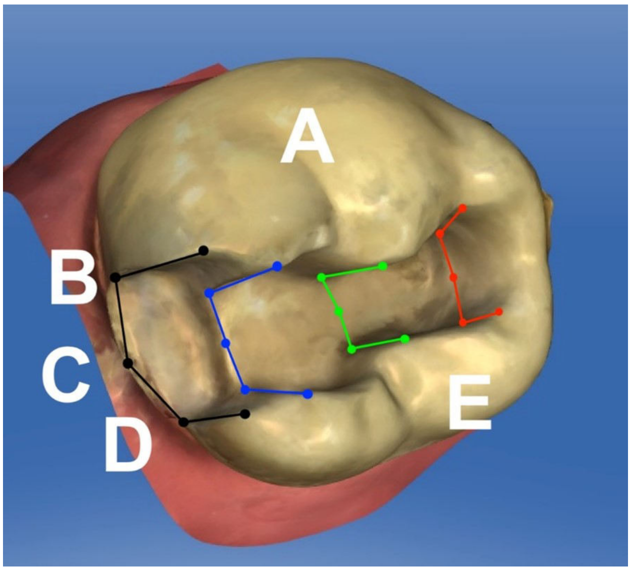

Figure 1. Measurement points. Black: Gingival circumferential tie margin and proximal flare margin, Blue: Isthmus, Green: Middle area of the occlusal box cavity, and Red: Occlusal box margin finish area. A: Buccal, B: Bucco-occlusal, C: Occlusal, D: Linguo-occlusal, E: Lingual.

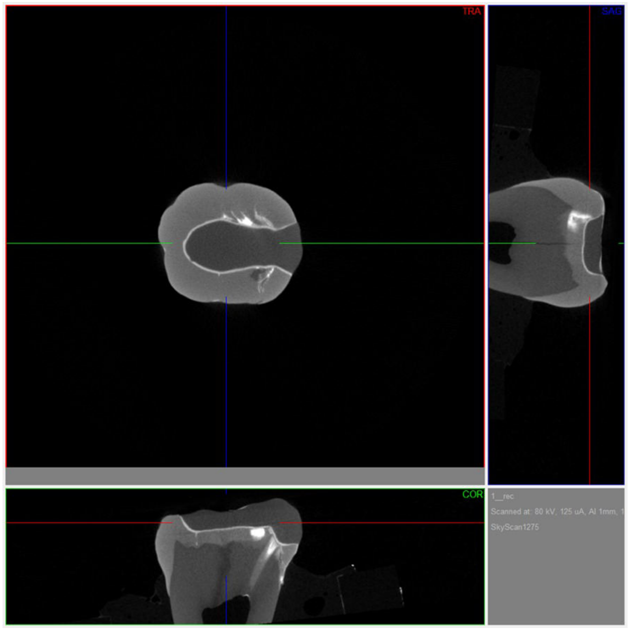

Figure 2. The two-dimensional image(Micro-CT Scans)

samples. These images were then imported into the CTan software, where two-dimensional linear measurements were performed to evaluate both the marginal and internal fit of the restorations. For the all-ceramic inlay preparations, five reference measurement points were used to determine the gap in micrometers for each localization (Fig. 1). These reference points were determined by modifying the measurement points used in the study by Ekici et al.[18] Each measurement point is described as follows:

- A: Buccal cavity margin
- B: Buccal intersection between cavity wall and floor
- C: Midpoint of the cavity preparation floor
- D: Lingual intersection between cavity wall and floor
- E: Lingual cavity margin

Volumetric Measurements

After the aging procedures, the inlay restorations were coated with two layers of nail varnish, except for a 1 mm thick area around the restoration margin and allowed to dry for 10 minutes. Next, all the restorations were immersed in a freshly prepared aqueous solution of 50 wt% ammoniacal silver nitrate (pH value = 9.5) for 24 hours (50% $AgNO_3$, Sinopharm, Beijing, China). They were then rinsed with running water for 2 minutes, immersed in a photo-developing solution (RPXOMAT, Kodak China, Shanghai, China), and exposed to light for 8 hours. Afterward, each specimen was ultrasonically cleaned for 1 minute with a toothbrush to eliminate any silver deposits on the surface. Each restoration was then individually scanned using micro-CT after being placed and fixed into the specimen holder.

Statistical analysis

The obtained data were analyzed using the IBM SPSS Statistics V25 software package (SPSS Inc, Chicago, IL, USA). Hypothesis tests were conducted at a significance level of α=0.05. One-way analysis of variance (ANOVA) was used to statistically compare the data, and the least significant difference (LSD) comparison test was used for inhomogeneous values and multiple comparisons of the averages.

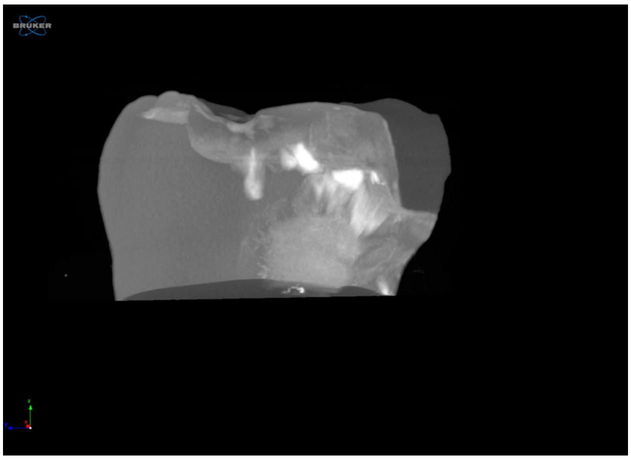

Figure 3. The three-dimensional image(Micro-CT Scans)

Results

The two-dimensional and three-dimensional micro CT images are shown in Fig. 2 and Fig. 3. Statistical comparisons of marginal or internal adaptation for each group are presented in Table 1,2,3 and 4. The statistical evaluation of marginal gap values at the circumferential gingival margin and proximal flare margin is as follows (Table 1). In the tables, groups sharing the same superscript letters do not exhibit statistically significant differences, whereas groups with different superscript letters show statistically significant differences. The marginal gap exhibited similar results across all groups at B, D, and E points ($p>0.05$); Group IV (205.52±23 µm) demonstrated a lower marginal gap compared to Group I (224.64±19 µm) and II (223.64±15 µm) at point A; and Group IV (1.64±3.97 µm) exhibited a lower marginal gap compared to Group I (6.36±7.01 µm) at point C ($p<0.05$).

The table 2 shows the fit of the isthmus (in µm) across five different regions (A, B, C, D, E) for four groups (Group I, II, III, IV) (Table 2). Each region presents mean (Mean), standard deviation (SD), and median (Median) values. In the tables, groups sharing the same superscript letters do not exhibit statistically significant differences, whereas groups with different superscript letters show

Table 1. Fit of gingival circumferential tie margin and proximal flare margin (µm)

	Group I		Group II		Group III		Group IV	
	Mean±SD[X]	Median	Mean±SD[X]	Median	Mean±SD[X]	Median	Mean±SD[X]	Median
A	224.64±19.47[a]	230.50	223.64±15.43[a]	226.50	209.86±23.66[a,b]	210.50	205.57±23.98[b]	199.00
B	192.57±17.34[a]	193.00	190.57±16.27[a]	191.50	190.36±19.10[a]	195.50	184.50±17.73[a]	184.00
C	6.36±7.01[a]	4.50	4.86±5.61[a,b]	4.00	4.64±4.27[a,b]	4.00	1.64±3.97[b]	0.00
D	156.50±12.09[a]	154.50	154.50±17.72[a]	154.50	149.86±10.26[a]	148.50	148.93±14.20[a]	148.00
E	123.57±17.26[a]	123.00	123.43±20.68[a]	118.50	117.57±17.13[a]	117.00	115.71±20.66[a]	114.00

Groups with the same superscript letters did not exhibit a statistical significance. Different superscript letters exhibit a statistical significance. The significance level is set at p=0.05. A: Buccal cavity margin B: Buccal intersection between cavity wall and floor C: Midpoint of the cavity preparation floor D: Lingual intersection between cavity wall and floor E: Lingual cavity margin * Each line was statistically compared within itself.

Table 2. Fit of Isthmus (µm)

	Group I		Group II		Group III		Group IV	
	Mean±SD[X]	Median	Mean±SD[X]	Median	Mean±SD[X]	Median	Mean±SD[X]	Median
A	330.71±30.38[a]	324.50	325.79±25.88[a]	328.50	317.86±28.72[a]	324.00	315.14±17.88[a]	318.50
B	177.14±16.34[a]	178.00	170.71±15.25[a]	168.50	169.79±16.55[a]	173.50	168.00±16.40[a]	163.00
C	5.00±5.50[a]	4.50	2.50±3.61[a,a]	0.00	2.86±3.57[a,a]	1.00	1.07±2.56[a]	0.00
D	163.50±22.51[a]	166.00	150.29±22.07[a,a]	151.50	147.50±18.63[a,a]	157.50	139.57±24.60[a]	145.00
E	120.36±8.45[a]	122.50	117.57±9.87[a]	120.00	117.36±11.72[a]	118.50	115.14±9.77[a]	115.00

Groups with the same superscript letters did not exhibit a statistical significance. Different superscript letters exhibit a statistical significance. The significance level is set at p=0.05. A: Buccal cavity margin B: Buccal intersection between cavity wall and floor C: Midpoint of the cavity preparation floor D: Lingual intersection between cavity wall and floor E: Lingual cavity margin * Each line was statistically compared within itself.

statistically significant differences. Group IV demonstrated a lower marginal gap compared to Group I at C (Group IV (1.07±2.56 µm; Group I (5.00±5.50 µm), and D (Group I: 163.50±22.51 µm, Group IV: 139.57±24.60 µm) points C ($p<0.05$). Other regions (A, B, E) did not exhibit statistically significant differences among the groups ($p>0.05$).

Table 3 presents the fit of the middle area of the occlusal box cavity (in µm) across four different groups (Group I, Group II, Group III, Group IV). Mean and standard deviation (SD) values, along with medians, are provided for each group. Comparisons between groups are indicated by the same superscript letters, indicating no statistical significance, while different superscript letters denote statistically significant differences (Table 3). Marginal gap displayed similar results across all groups at B, C, D, and E points ($p>0.05$); Group IV (186.93±14.54 µm) demonstrated a lower marginal gap compared to Group I (200.50±14.05 µm) at point A ($p<0.05$).

Table 4 presents the fit of the occlusal box margin finish area (in µm) among four distinct groups (Group I, Group II, Group III, Group IV). For each group, mean values with standard deviations (SD) and medians are provided. Comparisons between groups are indicated by the same superscript letters; identical letters denote no statistical significance, whereas different letters indicate statistically significant differences (Table 4). The marginal gap displayed similar results across all groups at A, C, and D points ($p>0.05$); Group IV (229.71±17.07 µm) demonstrated a lower marginal gap compared to Group I (245.93±15.59 µm) and III (244.36±20.76 µm) at point B; Group IV (103.79±7.95 µm) exhibited a lower marginal gap compared to Group I (109.93±7.20 µm) at point E ($p<0.05$).

Table 5 presents the volumetric microleakage of ceramic inlay restorations (in mm3) for four different groups (Group I, Group II, Group III, Group IV). Mean values with standard deviations (SD) and medians are provided for each group (Table 5). Statistical comparisons of the mean microleakage values among the groups revealed similar results ($p>0.05$).

Discussion

The null hypotheses of the study were partially confirmed. Micro-CT evaluation indicated that there was a statistical difference in the marginal and internal adaptation of ceramic inlay restorations due to the finishing method used at some points of the ceramic and cavity interface. However, this difference did not affect the microleakage of the restorations. Inlay/onlay restorations have a more complex geometry than crown restorations, which could explain variations in the adaptation of the restoration in some areas.[4]

The conventional method for determining microleakage is to evaluate the penetration of a specific tracer, such as organic dyes or silver nitrate (AgNO3), microscopically on sectioned specimens. AgNO3 is an electron-dense and radiopaque material that can be used with correlated microscopy techniques, such as scanning or transmission electron microscopy. Additionally, AgNO3 can be used with X-ray microcomputed tomography (micro-CT). However, a disadvantage of conventional microleakage tests is that the three-dimensional microleakage factor is assessed in only two dimensions. Furthermore, these tests are invasive, and the results are semiquantitative.[19]

In recent years, micro-CT has increasingly been used to evaluate the adaptation of restorations. Although it is more expensive than conventional methods, micro-CT is a non-destructive and reproducible technique.[20] It can achieve potential resolutions in the submicron range, depending on the computer's hardware capabilities and X-ray source characteristics.[19] Its superior feature compared to other methods is that it provides quantitative analysis and examination of the internal space of the restoration.[20,21] Furthermore, it is possible to perform multiple point measurements using the micro-CT method.[4,22]

The marginal seal is a crucial factor for the longevity of a restoration.[23,24] Several factors, such as restoration type, preparation design, restoration material, and cementation procedure, can affect the adaptation of the restoration. Poor marginal adaptation can result in luting cement degradation, microleakage, caries, periodontal disease, and marginal discoloration.[22] For ceramic inlay restorations, uniform internal adaptation is desired, and poor adaptation of the restoration can result in the cement being supported by the primer instead of the tooth structure.[21] Poor internal adaptation can increase cement thickness, reduce retention and restoration resistance, affect occlusion, and lead to poor marginal adaptation.[4]

There is no consensus on the marginal and internal gap for fixed restorations.[4,24] Some studies report an acceptable marginal range for adaptation as lower than 120 µm[4,11,25,26], while others report it as lower than 100 µm.[4,21,27,28] The acceptable marginal gap for CAD/CAM restorations is reportedly 58–200 µm.[21] Cement thickness below 200 µm is more resistant to wear at restoration

Table 3. The fit of the middle area of the occlusal box cavity (μm)

	Group I		Group II		Group III		Group IV	
	Mean±SD^{X}	Median	Mean±SD^{X}	Median	Mean±SD^{X}	Median	Mean±SD^{X}	Median
A	200.50±14.05^{a}	200.00	197.50±19.10^{a},^{b}	200.50	194.93±16.41^{a},^{a}	199.00	186.93±14.54^{b}	187.00
B	247.43±18.39^{a}	242.50	245.64±17.53^{a}	246.00	239.07±19.64^{a}	237.50	234.57±12.52^{a}	237.00
C	54.29±7.75^{a}	56.00	53.14±5.48^{a}	54.00	53.50±5.88^{a}	54.50	52.57±5.15^{a}	54.00
D	194.93±8.86^{a}	195.50	192.57±12.83^{a}	192.00	190.14±10.86^{a}	190.00	188.79±10.71^{a}	188.00
E	163.07±8.82^{a}	163.00	162.21±11.83^{a}	163.00	157.86±9.03^{a}	157.00	157.50±10.68^{a}	160.50

Groups with the same superscript letters did not exhibit a statistical significance. Different superscript letters exhibit a statistical significance. The significance level is set at p=0.05. A: Buccal cavity margin B: Buccal intersection between cavity wall and floor C: Midpoint of the cavity preparation floor D: Lingual intersection between cavity wall and floor E: Lingual cavity margin * Each line was statistically compared within itself.

Table 4. Fit of the occlusal box margin finish area (μm)

	Group I		Group II		Group III		Group IV	
	Mean±SD^{X}	Median	Mean±SD^{X}	Median	Mean±SD^{X}	Median	Mean±SD^{X}	Median
A	296.00±29.36^{a}	289.50	292.71±19.39^{a}	294.50	290.43±24.71^{a}	295.50	283.86±28.36^{a}	290.50
B	245.93±15.59^{a}	244.00	235.43±15.67^{a},^{b}	237.50	244.36±20.76^{a}	238.00	229.71±17.07^{b}	229.00
C	164.50±9.35^{a}	161.50	163.43±9.70^{a}	165.00	163.64±13.18^{a}	161.00	161.79±12.88^{a}	163.00
D	247.29±23.79^{a}	249.00	245.64±24.25^{a}	242.50	240.21±26.19^{a}	243.00	230.79±14.99^{a}	235.00
E	109.93±7.20^{a}	109.00	105.50±8.87^{a},^{b}	105.50	105.07±4.76^{a},^{b}	104.00	103.79±7.95^{b}	105.50

Groups with the same superscript letters did not exhibit a statistical significance. Different superscript letters exhibit a statistical significance. The significance level is set at p=0.05. A: Buccal cavity margin B: Buccal intersection between cavity wall and floor C: Midpoint of the cavity preparation floor D: Lingual intersection between cavity wall and floor E: Lingual cavity margin * Each line was statistically compared within itself.

Table 5. Volumetric microleakage of the ceramic inlay restorations (mm3)

	Mean±SD^{a}	Median
Group I	2.44±1.24^{a}	2.90
Group II	2.38±0.91^{a}	2.18
Group III	2.21±1.05^{a}	2.22
Group IV	2.11±0.75^{a}	2.27

*The mean difference is significant at the 0.05 level.

margins.[24]

In this study, marginal and internal gap values exceeded the acceptable values at some points. This could be due to several factors, such as the restoration material used, the sensitivity of the milling device, restoration adjustments after fabrication, and the cementation procedure used, among others. Increased internal space of the restoration can result in higher polymerization shrinkage of the luting cement and poor support of the restoration.[22]

The longevity of dental restorations is influenced by key factors such as restoration geometry, preparation methods, and loading conditions. Various instrumental methods for cavity preparation are available, including conventional rotating, sonic, ultrasonic, or laser methods. However, rotating instruments seem to cause more damage to the teeth.[29] Ultrasonic instruments have a vibrating motion, which makes them more effective and easier to use than conventional rotating instruments.[17] They are especially useful for beveling the enamel and dentin margins in difficult areas and can provide extremely precise finishing lines, which allows for better impressions and more adapted restorations with less microleakage.[30] Sonic and ultrasonic instruments have grainless tips, reducing the risk of damaging neighboring teeth and causing minimal trauma to the gingival attachment and pulp.[17,29] However, they can lead to more surface irregularities and border defects and can also cause iatrogenic damage to neighboring teeth.[17] Özcan et al.[31] reported acceptable marginal quality using ultrasonic tips and ceramic inserts.

CAD/CAM inlay restorations are vulnerable to imperfect preparation geometry.[30] Kim et al.[22] reported that the preparation design affects the adaptation of indirect partial ceramic crowns. It has been reported that a non-retentive cavity preparation exhibits higher adaptation than a retentive cavity preparation.[4] However, another study found similar marginal adaptation between minimally invasive cavity preparations with proximal undercuts and conventional divergent preparations.[32] Additionally, a study found that higher margin positioning results in less interfacial gap volume.[30]

Naumova et al.[17] evaluated the effect of different preparation methods (rotating, sonic, and ultrasonic) on the marginal quality of ceramic inlays using scanning electron microscopy (SEM). They reported that ultrasonic instruments led to increased surface roughness compared to rotating instruments. They also found no statistically significant differences between the groups' proximal microleakage, proximal marginal gap, and proximal margin quality. In this study, the microleakage values between the groups were similar; however, marginal gap values showed statistical differences at some points. This difference could be explained by the use of micro-CT analysis in this study instead of SEM.

Ellis et al.[29] compared two ultrasonic finishing protocols on the quality of the preparation margins and reported that the ultrasonic finishing protocol affected the results. However, in this study, only one type of ultrasonic finishing protocol was used, which is one of the study's limitations.

It has been reported that the marginal and internal adaptation of CAD/CAM restorations is affected by the type of restorative material used.[4,23] Restorative materials with a low elastic modulus and hardness can result in the removal of a greater amount of material during grinding.[4,33] However, less brittle materials are reported to show lower edge chipping, better machinability, and adaptation.[4,23,34] This study used only one type of restorative material, which can be considered a limitation. Studies including several types of materials are needed for more accurate results.

Conclusion

Within the limitations of this study, it can be concluded that using a special tapered bur and ultrasonic tip together for preparation provides better adaptation for inlay restorations. Furthermore, the tapered bur is more efficient than the straight bur and ultrasonic tip regarding preparation fit. However, recent literature on this topic is limited, and further studies are needed to validate these findings.

Author Contributions

Conceive and Design : A.S. , M.A.K.
Complete the Experiment : E.S. , M.C.T. , M.O , I.B.B
Write and Review : A.S. , M.C.T. , M.O.
Editing : M.A.K. , I.B.B.
Read and Approve : All Authors

Conflict of Interest

None.

Ethics Approval

Teeth collection was approved by the Ethical Committee of Ankara University Faculty of Dentistry (22.07.2020 Date, 08/6 Issue).

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References

1. Fan J, Xu Y, Si L, Li X, Fu B, Hannig M. Long-term Clinical Performance of Composite Resin or Ceramic Inlays, Onlays, and Overlays: A Systematic Review and Meta-analysis. Oper Dent. 2021;46(1):25–44. doi:10.2341/19-107-LIT.
2. Morimoto S, Rebello de Sampaio FB, Braga MM, Sesma N, Ozcan M. Survival Rate of Resin and Ceramic Inlays, Onlays, and Overlays: A Systematic Review and Meta-analysis. J Dent Res. 2016;95(9):985–994. doi:10.1177/0022034516652848.
3. Meyer J A, Cardoso LC, Araujo E, Baratieri LN. Ceramic inlays and onlays: clinical procedures for predictable results. J Esthet Restor Dent. 2003;15(6):338–352. doi:10.1111/j.1708-8240.2003.tb00307.x.
4. Goujat A, Abouelleil H, Colon P, Jeannin C, Pradelle N, Seux D, et al. Marginal and internal fit of CAD-CAM inlay/onlay restorations: A systematic review of in vitro studies. J Prosthet Dent. 2019;121(4):590–597 e3. doi:10.1016/j.prosdent.2018.06.006.
5. Holberg C, Rudzki-Janson I, Wichelhaus A, Winterhalder P. Ceramic inlays: is the inlay thickness an important factor influencing the fracture risk? J Dent. 2013;41(7):628–635. doi:10.1016/j.jdent.2013.04.010.
6. Zimmer S, Gohlich O, Ruttermann S, Lang H, Raab WH, Barthel CR. Long-term survival of Cerec restorations: a 10-year study. Oper Dent. 2008;33(5):484–487. doi:10.2341/07-142.
7. Hopp CD, Land MF. Considerations for ceramic inlays in posterior teeth: a review. Clin Cosmet Investig Dent. 2013;5:21–32. doi:10.2147/CCIDE.S42016.
8. Magne P, Belser UC. Porcelain versus composite inlays/onlays: effects of mechanical loads on stress distribution, adhesion, and crown flexure. Int J Periodontics Restorative Dent. 2003;23(6):543–555.
9. Mormann WH, Stawarczyk B, Ender A, Sener B, Attin T, Mehl A. Wear characteristics of current aesthetic dental restorative CAD/CAM materials: two-body wear, gloss retention, roughness and Martens hardness. J Mech Behav Biomed Mater. 2013;20:113–125. doi:10.1016/j.jmbbm.2013.01.003.
10. Thompson MC, Thompson KM, Swain M. The all-ceramic, inlay supported fixed partial denture. Part 1. Ceramic inlay preparation design: a literature review. Aust Dent J. 2010;55(2):120–231. doi:10.1111/j.1834-7819.2010.01214.x.
11. Kim DY, Kim JH, Kim HY, Kim WC. Comparison and evaluation of marginal and internal gaps in cobalt-chromium alloy copings fabricated using subtractive and additive manufacturing. J Prosthodont Res. 2018;62(1):56–64. doi:10.1016/j.jpor.2017.05.008.
12. Stappert CF, Chitmongkolsuk S, Silva NR, Att W, Strub JR. Effect of mouth-motion fatigue and thermal cycling on the marginal accuracy of partial coverage restorations made of various dental materials. Dent Mater. 2008;24(9):1248–1257. doi:10.1016/j.dental.2008.02.005.
13. da Silva TF, de Melo MP, Pereira JR, Takeshita WM, Ceribelli BM, Vessoni Iwaki LC. Subjective qualitative assessment of the finish line of prosthetic preparations submitted to different finishing instruments. J Prosthet Dent. 2016;116(3):375–381. doi:10.1016/j.prosdent.2016.02.003.
14. Chen YL, Chang HH, Chiang YC, Lin CP. Application and development of ultrasonics in dentistry. J Formos Med Assoc. 2013;112(11):659–665. doi:10.1016/j.jfma.2013.05.007.
15. Hadi L, Syafrinani M, Chairunnisa R. The Influence of Using Rotary and Ultrasonic Instruments on The Surface Roughness of Finishing Line and Marginal Adaptation In Metal-Porcelain Restoration. NVEO. 2021:2216–2230.
16. Horne P, Bennani V, Chandler N, Purton D. Ultrasonic margin preparation for fixed prosthodontics: a pilot study. J Esthet Restor Dent. 2012;24(3):201–209. doi:10.1111/j.1708-8240.2011.00477.x.
17. Naumova EA, Schiml F, Arnold WH, Piwowarczyk A. Marginal quality of ceramic inlays after three different instrumental cavity preparation methods of the proximal boxes. Clin Oral Investig. 2019;23(2):793–803. doi:10.1007/s00784-018-2492-0.
18. Ekici Z, Kilicarslan MA, Bilecenoglu B, Ocak M. Micro-CT Evaluation of the Marginal and Internal Fit of Crown and Inlay Restorations Fabricated Via Different Digital Scanners belonging to the Same CAD-CAM System. Int J Prosthodont. 2021;34(3):381–389. doi:10.11607/ijp.6822.
19. Scotti N, Baldi A, Vergano EA, Tempesta RM, Alovisi M, Pasqualini D, et al. Tridimensional Evaluation of the Interfacial Gap in Deep Cervical Margin Restorations: A Micro-CT Study. Oper Dent. 2020;45(5):E227–E236. doi:10.2341/19-161-L.
20. Bayrak A, Akat B, Ocak M, Kiotaliotacarslan MA, Ozcan M. Micro-Computed Tomography Analysis of Fit of Ceramic Inlays Produced with Different CAD Software Programs. Eur J Prosthodont Restor Dent. 2021;29(3):1–6. doi:10.1922/EJPRD_2046Bayrak06.
21. Alajaji NK, Bardwell D, Finkelman M, Ali A. Micro-CT Evaluation of Ceramic Inlays: Comparison of the Marginal and Internal Fit of Five and Three Axis CAM Systems with a Heat Press Technique. J Esthet Restor Dent. 2017;29(1):49–58. doi:10.1111/jerd.12271.
22. Kim JH, Cho BH, Lee JH, Kwon SJ, Yi YA, Shin Y, et al. Influence of preparation design on fit and ceramic thickness of CEREC 3 partial ceramic crowns after cementation. Acta Odontol Scand. 2015;73(2):107–113. doi:10.3109/00016357.2014.956145.
23. Rippe MP, Monaco C, Volpe L, Bottino MA, Scotti R, Valandro LF. Different Methods for Inlay Production: Effect on Internal and Marginal Adaptation, Adjustment Time, and Contact Point. Oper Dent. 2017;42(4):436–444. doi:10.2341/16-093-L.
24. Uzgur R, Ercan E, Uzgur Z, Colak H, Yalcin M, Ozcan M. Cement Thickness of Inlay Restorations Made of Lithium Disilicate, Polymer-Infiltrated Ceramic and Nano-Ceramic CAD/CAM Materials Evaluated Using 3D X-Ray Micro-Computed Tomography. J Prosthodont. 2018;27(5):456–460. doi:10.1111/jopr.12521.
25. Kale E, Seker E, Yilmaz B, Ozcelik TB. Effect of cement space on the marginal fit of CAD-CAM-fabricated monolithic zirconia crowns. J Prosthet Dent. 2016;116(6):890–895. doi:10.1016/j.prosdent.2016.05.006.

26. Sailer I, Feher A, Filser F, Gauckler LJ, Luthy H, Hammerle CH. Five-year clinical results of zirconia frameworks for posterior fixed partial dentures. Int J Prosthodont. 2007;20(4):383–388.
27. Keshvad A, Hooshmand T, Asefzadeh F, Khalilinejad F, Alihemmati M, Van Noort R. Marginal gap, internal fit, and fracture load of leucite-reinforced ceramic inlays fabricated by CEREC inLab and hot-pressed techniques. J Prosthodont. 2011;20(7):535–540. doi:10.1111/j.1532-849X.2011.00745.x.
28. Schaefer O, Decker M, Wittstock F, Kuepper H, Guentsch A. Impact of digital impression techniques on the adaption of ceramic partial crowns in vitro. J Dent. 2014;42(6):677–683. doi:10.1016/j.jdent.2014.01.016.
29. Ellis R, Bennani V, Purton D, Chandler N, Lowe B. The effect of ultrasonic instruments on the quality of preparation margins and bonding to dentin. J Esthet Restor Dent. 2012;24(4):278–285. doi:10.1111/j.1708-8240.2011.00495.x.
30. Moon W, Chung SH, Chang J. Effect of Deep Margin Elevation on Interfacial Gap Development of CAD/CAM Inlays after Thermomechanical Cycling. Oper Dent. 2021;46(5):529–536. doi:10.2341/20-310-L.
31. Ozcan M, Pfeiffer P, Nergiz I. Marginal adaptation of ceramic inserts after cementation. Oper Dent. 2002;27(2):132–136.
32. Zaruba M, Kasper R, Kazama R, Wegehaupt FJ, Ender A, Attin T, et al. Marginal adaptation of ceramic and composite inlays in minimally invasive mod cavities. Clin Oral Investig. 2014;18(2):579–587. doi:10.1007/s00784-013-0988-1.
33. Coldea A, Fischer J, Swain MV, Thiel N. Damage tolerance of indirect restorative materials (including PICN) after simulated bur adjustments. Dent Mater. 2015;31(6):684–694. doi:10.1016/j.dental.2015.03.007.
34. Bottino MA, Campos F, Ramos NC, Rippe MP, Valandro LF, Melo RM. Inlays made from a hybrid material: adaptation and bond strengths. Oper Dent. 2015;40(3):E83–91. doi:10.2341/13-343-L.

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ORIGINAL RESEARCH ARTICLE

Assessment of Parents' Awareness Towards Space Maintainers: A Cross-Sectional Study

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Abstract

Purpose: Premature primary tooth loss in primary and mixed dentition can cause malocclusions in permanent dentition. Children with primary and mixed dentitions require space maintainers to prevent malocclusions. The purpose of this study was to evaluate the level of parental awareness regarding the use of space maintainers, oral hygiene practices, and the significance of primary teeth.

Materials and Methods: In this descriptive cross-sectional study, a survey comprising 20 questions and four primary categories, which were 1) sociodemographic data, 2) parental awareness regarding oral hygiene habits, 3) recognition of the significance of primary teeth and the children's previous tooth extraction experience, and 4) knowledge about the use of space maintainers, was utilized. The survey was administered to 240 parents who had children aged between 2 and 15 years. Descriptive statistical analyses were employed to interpret the results.

Results: While 45% of children lost primary teeth due to decay, trauma, or other reasons, 40.9% of parents declared that they had no idea that the early loss of primary teeth could damage permanent teeth. Additionally, only 35.8% of parents stated that they had knowledge of what a space maintainer is, and it was found that the parents who were familiar with space maintainers also had a high amount of knowledge about their use.

Conclusions: It is concluded that there is a need to raise parental awareness concerning the utilization of space maintainers as a preventive measure following the premature loss of primary teeth.

Keywords: Awareness; Interceptive Orthodontics; Malocclusion; Parents; Space Maintenance

Introduction

Primary dentition is a significant period in a child's growth and development process. Primary teeth are essential for speech, chewing, appearance, and preventing bad habits. Moreover, they play a crucial role in guiding and facilitating the eruption of permanent teeth. Notably, primary teeth serve as optimal space maintainers for permanent dentition. Understanding their role is vital for promoting dental health in children. [1,2]

Although the exfoliation of primary teeth is a natural physiological process, the disruption of the normal process of teeth eruption, whether due to the premature loss of primary teeth, proximal carious lesions, or other factors, can lead to mesial migration of teeth. [3,4] This migration may result in the loss of arch length and manifest as a malocclusion in permanent dentition. The rising prevalence of malocclusions among children resulting from the premature extraction of primary teeth has become a significant concern within the field of pediatric dentistry. This issue is one of the most common dental problems, alongside dental caries, gingival disease, and dental fluorosis. The impact of this trend on the oral health and overall well-being of young individuals should not be overstated. [5,6]

Preventive and interceptive orthodontic treatments aim to address issues observed in children's dental and skeletal development at an early stage, thus preventing them from progressing into severe malocclusions that may require lengthy and complex interventions later. Therefore, it is imperative for oral health professionals to be vigilant in recognizing these cases early on and referring them to orthodontic specialists for timely intervention. Preventive methods include "space maintenance," which involves the use of specific equipment known as "space maintainers." These appliances can be fixed or movable, and their purpose is to maintain arch length after the premature loss of a primary tooth. [7] Malocclusion may present as crowding, the impaction of permanent teeth, or the supraeruption of opposing teeth. [4] Space closure occurs six months after extraction, or in some cases, within days. The best method to

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prevent this is to insert a space maintainer right after extraction.[8] The loss of arch length can have significant consequences for dental health. When arch length is compromised, issues such as crowding, ectopic eruption, dental impaction, crossbite formation, and dental centerline discrepancies may arise. For this reason, the use of space maintainers plays a crucial role in shaping the future of orthodontic treatment.[9]

Parents have a substantial influence in their children's healthcare decisions. Research shows that there is a strong correlation between the opinions and awareness of parents regarding their children's oral health and the actual condition and their perceived need for treatment.[10,11] Therefore, it is expected that the knowledge and awareness of parents regarding the protection of oral health would affect their children's potential to benefit from preventive oral health practices. Several studies on this subject have been conducted in different populations.[12–15] Ali et al. reported the knowledge rate of parents regarding space maintainers as 49.8%, which was considered inadequate.[13] In line with the findings of many studies, it is clear that parents do not have enough information regarding practices involving space maintainers. According to the results of the literature review, there is a lack of studies on the subject in a Turkish population. Therefore, the aim of this study was to evaluate the awareness levels of parents regarding space maintainers as a protective measure for their children's oral health. The hypothesis of this study was the level of parental awareness regarding space maintainers is low.

Material and Methods

Population

This was a cross-sectional survey study conducted with a sample of 240 parents. The data were collected over a two-month period, from January to March 2024. The survey was administered to parents of patients aged between 2 and 15 years who sought routine examinations and dental treatments at the Pediatric Dentistry Clinics of Ankara Yıldırım Beyazıt University, Faculty of Dentistry Hospital. The study included parents who were physically and psychologically healthy, literate in Turkish, and capable of completing a survey. The sample size needed to conduct the study was calculated by power analysis based on a previous study,[12] wherein the percentage of awareness about space maintainers was 18%, with 95% power and a 5% error margin. The results of the power analysis revealed that at least 227 participants needed to be included. This number was rounded up to 240 participants.

Ethics committee approval was obtained from Ankara Yıldırım Bezayıt University Health Sciences Ethics Committee (no: 09/396, date: 23.11.2023). The principles of the Declaration of Helsinki and good clinical practices were followed during the study. All participants signed an informed consent form after they were informed about the study.

Survey

To evaluate the awareness of the participants regarding space maintainers, the researchers administered a survey in a face-to-face manner. The survey, designed based on a thorough review of the literature, consisted of 20 questions and 4 parts:

- (1) the sociodemographic characteristics of the parents,
- (2) their levels of knowledge about oral hygiene habits,
- (3) their awareness of the importance of primary teeth and their children's previous tooth extraction experiences,
- (4) their levels of knowledge about the use of space maintainers.

The sociodemographic data collected in the study included age, gender, education level, and number of children. The oral health knowledge section comprised four multiple-choice questions aimed at gauging the understanding of the participants regarding brushing habits and parental involvement in children's brushing routines. The section on the importance of primary teeth and children's previous tooth extraction experiences had four multiple-choice questions that were designed to assess the frequency of the dentist visits of the children of the participants, their previous experience with early loss of primary teeth, and their previous exposure to space maintainers. The final section consisted of eight multiple-choice questions focused on assessing the knowledge of the participants regarding the application and maintenance of space maintainers. After the survey was prepared, 25 randomly selected participants were asked to respond to the survey twice at two different time intervals to check the reliability of the form (Kappa=0.876).

Table 1. Sociodemographic characteristics of the participants

		n (%)
Gender	Female	166 (69.2%)
	Male	74 (30.8%)
Age	21-30	28 (11.6%)
	31-40	126 (52.5%)
	41 or older	86 (35.9%)
Education level	Illiterate	7 (3%)
	Literate with no formal degree	23 (9.6%)
	Primary-secondary school	37 (15.4%)
	High school	95 (39.6%)
	University	67 (27.9%)
	Postgraduate	11 (4.5%)
Number of children	1	25 (10.4%)
	2	111 (46.2%)
	3	78 (32.5%)
	4	26 (10.9%)

Statistical analysis

The statistical analyses were performed with the IBM SPSS Statistics 26.0 program (IBM Corporation, Armonk, NY, USA). Descriptive statistics are presented as mean ± standard deviation values for the discrete numeric variables, while the categorical variables are expressed as frequencies (%).

Results

Sociodemographic Characteristics

The sample of the study consisted of a total of 240 parents, including 166 (69.2%) female parents and 74 (30.8%) male parents. The majority of the participants were 31-40 years old (52.5%), 39.6% had completed high school as their highest level of education, and 46.2% had two children (Table 1).

Survey Responses

While 32.5% of the participants stated that they started brushing their children's teeth when their primary teeth erupted, 26.6% expressed uncertainty about the appropriate time for starting brushing. It was stated by 97.5% of the participants that children's teeth should be brushed at least twice a day, 45% were aware of the necessity to use fluoride-containing paste, and 74.2% were aware that they should assist their children in brushing their teeth (Table 2).

It was thought by 89.6% of the participants that their children should be taken to the dentist for regular check-ups. Most participants (77.1%) were aware that primary teeth should be treated in cases of decay, trauma, or pain. While the children of 50.4% of

Table 2. Responses of the participants to the survey questions about their children's toothbrushing habits and their parental involvement

Questions	Options	n (%)
Q1. When did you first start brushing your child's teeth?	When the first primary tooth erupted	78 (32.5%)
	When the first primary molar tooth erupted	43 (17.9%)
	When the first permanent tooth erupted	55 (23%)
	No idea	64 (26.6%)
Q2. Your child's teeth should be brushed at least twice a day.	Yes	234 (97.5%)
	No	2 (0.8%)
	No idea	4 (1.67%)
Q3. Your child's teeth should be brushed with fluoride-containing paste.	Yes	108 (45%)
	No	42 (17.5%)
	No idea	90 (37.5%)
Q4. You should help your child brush his/her teeth until he/she is 10-11 years old.	Yes	178 (74.2%)
	No	45 (18.7%)
	No idea	17 (7.1%)

Table 3. Responses of the participants to the survey questions about the importance of primary teeth and their children's dental experiences

Questions	Yes n (%)	No n (%)	No idea n (%)
Q5. Your child should be taken to the dentist for check-ups at regular intervals of 3-6 months.	215 (89.6%)	8 (3.3%)	17 (7.1%)
Q6. Since primary teeth are replaced by permanent teeth, it is not necessary to treat them in cases of decay, trauma, or pain.	22 (9.2%)	185 (77.1%)	33 (13.7%)
Q7. Has your child ever lost any primary teeth due to decay, trauma, or any other reason?	108 (45%)	121 (50.4%)	11 (4.6%)
Q8. Premature loss of primary teeth could damage permanent teeth.	122 (50.8%)	20 (8.3%)	98 (40.9%)

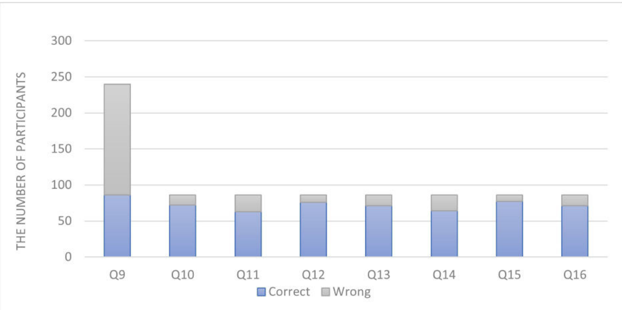

Figure 1. Responses of the participants to the knowledge and awareness questions regarding the use of space maintainers.

the participants had not experienced a loss of primary teeth before, the children of 45% of the participants had previous experience of tooth extraction. Besides, 50.8% of the participants believed that the premature loss of primary teeth could damage permanent teeth (Table 3).

Table 4 and Figure 1 detail the answers given by the participants to questions about the use of space maintainers. The rates of parental knowledge and awareness concerning the use of space maintainers were calculated based on responses from the participants acquainted with the concept of a space maintainer. Although the majority of the participants were unfamiliar with space maintainers (64.2%), those who were familiar exhibited a significantly higher proportion of correct responses to inquiries regarding their application. The percentages of correct responses to questions 10-16 ranged between 73.2% and 89.5%.

Discussion

Tooth decay remains a significant public health problem in the present day. According to a systematic review and meta-analysis published in 2020, the prevalence of caries was 46.2% in primary teeth and 53.8% in permanent teeth in children worldwide.[16] Moreover, with its high prevalence, caries remains the most common reason for tooth extraction in children.[17] As in all treatments, parents are accountable for their children's dental health and should be aware of the potential impacts of space loss. There is limited information on parents' awareness regarding the management of early primary tooth loss and the use of space maintainers.[13,14,18,19] Therefore, the primary purpose of this study was to evaluate the knowledge and attitudes of a group of parents regarding the importance of using space maintainers. Besides, the knowledge of parents about oral hygiene habits and the significance attributed to primary teeth and their children's previous tooth extraction experiences was questioned.

The main finding of this study was that the participants had low levels of knowledge about the use of space maintainers in general. The rate of participants who were aware of space maintainers was 35.8%. Studies conducted in different populations have shown variations in the awareness levels of parents, with figures of 17.9%, 18.5%, and 42.5% reported in Saudi Arabia and 57% in Iran.[12–15,20] It is worth noting that differences in findings may be attributed to factors such as variations in sample size, geographical differences, and cultural distinctions among the populations under study.

In this study, it was also found that although the children of 45% of the participants had experienced primary tooth loss, only 35.8% of the participants were aware of space maintainers. Similarly, Al Maaedeni et al. stated that while the incidence of premature loss of primary teeth in children was 20%, only 18.5% of parents were aware of space maintainers.[20] Moreover, Ali et al. reported that although 37% of the studied children had lost primary teeth before, a mere 17% of the dentists who conducted the extractions informed the patients about the potential application of space maintainers thereafter.[13] Additionally, in the study conducted by Andreeva et al. with 200 dentists, it was revealed that 87% of the dentists treated patients under the age of 12 and performed primary tooth extractions, whereas only 8% administered space maintainer applications.[21] In Türkiye, this rate was determined as 40%.[22] In accor-

Table 4. Responses of the participants to the survey questions regarding the use of space maintainers

Questions	Options	n (%)
Q9. Do you know what a space maintainer is?	Yes	86 (35.8%)
	No	154 (64.2%)
Q10. Space maintainers are applied to preserve the spaces of prematurely lost permanent teeth.	Yes	72 (83.7%)
	No	2 (2.3%)
	No idea	12 (14%)
Q11. What is the source of your knowledge about space maintainers?	Dentist	63 (73.2%)
	Social circle	17 (19.8 %)
	Internet	3 (3.5%)
	I don't know	3 (3.5%)
Q12. The use of space maintainers requires regular dentist check-ups.	Yes	76 (88.4%)
	No	5 (5.8%)
	No idea	5 (5.8%)
Q13. What type of food is prohibited for children wearing a fixed space maintainer?	Sticky foods (such as gum, jellybeans)	71 (82.6%)
	Fruits-vegetables	2 (2.3%)
	No idea	13 (15.1%)
Q14. Removable space maintainers need to be cleaned daily.	Yes	64 (74.4%)
	No	1 (1.2%)
	No idea	21 (24.4%)
Q15. What would you do if a space maintainer breaks or is lost?	I would leave it	1 (1.2%)
	I would wait for the time of a dentist appointment	5 (5.8%)
	I would immediately go to the dentist	77 (89.5%)
	No idea	3 (3.5%)
Q16. What would you do if permanent teeth start erupting while the child is still wearing space maintainers?	I would leave them	1 (1.2%)
	I would wait for the time of a dentist appointment	8 (9.3%)
	I would immediately go to the dentist	71 (82.5%)
	No idea	6 (7%)

dance with the findings of this study, only 32.4% of the parental cohort had university education or beyond. The cognizance of parents is influenced by various factors including education levels, income, and occupation.[14,23] Considering the data obtained in different studies, the improvement of parental knowledge concerning this matter necessitates the formulation of comprehensive social awareness initiatives and educational programs targeting all strata of society.

Space maintainers require diligent care, including dietary choices, regular dental appointments, and ongoing monitoring. A significant percentage of the participants of this study who were aware of space maintainers answered the questions in the survey regarding the use of space maintainers (questions 12-14) correctly. These findings differed from the results reported by Almeedani et al., who demonstrated low parental awareness levels regarding space maintainer utilization and dietary restrictions.[20] Similarly, studies conducted by Ali et al., Shamsaddin et al., and Linjawi et al. underscored the widespread lack of parental awareness regarding suitable dietary practices while employing space maintainers.[13–15] These results can be attributed to the possibility that the dentists visited by these parents provided sufficient information regarding the proper utilization of space maintainers.

The current study yielded notable findings concerning parental awareness of children's oral hygiene practices. While the participants demonstrated satisfactory knowledge regarding the frequency of daily brushings, the use of fluoride toothpaste, and parental involvement in tooth brushing, only 32.5% accurately identified the appropriate age for initiating their children's toothbrushing routine. This indicates that many parents do not have clear knowledge of when to start brushing their children's teeth. Hence, there is a need for educating parents about oral hygiene practices which is consistent with many other studies.[24,25]

This study was a hospital-based study which included participants whose children attended dental treatments and follow-up visits in two Pediatric Dentistry Clinics of a University Hospital located in Central and Western Türkiye. Therefore, the results of this study might not accurately reflect the broader population. Hence, the findings of the study should be generalized carefully, and further studies involving larger samples are warranted to provide comprehensive insights into the subject matter.

Conclusion

In conclusion, the results of this study revealed that parents lack adequate awareness of space maintainers as a preventive approach. It is crucial for pediatric dentists to educate parents during routine dental appointments about the importance of space maintainers and their longevity. This education is essential for preserving arch integrity and minimizing occlusal discrepancies.

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Author Contributions

Design : E.C.T. , N.Y.
Data Collection : E.C.T.
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Editing and Supervising : E.C.T. , N.Y.

Conflict of Interest

The authors declare that they have no competing interests.

Ethics Approval

Ethics committee approval was obtained from Ankara Yıldırım Bezayıt University Health Sciences Ethics Committee (no: 09/396, date: 23.11.2023). The principles of the Declaration of Helsinki and good clinical practices were followed during the study. All participants signed an informed consent form after they were informed about the study.

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References

1. Barbería E, Lucavechi T, Cárdenas D, Maroto M. Free-end space maintainers: design, utilization and advantages. JOCPD. 2007;31(1):5–8. doi:10.17796/jcpd.31.1.p87112173240x80m.
2. Pawar BA. Maintenance of space by innovative three-dimensional-printed band and loop space maintainer. J Indian Soc Pedod Prev Dent. 2019;37(2):205–208. doi:10.4103/JISPPD.JISPPD_9_19.
3. Rao A, Sarkar S. Changes in the arch length following premature loss of deciduous molars. J Indian Soc Pedod Prev Dent. 1999;17(1):29–32.
4. Setia V, Pandit IK, Srivastava N, Gugnani N, Sekhon HK. Space maintainers in dentistry: past to present. JCDR. 2013;7(10):2402. doi:10.7860/JCDR/2013/6604.3539.
5. Asiry MA. Occlusal status among 12-16 year-old school children in Riyadh, Saudi Arabia. J Int Oral Health. 2015;7(5):20.
6. Dhar V, Jain A, Van Dyke T, Kohli A. Prevalence of gingival diseases, malocclusion and fluorosis in school-going children of rural areas in Udaipur district. J Indian Soc Pedod Prev Dent. 2007;25(2):103–105. doi:10.4103/0970-4388.33458.
7. Green J. Mind the gap: Overview of space maintaining appliances. Dental Nursing. 2015;11(1):24–27. doi:10.12968/denn.2015.11.1.24.
8. Albati M, Showlag R, Akili A, Hanafiyyah H, AlNashri H, Aladwani W, et al. Space maintainers application, indication and complications. Int J Community Med Public Health. 2018;5(11):4970–4974. doi:10.18203/2394-6040.ijcmph20184251.
9. Keski-Nisula K, Hernesniemi R, Heiskanen M, Keski-Nisula L, Varrela J. Orthodontic intervention in the early mixed dentition: a prospective, controlled study on the effects of the eruption guidance appliance. Am J Orthod Dentofacial Orthop. 2008;133(2):254–260. doi:10.1016/j.ajodo.2006.05.039.
10. Gross GJ, Howard M. Mothers' decision-making processes regarding health care for their children. PHN. 2001;18(3):157–168. doi:10.1046/j.1525-1446.2001.00157.x.
11. Nagarajappa R, Kakatkar G, Sharda AJ, Asawa K, Ramesh G, Sandesh N. Infant oral health: Knowledge, attitude and practices of parents in Udaipur, India. J Dent Res. 2013;10(5):659.
12. Alduraihim HS, Alsulami SR, Alotaibi SZ, El-Patal MAE, Gowdar IM, Chandrappa PN. Assessment of Saudi parent's awareness towards space maintainers at Alkharj city: A cross-sectional study. TJFMPC. 2020;9(3):1608. doi:10.4103/jfmpc.jfmpc_1146_19.
13. Ali A, Hebbal M, Aldakheel N, Al Ghamdi N, Eldwakhly E. Assessment of Parental Knowledge towards Space Maintainer as an Essential Intervention after Premature Extraction of Primary Teeth. In: Healthcare. vol. 10. MDPI; 2022. p. 1057. doi:10.3390/healthcare10061057.
14. Linjawi AI, Alajlan SA, Bahammam HA, Alabbadi AM, Bahammam MA. Space maintainers: Knowledge and awareness among Saudi adult population. J Int Oral Health. 2016;8(6):733–738. doi:10.2047/jioh-08-06-18.
15. Shamsaddin H, Shojaeipour R, Haghighat Seir T, Pouraskari Z, Sayadizadeh M. Assessing the awareness of parents and satisfaction of children with intraoral space maintainers. JIDA. 2019;31(1):33–39. doi:10.30699/jidai.31.1.6.
16. Kazeminia M, Abdi A, Shohaimi S, Jalali R, Vaisi-Raygani A, Salari N, et al. Dental caries in primary and permanent teeth in children's worldwide, 1995 to 2019: a systematic review and meta-analysis. Head Face Med. 2020;16(1):1–21. doi:10.1186/s13005-020-00237-z.
17. Tatlı EC, Sarı AH. Evaluation of the Frequency of Primary and Permanent Teeth Extraction in Children at a Dental Hospital: A Cross-Sectional Study. Turkiye Klinikleri J Dental Sci. 2022;28(4):839–845. doi:10.5336/dentalsci.2022-90792.
18. Estupiñan-Alberco CJ, Arbildo-Vega HI, Farje-Gallardo CA, Coronel-Zubiate FT. Knowledge and attitude about the importance of maintaining primary dentition in parents of the Cercado de Lima District. Environ Soc Psychol. 2024;9(4). doi:10.54517/esp.v9i4.2174.
19. Ramakrishnan M, Banu S, Ningthoujam S, Samuel VA. Evaluation of knowledge and attitude of parents about the importance of maintaining primary dentition-A cross-sectional study. TJFMPC. 2019;8(2):414. doi:10.4103/jfmpc.jfmpc_371_18.
20. AlMeedani LA, Al-Ghanim HZ, Al-Sahwan NG, AlMeedani SA. Prevalence of premature loss of primary teeth among children in Dammam city and parents' awareness toward space maintainers. Saudi J Oral Sci. 2020;7(2):85–89. doi:10.4103/sjos.SJOralSci_9_19.
21. Andreeava R, Arnautska H, Belcheva A. Awareness of the Dental Practitioners about the Possibility to Use Space maintainers When Premature Temporary Teeth Extractions. Int J Sci Res Publ. 2015;5:194.
22. Öz E, Kırzıoğlu Z. Mezuniyet Sonrasi Diş Hekimlerinin Pedodontik Tedavilere Yaklaşımları. BAUN Sağ Bil Derg. 2018;7(1):23–33. doi:10.5505/bsbd.2018.53386.
23. Mikami Y, Wakai S, Croucher R, Hector MP, Nakamura Y. Children's dental health: British expatriate residents in Tokyo, Japan. Int Dent J. 2003;53(5):280–284. doi:10.1111/j.1875-595x.2003.tb00760.x.
24. ElKarmi R, Shore E, O'Connell A. Knowledge and behaviour of parents in relation to the oral and dental health of children aged 4–6 years. EAPD. 2015;16:199–204. doi:10.1007/s40368-014-0155-7.
25. Prabhu A, Rao AP, Reddy V, Ahamed SS, Muhammad S, Thayumanavan S. Parental knowledge of pre-school child oral health. J Community Health. 2013;38:880–884. doi:10.1007/s10900-013-9693-x.

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ORIGINAL RESEARCH ARTICLE

The Influences of Incisor Positional Changes Due to Fixed Appliance Therapy on Tongue Position

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Abstract

Purpose: The positional changes of the tongue due to fixed appliance therapy, the relationship between the positional changes of lower incisor, the tongue and the attribution of this relationship was investigated.
Materials and Methods: In this retrospective study, lateral cephalograms of pre and posttreatment records were evaluated. According to the mathematical differences of 1-NB parameters, subgroups namely; retrusion and protrusion groups were formed. Pretreatment measurements were performed from horizontal and vertical reference planes defined, posttreatment measurements were evaluated with the transportation of these reference lines using the total structural superimpositional method. The positional and linear dimensional changes of the tongue were evaluated using Rakosi tongue analysis with a modification of the reference line. Cephalometric tongue images were digitized and the tongue area were calculated.
Results: The positional changes of the tip of the tongue were concordant with the positional changes of the lower incisor, elevation of the dorsum of the tongue and stoopness of the base of the tongue occurred in the retrusion group. Tongue area increased in both groups.
Conclusions: The tip of the tongue followed the movement of the lower incisor altered with fixed appliance therapy in sagittal direction. In cases where upper incisor retraction is planned, tongue tip should be expected to adapt by rising vertically.

Keywords: Cephalometric tongue position; Fixed appliance therapy; Incisors; Rakosi tongue analysis; Tongue area

Introduction

In orthodontics, skeletal and dental structures have much been focused on, but the roles of surrounding muscle structures have often been ignored.[1–3] Dental and skeletal morphology affects physiological functions whereas functional compensations occur due to physiological needs. However, there are limits both for morphological and functional adaptations.[4] It has not yet been fully clarified whether the tongue determines the form of the dental arch or whether it functions according to dentoalveolar morphology.[5] Orthodontic fixed appliance therapy has functional and positional effects on dentoalveolar structures as well as on orofacial soft tissues. The functional and resting position of the tongue, as well as the dimensional influence of the tongue were emphasized, but there is still little to no information whether there exists a relationship between fixed appliance therapy and changes in tongue position or lower incisor position.[6] The aimed to investigate whether there exists a relationship. The study hypothesizes that the tongue tip adjusts to the lower incisors' positional changes altered with the fixed appliance therapy.

Material and Methods

A retrospective study was conducted on 34 patients who had undergone fixed edgewise therapy with Angle Class 1 and 2 anomalies on permanent or late mixed dentition stage from the archive of Ankara University Faculty of Dentistry Department of Orthodontics. The lateral cephalograms taken at pre and posttreatment on which the tongue can be seen clearly, and the patient did not swallow during exposure were selected. Patients with Angle Class 3 anomalies, crossbites and missing teeth were excluded. Total of 34 patients (total group), two subgroups were formed according to the linear measurement of position of the lower incisor to line NB. Individuals exhibiting lower incisor movement between 0-1 mm were used only in the total group. The values <0 mm was grouped as retrusion group ($\bar{x}$ =-2,21mm) (n=10), the values >1mm were grouped as protrusion group ($\bar{x}$ =2,36mm) (n=10). Chronological mean ages were 13.69 ±0.42 for total group, 13.40 ±0.52 for retrusion group and 14.32 ±1.17 for protrusion group. The landmarks and measurements used in the study are shown on Table 1, Figure 3. The borders of the cephalometric tongue image are limited

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Figure 1. Superimpositon of tongue areal changes of a retrusion case

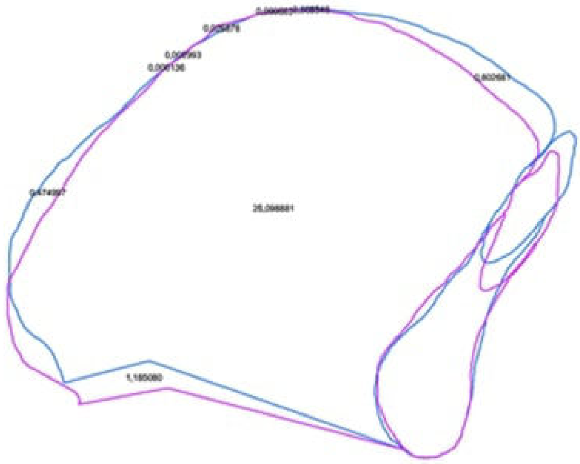

Figure 2. Superimpositon of tongue areal changes of a protrusion case

with tongue tip (TT) anteriorly, the dorsum above and posteriorly and the visible tongue image up to the epiglottis (E). In order to determine the tongue base, the E and Hy points are used for identifying a line which was extended to the innermost and lowest point on the lingual side of the symphysis. The lingual borders of the symphysis are drawn up to the TT and completed. Tongue images were digitized on an AccuTab GTCO table (GTCO CalComp 14557 N, 82nd St. Scotsdale, AZ 85260, US). The tongue area was calculated with the MicroStation 95 Programme (Bentley Systems, Incorporated, 685, Stockton Drive Exton, PA, 19341, US). Pre and posttreatment cephalometric radiographs were superimposed due to Björk and Skieller's local mandibular structural superimposition technique.[7] Digitized and superimposed as seen on Figure 1,2. The dimensional and linear changes of the tongue were evaluated by Rakosi tongue analysis.[8] Referring to Rakosi tongue analysis a reference line was conducted among the most prominent lower incisors incisal edge passing through distocervical enamel cement junction of lower first molar and this line is limited by the lowest point or the projection of that point of soft palate (Figure 4). The midpoint is marked as point O. Six angles of 30° were made through point O. The cut off points of these linear extensions on tongue were named as 'tg' points and on hard and soft palate were 'ltg' points starting from anterior to posterior ranking from 1 to 7 (Figure 5). In the study, the modification was made in the reference plane. The lower permanent first molar was used instead of terminal molar as described in Rakosi tongue analysis. Linear and angular measurements were done on cephalometric radiographs. For total measurements, a vertical reference plane (VR) was conducted with a line passing through the point Sella perpendicular to the occlusal plane (OD) and a horizontal reference plane (HR) was conducted with a line parallel to OD. For maxillary measurements; the ANS-PNS plane is used as the maxillary horizontal reference plane (max.HR), and the maxillary vertical reference plane (max.VR) was formed with the line drawn perpendicular to this plane from the point ANS. For mandibular measurements, Menton-Gonion was used as the mandibular horizontal reference plane (mand.HR), and the perpendicular descending from Pogonion to this plane was used as the vertical reference plane (mand.VR). Descriptive statistics of pre and posttreatment characteristics were done. Intragroup and intergroup differences were tested with student t-test and paired t-test (Table 2,3). Pearson correlation analysis was applied in order to evaluate the relationship between the parameters and tongue (Table 4).

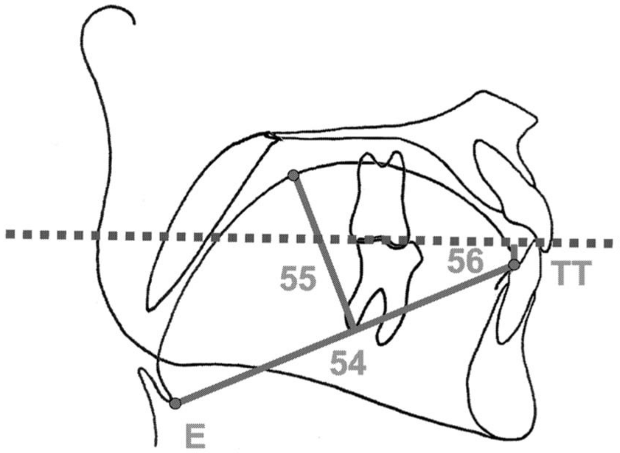

Figure 3. Tongue length (TGL) and tongue height (TGH) measurement

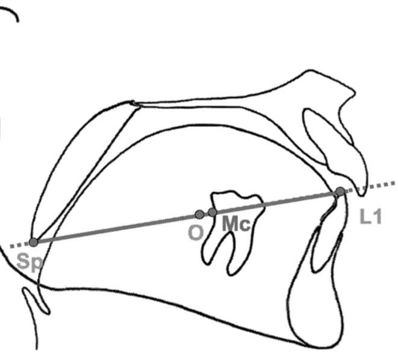

Figure 4. Rakosi reference line

Results

Descriptive statistics and comparison of the parameters were done (Table 2). Rakosi parameters which are O-tg1 and O-ltg1, were

Table 1. Definition of landmarks and measurements used in the study

Landmark/ Measurement	Definition
OD	(occlusal plane) the line passing through the midpoint of the occlusal closure points of first upper and lower permanent molars and midpoint of the occlusal closure points of most prominent upper and lower incisors
VR	(vertical reference plane) a 90^{0} vertical line from the point Sella to the occlusal plane
HR	(horizontal reference plane) a parallel line to the occlusal plane passing through point Sella
TT	(tip of the tongue) the most prominent point of the tongue in the sagittal plane
TGL	(length of the tongue) the linear distance between point TT and point E
u	The shortest linear distance between the ANS-PNS plane and the dorsum of the tongue
U1	the most prominent incisal point of the upper incisor in the sagittal plane
L1	the most prominent incisal point of the lower incisor
E-Shor	linear distance of the epiglottis point to the horizontal reference plane

Table 2. Descriptive statistics of parameters of subgroups at pretreatment and posttreatment and the comparison (student t-test) according to the subgroups

	to			t1		
	Retrusion	Protrusion	test	Retrusion	Protrusion	test
	X ±Sx	X ±Sx		X ±Sx	X ±Sx	
1/NB	29.47 ±2.66	26.43 ±1.66		21.51 ±2.63	33.80 ±2.94	**
1-NB	6.85 ±0.84	5.75 ±0.52		4.64 ±0.85	8.11 ±0.71	**
L1/mand.HR	96.55 ±2.75	93.43 ±2.08		89.09 ±2.66	99.62 ±3.73	*
APog-1	3.29 ±0.59	2.86 ±0.38		0.98 ±0.62	5.20 ±0.42	***
U1-max.HR	28.64 ±0.86	31.92 ±0.80	*	29.07 ±0.74	33.67 ±1.20	**
O-tg1	29.81 ±0.92	31.71 ±0.66		30.75 ±0.94	33.36 ±0.49	*
O-tg2	23.91 ±1.03	25.49 ±1.33		26.52 ±0.93	26.85 ±0.76	
O-tg3	20.74 ±1.28	22.82 ±1.56		24.02 ±1.12	23.72 ±1.09	
O-tg4	20.60 ±1.30	22.26 ±1.47		23.78 ±1.03	23.71 ±1.21	
O-tg5	22.51 ±1.00	24.02 ±1.25		24.75 ±0.94	24.98 ±1.14	
O-tg6	26.70 ±0.82	27.54 ±0.98		27.59 ±1.08	27.92 ±0.83	
O-tg7	34.00 ±1.22	34.62 ±0.83		34.46 ±1.49	35.28 ±0.72	
O-ltg1	35.25 ±0.92	35.15 ±0.39		33.89 ±1.02	36.39 ±0.31	*
O-ltg2	28.83 ±0.71	30.21 ±0.79		30.44 ±0.83	30.59 ±0.42	
O-ltg3	28.63 ±0.32	29.86 ±0.75		30.92 ±0.53	31.90 ±0.73	
O-ltg4	27.76 ±0.55	28.53 ±1.08		29.81 ±0.51	30.24 ±0.81	
O-ltg5	26.36 ±0.54	27.02 ±1.02		27.31 ±0.85	27.88 ±0.84	
O-ltg6	28.42 ±0.71	29.06 ±1.02		29.52 ±1.07	29.35±0.75	
O-ltg7	34.99 ±0.94	35.12 ±0.34		33.65 ±1.27	36.18 ±0.93	
TGL	71.96 ±1.42	73.35 ±1.82		74.52 ±1.50	75.93 ±1.17	
TGH	33.15 ±1.56	36.37 ±1.45		36.13 ±1.13	38.85 ±1.63	

X: mean value, Sx: standart deviation of mean value, t0: pretreatment, t1: posttreatment. *$p<0.05$, **$p<0.01$ ***$p<0.001$.

Table 3. Descriptive statistics of subgroup parameters (D±Sd) achieved with the treatment, comparison of the differences(paired t-test) and comparison of head differences a(student t-test)

	Retrusion Group		Protrusion Group		
	D±Sd	test	D±Sd	test	test
Hy-Svert	1.98 ±2.17		5.60 ±2.26	*	
Hy-Shor	7.39 ±2.18	**	5.43 ±2.44		
Pd	0.62 ±0.19	*	0.77 ±0.22	**	
U1-maxVR	-2.72 ±1.19	*	-0.54 ±0.79		
L1/mand.HR	-7.47 ±1.70	**	6.19 ±2.89		**
1/NB°	-7.96 ±1.70	**	7.37 ±2.77	*	***
1-NB	-2.21 ±0.50	**	2.36 ±.0.36	***	***
APog-1	-2.32 ±0.59	**	2.34 ±0.44	***	***
L1-mand.VR	3.60 ±0.67	***	-1.14 ±0.78		***
O-tg1	0.94 ±0.74		1.65 ±0.61		*
O-tg3	3.28 ±1.22	*	0.90 ±1.02		
O-tg4	3.18 ±1.13	*	1.45 ±0.86		
O-ltg1	-1.36 ±0.62		1.24 ±0.41	*	**
O-ltg2	1.60 ±0.34	**	0.39 ±0.57		
O-ltg3	2.29 ±0.42	***	2.04 ±0.54	**	
O-ltg4	2.05 ±0.59	**	1.70 ±0.69	*	
O-ltg7	-1.34 ±0.84		1.06 ±0.69		*
TGH	2.97 ±0.95	*	2.48 ±0.90	*	
TT-mand.HR	2.26 ±0.88	*	1.70 ±0.95		
TT-mand.VR	1.79 ±0.64	*	-0.89 ±0.79		*
TT-Shor	4.17 ±0.59	***	2.77 ±1.34		
TT-Svert	0.20 ±1.01		2.10 ±0.80	*	
E-Shor	7.63 ±2.08	**	4.25 ±2.47		
Tongue Area	3.84 ±0.98	**	2.08 ±0.66	*	
u	-0.84 ±1.00		0.56 ±0.88		
TGL	2.56 ±1.73		2.57 ±2.19		

D: mean difference, Sd: standard error of mean difference, * p<0.05, ** p<0.01, *** p<0.001

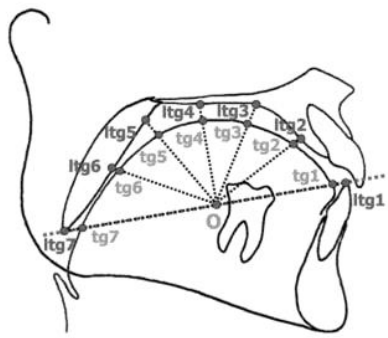

Figure 5. Cephalometric landmarks of Rakosi tongue analysis

found to be similar at pretreatment but were statistically differed at posttreatment. Other Rakosi parameters did not show any significant difference. TGL and TGH parameters were found to be similar. Paired t-test was done for pre and posttreatment evaluation of values for each subgroup (Table 3). Tongue area was significantly increased in both subgroups. TT-mand.HR and TT-mand.VR were significant in retrusion group. Intergroup differences were compared with student t-test (Table 3). Hy-Svert increased in protrusion group, Hy-Shor increased in retrusion group, O-ltg1 increased in protrusion group and was significantly different between groups. TT-mand.VR increased in retrusion group and significantly different between groups. According to Pearson correlation analysis for the total group TT-mand.VR was found to be correlated with 1-NB, 1/NB, A-Pog1, L1-mand.VR and L1-mand.HR (Table 4). Correlation analysis results for retrusion group showed that TT-mand.VR and L1-mand.VR, 1-NA and TT-Shor were significantly correlated while for protrusion group TT-mand.VR was negatively correlated with APog-1 and 1-NB. TT-mand.HR was correlated with L1-mand.HR and TGH was negatively correlated with U1-max.HR and L1/mand.HR.

Discussion

The positional changes of the tongue due to fixed appliance therapy, the relationship between the positional changes of lower incisor, the tongue and the attribution of this relationship was investigated. Our study showed that TT followed the movement of the lower incisor in sagittal direction. The tongue is positioned on the floor of the mouth, while TT taking part behind the incisal edges of lower incisors, the dorsum of the tongue over the teeth levels and spreading all over the oral cavity.[9] At rest, the TT is positioned on the lingual surface of the lower incisors exerting a certain amount of resting pressure and has a strong relationship with the mandibular arch.[10,11] Changes in the size of the oral cavity due to different treatment protocols might affect tongue position.[12] Soft tissues, affect hard tissues and orthodontic treatment results, therefore, soft tissue limitations should be assessed more precisely.[13] An alteration of incisors and soft tissue position could potentially affect tongue position.[14,15] These studies have shown that; there exists a close relationship between the TT and the lower incisors. The lower incisors are an important factor in providing ideal overbite and overjet, in determining the profile esthetics, and have been heavily involved in almost all of the cephalometric analyses.[16,17] Considering that the fixed orthodontic treatment plans are made by targeting the lower dentition; this relationship needs to be taken into account. In this context, in the study; two subgroups were formed as the retrusion and the protrusion group according to 1-NB.

Rakosi tongue analysis enables the evaluation of positional changes of the tongue in horizontal and vertical dimensions.[8] In original Rakosi tongue analysis the mandibular terminal molar

Table 4. Pearson correlation analysis results for total group, protrusion group and retrusion group

TOTAL GROUP	TGL	TT-Svert	E-Svert	TT-mand.VR	TT-Shor	E-Shor	TT-mand.HR	tongue area
1/NA		0.365 *						
U1/max.HR	0.398 *	0.382 *						
U1-max.HR					0.361 *			
1/NB				-0.706 ***		-0.396 *		
L1/mand.HR				-0.733 ***		-0.373 *		
1-NB				-0.662 ***				
APog-1				-0.626 ***		-0.368 *		
L1-mand.VR				0.803 ***		0.414 *		0.374 *
L1-mand.HR	0.426*		-0.572 ***	0.371 *		0.415 *	0.578 ***	
PROTRUSION GROUP	TGH	TT-OD	E-Svert	TT-mand.VR	TT-Shor	TT-mand.HR	u	
1/NA			-0.743 *					
U1/max.HR			-0.739 *					
1/NB	-0.680 *						-0.647 *	
L1/mand.HR				-0.708 *				
1-NB	-0.724 *	-0.642 *					-0.900 ***	
APog-1				-0.784 **				
L1-mand.VR				-0.788 **				
Pg-NB				0.888 **				
L1-mand.HR					-0.639 *			
RETRUSION GROUP			-0.755 *	0.717 *		0.867 **		
1-NA	0.648 *							
U1-max.HR			0.680 *					
L1-mand.VR		0.735 *						
Pg-NB				0.678 *				

*p<0.05, **p<0.01, ***p<0.001.

is used as an identification point of the reference plane. We used mandibular first molar instead because permanent first molars are the identification landmarks of occlusion and are widely used in cephalometric analysis.[18]

This study revealed that tongue-related parameters are heavily correlated with the mandibular dentoalveolar parameters. The significant negative correlation between parameters 1-NB and TT-mand.VR, 1/NB and TT-mand.VR, L1/mand.HR and APog-1 and TT-mand.VR shows that TT moves backwards in cases of advanced retrusion, that is, the TT tries to adapt to the form by following the linear and angular changes of the lower incisor (Table 4). The significant positive correlation between L1-mand.VR and TT-mand.VR supports the fact that the TT moves in the same direction as the lower incisor (Table 4). As contraray to our finding the relationship of TT with the lower incisors was told to be preserved at the end of the treatment, regardless of the lower incisor position.[3] However; our results revealed that the tongue adapts to the current morphological state of the oral cavity rather than forming the dental arches.[19] Besides, TGL is also found to be correlated with L1-mand.HR (Table 4). So; we can confirm the opinion that the tongue adapts to the changing occlusion and environment and that altering incisor and soft tissue position and arch dimension could significantly reduce TGL, as a result, affect the tongue position.[20] Additionally, the correlations between the parameters 1/NB and TT-mand.VR, L1-mand.HR and TGL can be explained with the adaptation of the tongue to the altered incisal inclinations, unlike the authors who claimed that incisor inclinations were not due to muscle action (Table 4).[21] The correlation between 1/NA and TT-Svert, U1/max.VR and TT-Svert indicates that forward or backward movement of the upper incisor was followed by the similar movement of TT on sagittal dimension (Table 4). The positive correlation between L1-mand.VR and TT-mand.VR also supports the fact that TT moves in the same direction as the incisor (Table 4). So the tongue adapts to the surrounding structures when the occlusion is changed.[14,15,22] Altered incisor and soft tissue position and arch dimension could significantly reduce TGL and as a result affect the tongue position.[20]

In vertical dimension we found that vertical position of the upper incisor relative to its base and the vertical position of the TT are statistically corraleted (Table 4). However, it is not clear whether this correlation causes lowering of TT as a result of the altered vertical position of the upper incisor or whether it is due to dentoalveolar development. It is also well accepted that the vertical position of the TT showed a highly positive correlation with the mandible, lower incisors and mandibular dentition rather than the upper incisor.[2]

Tongue area were measured digitally with planimeter devices.[23,24] According to our results; tongue area decreased in lower incisor protrusion cases and increased in retrusion cases. It is known that the TT moves forward to the incisors and lips to provide anterior oral seal, and the tongue spreads to the floor of the mouth when the length of the oral cavity increases.[25] But at this point the transversal dimension should be taken into consideration. In cases with protrusion, while TT is similarly positioned forward, the increase in the dorsum region is less in the retrusion group. It can be assumed that the tongue has undergone a positional change by spreading itself in the transversal dimension. Also, the backward movement of the lower incisors in the sagittal direction was accompanied by an increase in the vertical direction. In fixed appliance therapy, the incisal edge was positioned higher in the vertical direction due to the retrusion of the lower incisors.[26] So this may be due to retrusion and/or dentoalveolar development. In mandibular retrognathic Class 2 cases, the tongue is told to be positioned higher than normal occlusion cases, which is attributed to the soft tissues adaptation to environment in order to meet physiological needs as evident with our findings.[2] TT-Shor and E-Shor measurements revealed that the dimensional increase of the tongue in the vertical dimension is not only due to the rise in the dorsum region, but also to the lowering of the tongue base (Table 4). This was also reflected in the tongue area as a significant increase in the retrusion group (Table 3). According to this study, when retrusion occurs in the upper incisor, TT rises (Table 4). In cases where upper incisor retraction is planned, TT should be expected to adapt by rising vertically. In lower incisor protrusion cases, the tongue accompanied in a similar way with the lower incisor. The TT was positioned significantly ahead of the vertical reference plane (Table 4), increased significantly in size (O-ltg1) (Table 3), and showed non-important forward movement relative to mandibular vertical plane (Table 3). In the vertical direction, the TT did not show a significant lowering relative to the reference plane, no significant elevation was detected relative to the mandibular base (Table 3). The insignificant forward movement of E in the protrusion group can be considered as an attempt to compensate for the significant forward movement of TT (Table 3). With this possible compensation mechanism, it can be thought that TGL may have been tried to be preserved. Dimensional increase in tongue dimensions in both genders at different times was reported.[23] In the vertical direction; the elevation of the lower incisor relative to the mandibular base is also observed at TT. As in line with parameters u and TGH, the distance between the dorsum of the tongue and the maxillary base may decrease in relation to the positional and angular changes in the upper and lower incisors due to protrusion (Table 4). The shape of the tongue and dimensions are as important as incisor position and inclination during diagnosis.[19]

The hyoid bone and tongue descend in line with age, profile flattens, crowding occurs in the mandibular anterior region, and this is attributed to the lowering of the tongue. When retraction was performed, the tongue was told to be positioned below.[27] In this study the significant lowering of TT, Hy and E gives information about the vertical positions of the TT (Table 3). In the protrusion group, there is a non-significant decrease. So, when incisor retraction is planned in the early period, it should be taken into account that the advanced Hy and tongue will descend and the profile will tend to flatten. A positive relationship is reported between Hy and mandibular position.[28] The most protruding part of the dorsum of the tongue facing the pharyngeal cavity is located further back in Class 2 cases, independent of the tongue root and Hy position. This was explained as an adaptation in the genioglossus muscle which allows the tongue to protrude. In Class 3 cases; Hy was told to be positioned further due to increased genioglossus activity. In our study O-ltg7 showed significant difference between groups, and can be interpreted as tongue dorsum and Hy adaptation to the changing environment (Table 3). Besides postextraction tongue position is reported to influence the Hy.[29] But tongue size was stated as independent of the sizes of bone structures and gender differences.[30] Also tongue length was reported as not to differ in gender in Class 1 and 2, but it was found to be shorter in Class 3.[31] In our study, E and TT moved similarly in both groups in sagittal and vertical dimensions which suggests that TGL will not show a significant change (Table 3). Our findings confirm that the tongue does not show a dimensionally relationship with the dimensions of the skeletodental structures. However, TGL was significantly correlated with the distance of the upper and lower incisors to their bases (Table 3). TGL may be related to the vertical position of the incisors in the sagittal direction rather than the movement. In an opposite conclusion, Al Maaitah et al reported a decrease in TGL in bimaxillary extraction cases.[20] In our study, O-tg3 and O-tg4 parameters, increased significantly in the retrusion group, whereas no significant change was found in protrusion group (Table 3). However, it should be considered that, the movement of the lower incisors may cause a change in the Rakosi reference plane and should be evaluated together with other parameters. It may be more accurate to evaluate the dorsum of the tongue not only with Rakosi parameters, but also with the directly measured TGH and u parameters. In the retrusion group 'u' decreased at an insignificant level, indicating that the dorsum approached the maxillary base, in the protrusion group it decreased at an insignificant level, indicating that it moved away. However, these changes were not statistically significant either within the group or between the groups (Table 3). It is seen that there is a less increase in the dorsum region (O-tg2, O-tg3, O-tg4, O-tg5, O-tg6) in protrusion cases compared to the retrusion cases. However, it was determined that the forward movement was more pronounced in the anterior region (O-ltg1, TT-Svert) in the sagittal direction. Also, TGH increases in size, but it does not show a significant approximation to the maxillary base. The insignificant elevation of the dorsum of the tongue towards the hard palate is a finding contrary to what other studies have reported.[23] Besides dorsal tongue height was reported as higher in children compared to adults.[25] Besides changing tooth positions is told to affect tongue posture and functions, and these changes may also be reflected in palatal form and volume.[10,32–34] The reader should take into account that our study was conducted on lateral cephalometric films so were 2D and the transversal dimension were ignored.

Conclusion

The TT followed the movement of the lower incisor in sagittal direction. The tongue tried to adapt to the new form altered by the fixed therapy in the vertical direction as if following the mandibular dentition. In cases where upper incisor retraction is planned, TT should be expected to adapt by rising vertically. TGH increases in size, but it does not show a significant approximation to the maxillary base spatially in the oral cavity. In cases where incisor retraction is planned in the early period, it should be taken into account that the advanced Hy and tongue will descend, and the profile will tend to flatten. The readers should evaluate the findings as treatment results. Long-term results should be considered.

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Data Collection : A.A.
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Draft of the manuscript : A.A.
Critical revision of manuscript : All Authors
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Conflict of Interest

Authors declare that they have no conflict of interest.

Ethics Approval

Due to the "Ankara University Faculty of Dentistry, Clinical Research Ethics Committee" decision about this study; ethical approval was not deemed necessary at the specified dates (2006). Decision No: 36290600/57/2024

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References

1. Christiansen RL, Evans CA, Sue SK. Resting tongue pressures. Angle Orthod. 1979;49(2):92–97.
2. Cleall JF. Deglutition: A Study Of Form And Function. Am J Orthod. 1965;51:566–594.
3. Subtelny JD. Malocclusions, orthodontic corrections and orofacial muscle adaptation. Angle Orthod. 1970;40(3):170–201.
4. Guay AH, Maxwell DL, Beecher R. A radiographic study of tongue posture at rest and during the phonation of /s/ in class III malocclusion. Angle Orthod. 1978;48(1):10–22.
5. Ruan WH, Chen MD, Gu ZY, Lu Y, Su JM, Guo Q. Muscular forces exerted on the normal deciduous dentition. Angle Orthod. 2005;75(5):785–790.
6. Richardson ME. Late lower arch crowding in relation to soft tissue maturation. Am J Orthod Dentofacial Orthop. 1997;112(2):159–164. doi:10.1016/s0889-5406(97)70241-5.
7. Björk A, Skieller V. Normal and abnormal growth of the mandible. A synthesis of longitudinal cephalometric implant studies over a period of 25 years. Eur J Orthod. 1983;5(1):1–46. doi:10.1093/ejo/5.1.1.
8. Rákosi T. [Radiocephalometric studies on the changes of the tongue position in orthodontic treatment]. Fortschr Kieferorthop. 1966;27(2):234–246. doi:10.1007/bf02163911.
9. Baker R. The tongue and dental function. Am J Orthod. 1954;40(12):927–939. doi:10.1016/S0002-9416(54)90044-5.
10. Harvold EP, Chierici G, Vargervik K. Experiments on the development of dental malocclusions. Am J Orthod. 1972;61(1):38–44. doi:10.1016/0002-9416(72)90174-1.
11. Winders RV. Forces exerted on the dentition by the perioral and lingual musculature during swallowing. Angle Orthod. 1958;28(4):226–235.
12. Marşan G, Vasfi Kuvat S, Oztaş E, Cura N, Süsal Z, Emekli U. Oropharyngeal airway changes following bimaxillary surgery in Class III female adults. J Craniomaxillofac Surg. 2009;37(2):69–73. doi:10.1016/j.jcms.2008.11.001.
13. Partal I, Aksu M. Changes in lips, cheeks and tongue pressures after upper incisor protrusion in Class II division 2 malocclusion: a prospective study. Prog Orthod. 2017;18(1):29. doi:10.1186/s40510-017-0182-0.
14. Germec-Cakan D, Taner T, Akan S. Uvulo-glossopharyngeal dimensions in non-extraction, extraction with minimum anchorage, and extraction with maximum anchorage. Eur J Orthod. 2011;33(5):515–520. doi:10.1093/ejo/cjq109.
15. Valiathan M, El H, Hans MG, Palomo MJ. Effects of extraction versus non-extraction treatment on oropharyngeal airway volume. Angle Orthod. 2010;80(6):1068–1074. doi:10.2319/010810-19.1.
16. Ricketts RM. The keystone triad: I. Anatomy, phylogenetics, and clinical references. Am J Orthod. 1964;50(4):244–264. doi:10.1016/S0002-9416(64)80003-8.
17. Tweed CH. The Frankfort-mandibular plane angle in orthodontic diagnosis, classification, treatment planning, and prognosis. Am J Orthod Oral Surg. 1946;32:175–230.
18. Steiner CC. Orientation of Teeth in the Dental Arches. Angle Orthod. 1934;4(1):35–56.
19. Fröhlich K, Ingervall B, Thüer U. Further studies of the pressure from the tongue on the teeth in young adults. Eur J Orthod. 1992;14(3):229–239. doi:10.1093/ejo/14.3.229.
20. Al Maaitah E, El Said N, Abu Alhaija ES. First premolar extraction effects on upper airway dimension in bimaxillary proclination patients. Angle Orthod. 2012;82(5):853–859. doi:10.2319/101711-646.1.
21. Sims FW. The pressure exerted on the maxillary and mandibular central incisors by the perioral and lingual musculature in acceptable occlusion. Am J Orthod. 1958;44:64–65. doi:10.1016/s0002-9416(58)90185-4.

22. Subtelny JD, Sakuda M. Muscle function, oral malformation, and growth changes. Am J Orthod. 1966;52(7):495–517. doi:10.1016/0002-9416(66)90104-7.
23. Cohen AM, Vig PS. A serial growth study of the tongue and intermaxillary space. Angle Orthod. 1976;46(4):332–337.
24. Tuncer AV DS Işıksal E. Cephalometric Evaluation Of Tongue in Varıous Malocclusions. Turk J Orthod. 1991;4(2):1–8. doi:10.13076/1300-3550-4-2-1.
25. Peat JH. A cephalometric study of tongue position. Am J Orthod. 1968;54(5):339–351. doi:10.1016/0002-9416(68)90303-5.
26. Mustafa U. Chapter 11. In: Ortodontik tedavi prensipleri. Istanbul University; 1993. p. 161–196.
27. Bench RW. Growth of the cervical vertebrae as related to tongue, face, and denture behavior. Am J Orthod. 1963;49(3):183–214. doi:10.1016/0002-9416(63)90050-2.
28. Yamaoka M, Furusawa K, Uematsu T, Okafuji N, Kayamoto D, Kurihara S. Relationship of the hyoid bone and posterior surface of the tongue in prognathism and micrognathia. J Oral Rehabil. 2003;30(9):914–920. doi:10.1046/j.1365-2842.2003.01069.x.
29. Sharma K, Shrivastav S, Sharma N, Hotwani K, Murrell MD. Effects of first premolar extraction on airway dimensions in young adolescents: A retrospective cephalometric appraisal. Contemp Clin Dent. 2014;5(2):190–194. doi:https://doi.org/10.4103/0976-237X.132314.
30. Hopkin GB. Neonatal and adult tongue dimensions. Angle Orthod. 1967;37(2):132–133.
31. Abu Allhaija ES, Al-Khateeb SN. Uvulo-glosso-pharyngeal dimensions in different anteroposterior skeletal patterns. Angle Orthod. 2005;75(6):1012–1018.
32. Heiser W, Niederwanger A, Bancher B, Bittermann G, Neunteufel N, Kulmer S. Three-dimensional dental arch and palatal form changes after extraction and nonextraction treatment. Part 1. Arch length and area. Am J Orthod Dentofacial Orthop. 2004;126(1):71–81. doi:10.1016/j.ajodo.2003.05.015.
33. Heiser W, Niederwanger A, Bancher B, Bittermann G, Neunteufel N, Kulmer S. Three-dimensional dental arch and palatal form changes after extraction and nonextraction treatment. Part 2. Palatal volume and height. Am J Orthod Dentofacial Orthop. 2004;126(1):82–90. doi:10.1016/j.ajodo.2003.05.016.
34. Ozbek MM, Memikoglu UT, Altug-Atac AT, Lowe AA. Stability of maxillary expansion and tongue posture. Angle Orthod. 2009;79(2):214–220. doi:10.2319/010908-12.1.

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ORIGINAL RESEARCH ARTICLE

Comparative Analysis of the Accuracy of Dentate Complete-Arch Scans of Six Intraoral Scanners

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Abstract

Objective: This in vitro study aimed to evaluate the scan accuracy of 6 intraoral scanners (IOSs) by using a dentate model.
Methods: A maxillary dentate reference model was digitized with an industrial-grade blue light optical scanner to generate a reference standard tessellation language (STL) file. The same model was digitized by using 6 IOSs (TRIOS 4, TRIOS 3, Primescan, Omnicam, Emerald S, and Medit i700) (n=10) to generate test scan STLs. All STL files were imported into a 3-dimensional analysis software program (Geomagic Control X). Test scan STLs were superimposed over the reference STL by using the initial and best-fit alignments of the software program, and the deviations of the scans of IOS from that of the optical scanner were calculated with the root mean square (RMS) method. The average deviation method was used to define the precision of the scans. Kruskal-Wallis and Bonferroni tests were used to statistically evaluate the data (α=0.05).
Results: A significant difference was observed between groups in terms of RMS values ($p<0.001$). The Medit i700 and Primescan IOS systems had the lowest RMS values, respectively, indicating the highest trueness. No significant difference was observed between the groups in terms of precision. ($p=0.055$)
Conclusions: While differences were observed among the six intraoral scanners, the accuracy of the selected IOSs remained within the clinically acceptable ranges. The Medit i700 and Primescan IOS exhibited a higher level of precision in comparison to the other devices. The accuracy of the scanner should be assessed, taking into account clinician, patient, and IOS dependent variables.

Keywords: Digital impression; Intraoral scanner; 3D analysis

Introduction

An exact replication of the intraoral environment, represented in a precise definitive cast, is a crucial precondition for ensuring the sustained success of prosthodontic treatment.[1,2] The factors influencing the accuracy of definitive casts have been extensively researched.[3–5]

Numerous studies have examined the impact of factors such as impression materials, impression techniques, tray selection, die materials, and removable die systems on cast accuracy. It's been observed that nearly every material and method used in the production process of definitive casts can be linked to some form of dimensional alteration.[5] The digital workflow mitigates the need for impression procedures, disinfection, and definitive cast fabrication, which are conventional methods often leading to dimensional changes in the definitive casts.[6,7]

The digital workflow comprises three primary stages: the collection of data (either directly or indirectly), restoration design, and the manufacturing process.[8,9] The data acquisition phase uses two varieties of scanners: intraoral and extraoral. Intraoral scanners are specifically utilized for digitizing patient arches chairside.[10,11]

Using an intraoral scanner (IOS) over traditional impression methods offers numerous benefits. These include a decrease in patient discomfort, particularly for those with a pronounced gag reflex, and the elimination of casting and storage processes. Furthermore, IOS promotes more straightforward patient communication and facilitates speedier, cost-effective interaction between the dental clinic and laboratory technician.[12–16]

At present, various intraoral scanners have been launched and are being utilized in clinical conditions.[2,17] So far, intraoral scanners have been used for creating study models, detecting impressions required for designing and producing a range of restorations

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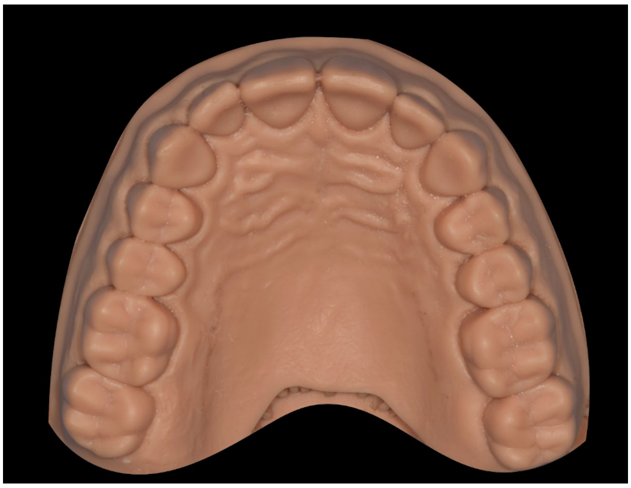

Figure 1. The master model

(including single crowns, fixed partial dentures, and in certain cases, complete fixed arches), and for surgical applications (incorporated into acquisition procedures for guided surgery). They are also used in orthodontics for fabricating aligners and various customized orthodontic devices.[12]

Indeed, the accuracy of an intraoral scanner, as a blend of trueness and precision, is a critical feature. As defined by the International Standard Organization (ISO) 5725:1[18], trueness refers to the 'degree of alignment between the arithmetic mean of a large number of test outcomes and the true or acknowledged reference value.' Meanwhile, precision is understood as 'the degree of concurrence between varied test results.' Both accuracy and precision are vital for achieving a satisfactory digital scan, leading to an exceptional final product.[19]

Currently, advanced scanning technologies are in use, encompassing methodologies such as the triangulation technique, active wavefront sampling, and confocal scanning technique.[20,21]

Different scanning settings are recommended by the manufacturers, and the choice of scanning technique can often depend on the operator's preferences. With the evolving advancements in intraoral 3D scanning technology, assessing the scanning accuracy of different IOSs available in the market becomes a matter of importance. Consequently, this in vitro study sets out to explore the accuracy of six such scanners. The null hypothesis was that IOS type would not affect the accuracy (trueness and precision) of dentate maxillary arch scans.

Material and Methods

This study does not contain human participants or animals by any authors. Therefore, this type of study does not require ethics committee and consent form information. To assess the accuracy of complete arch measurements across six different intraoral scanners, a standard full-dentate maxillary model (KaVo Dental, Biberach, Germany) was selected as the master model. The master model was produced by using a 3-dimensional (3D) printer using SLA technology (Form 3; Formlabs) and Model V2 Resin (Formlabs) material (Figure 1). All 3D printing procedures were performed following the manufacturer's instructions. After production, the 3D-printed master model was stored in a light-impermeable container for 24 hours before the scanning procedures commenced.

After a thin layer of (2 µm) antireflective spray was applied, the model was scanned by using an industrial-grade blue light optical scanner (RS) (ATOS Core 80 5MP; GOM GmbH, Braunschweig, Germany), a device that leverages stereo camera-based triangulation (1 µm probing error form, 3 µm probing error size, 5 µm sphere spacing error, and 7 µm length measurement error). Prior to the study, RS was calibrated using a calibration panel (GOM Inspect; GOM, Braunschweig, Germany GOM Tip/SN CP40/200/100846). It was then scanned by using the RS (RS-STL).

In this study, six intraoral scanners, listed in Table 1 for models and characteristics, were scanned from the reference model using a dark environment with no direct light to replicate the intraoral region. The IOSs were calibrated according to the respective manufacturer's instructions before the measurements and then repeated 10 times for each IOS according to the manufacturer's instructions. Ten scans of data from each scanner were exported and saved in standard tessellation language (STL) file format (IOS-STLs). All scanning procedures were performed by an experienced operator (M.D.) in the field.

All STL files (RS-STL and IOS STLs) were imported into a 3D analysis software program (Geomagic Control X; 3D Systems). The reference STL was imported as the reference data and the "auto segment" feature of the "region tool" of the software program was used to automatically segment the entire dental arch. Automatically segmented regions on the dental arch were then merged by using the "merge" feature of the "region tool". Then, IOS scan STLs (IOS-STLs) were superimposed over the reference STL (RS-STLs) with initial alignment and local best-fit alignment tools of the software program to evaluate the trueness. After superimpositions, the "3D Compare" tool of the software program was used to generate color maps for qualitative evaluation (maximum-minimum deviations: ± 100 µm, tolerance range: ± 10 µm), and the deviations of were automatically calculated by using the root-mean-square method. The software program (Geomagic Control X; 3D Systems) was used to generate color maps with red representing overcontoured surfaces, blue representing undercontoured surfaces, and green representing acceptable deviations. Figure 2

Statistical analysis

An a priori power analysis was carried out to determine the number of specimens in each group and found that 3 specimens were sufficient ($f=1.23$, $1-\beta=95\%$, $\alpha=.05$)[22]. However, 10 scans per group were performed to increase statistical power. The normality was assessed by using the Shapiro-Wilks test. Given that normality was refuted, Kruskal-Wallis and Bonferroni tests were used to evaluate RMS values. Precision was defined as the average deviation and further analyzed by using the same analyzes. All analyzes were conducted by using a statistical analysis software program (SPSS v20, IBM Corp., Chicago, IL, USA) with a confidence level of 95%.

Results

The trueness of different scanning technologies is reflected in Table 2. The Medit i700 and Primescan IOS systems had the highest trueness and lowest RMS, respectively. However, there was no significant difference found between the trueness of the Medit i700 and Primescan ($p=0.854$). TRIOS 4 had similar results to TRIOS 3 ($p=0.186$), Omnicam ($p=0.997$) and Emerald S ($p=1.000$).

Table 3 provides a comparison of precision values across different scanning technologies. The Omnicam IOS system exhibited the lowest precision value, although this difference was statistically insignificant when compared to other systems ($p=0.055$). The only exception to this observation was the difference between the TRIOS 4 and Omnicam systems, where the difference in precision was significant. ($p=0.046$).

Discussion

As a result of this study, significant differences were observed in both trueness and precision among the different IOSs. Therefore,

Table 1. Models and features of intraoral scanners used in the study

IOS	Version	Manufacturer	Scanning Technology	Source of Light	Working Principle
Emerald S	**Romexis 6.4**	Planmeca	Partial Triangulation	Red Green Blue Laser	Multi-imaging, Video
Medit i700	**Medit Link 3.3.2**	Medit	Optical Triangulation	Visible Light	Quick video viewing
Omnicam	**CEREC 5.2.7**	Dentsply Sirona	Active Triangulation	Visible Light	Multi-imaging, Video
Primescan	**CEREC 5.2.7**	Dentsply Sirona	Active Triangulation	Blue Led Technology	Multi Image
TRIOS 4	**TRIOS 23.1**	3Shape	Confocal Microscopy	Light Laser and Led Reference	Multi Image
TRIOS 3	**TRIOS 23.1**	3Shape	Confocal Microscopy	Light Laser and Led Reference	Multi Image

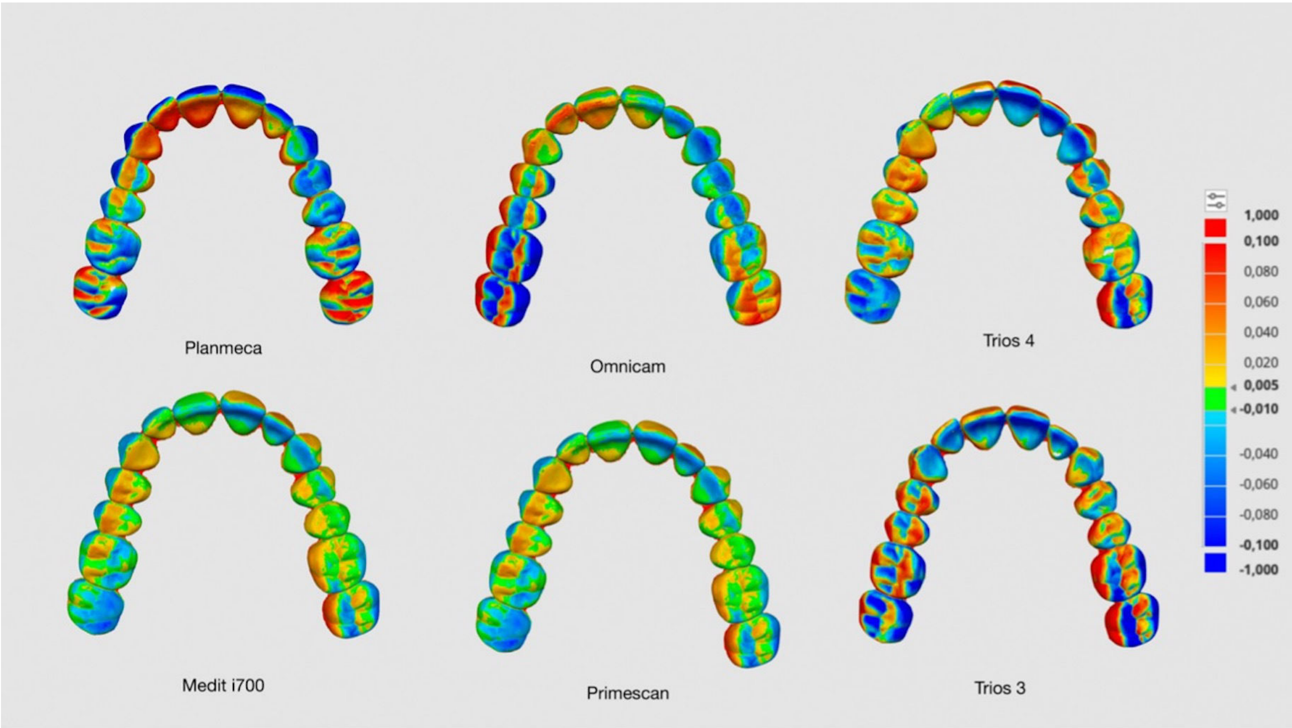

Figure 2. Color-coded maps obtained with different IOSs. Yellow-red colors show expansions, while light blue-dark blue areas show contractions.

Table 2. Trueness findings of the measurements obtained with different intraoral scanners

IOS	Median^X	Std. Deviation	Minimum	Maximum
TRIOS 4	74.00^b	14.32	68.00	105.00
TRIOS 3	92.00^b	7.98	83.00	106.00
Primescan	58.00^a	4.96	50.00	63.00
Omnicam	74.00^a	4.68	69.00	81.00
Emerald S	76.00^b	8.90	73.00	95.00
Medit i700	55.00^a	6.42	43.00	61.00

*Different superscript uppercase letters indicate significant differences among study groups(**P<.05**).

Table 3. Precision findings of the measurements obtained with different intraoral scanners

IOS	Median	Std. Deviation	Minimum	Maximum
TRIOS4	10.00	7.82	1.00	24.00
TRIOS3	3.00	4.59	2.00	12.00
Primescan	4.00	2.25	1.00	7.00
Omnicam	4.00	2.10	1.00	7.00
Emerald S	8.00	3.30	5.00	14.00
Medit i700	3.00	3.36	2.00	10.00

*Absence of different letters on the median values indicates that there is no significant difference between the groups ($P \geq .05$).

the study's null hypothesis, presuming no significant differences among the IOSs, was rejected. The intraoral scanners evaluated in this study are not only extensively employed within the dental field, but they also represent the pinnacle of standards achievable with the current generation of intraoral scanner technology. Evaluating the accuracy of complete arch scans is critical, as situations requiring the fabrication of longer-span or full-arch fixed partial dentures are a common occurrence in dental practice.[23]

This study utilized a reference dataset derived from an industrial high-accuracy scanner and implemented a best-fit alignment method to evaluate and interpret the spatial discrepancies between different datasets. Trueness was computed via RMS values, while precision was determined through the standard deviation of this superimposition. Notably, all the IOSs tested displayed an accuracy within the clinically acceptable limits (below 120 µm), with values ranging from 55.0 µm to 92.0 µm.[23,24] Given the differences in the (trueness) variables tested and the IOSs used across various studies, making a direct comparison can prove to be challenging. Variations in the accuracy of different intraoral scanners (IOSs) have been well-documented in prior research.[25,26] Most studies that have evaluated the accuracy of optical impression systems were performed in vitro.[27–29]

Schmalzl et al.[23] utilized TRIOS 3 and TRIOS 4, which have 2 different software from 2 different years, for complete arch scans. The study revealed that the trueness values varied substantially. For TRIOS 3, the range between years was found to be 47.44±9.17 µm up to 90.24±15.35 µm. As for TRIOS 4, the trueness values were somewhat lower, ranging between years from 31.06±5.24 µm to 52.91±7.44 µm. Importantly, these variations were linked to the different software versions of the intraoral scanners.[23] The values obtained from this research aligned closely with the findings of the aforementioned study.

In the research conducted by Medina-Sotomayor et al.[24], the observed accuracy values in the complete arch model varied notably. They found these values to range from 32.1±13.7 µm to as high as 98.3±14 µm. Meanwhile, the precision values in the same model also exhibited a substantial range, from 98.8±40.4 µm to 261.8±32.6 µm.[24]

In a similar research, Malik et al.[30] conducted a study using a maxillary model, during which they compared two IOSs. Their research findings indicated a variation in the trueness values: for Omnicam, the trueness value was 80.3±12.1 µm, whereas, for the TRIOS 3, it was slightly higher at 87.1±7.9 µm.[30]

Atieh et al.[27] used a mandibular complete arch master model in their study and determined the trueness of the Omnicam to be 46.2±11.4 µm. However, their selection of two molar, premolar, and two incisor teeth for deviation analysis may explain the relatively lower trueness values reported in their research.[27] In a study by Luthardt et al.[31], the researchers identified a mean deviation, or trueness, of 27.9 µm for three teeth, a figure derived through root mean square (RMS) error computation.[31] Another investigation by Mehl et al. reported trueness of 14.3 µm for Bluecam.[32]

In further research, Ender et al.[33] evaluated the trueness of seven different intraoral scanners (IOSs) on a quadrant arch. They discovered that the Lava True Definition scanner had a trueness value of 21.7±7.4 µm, the Lava COS was at 47.7±16.1µm, and the Cadent iTero exhibited 49.0±12.4 µm. For the TRIOS and TRIOS Color scanners, the trueness values were 25.7±4.9 µm and 26.1±3.8 µm, respectively. The CEREC Bluecam, depending on the software version, showed 34.2±10.5 µm for Software 4.0, and 43.3±19.6 µm for Software 4.2. Lastly, the CEREC Omnicam demonstrated a trueness value of 37.4±8.1 µm.[33]

The color-coded maps provide a revealing picture of the performance of different scanners. Emerald primarily exhibits contractions on the buccal sides of the teeth. In contrast, Omnicam demonstrates contraction on the occlusal and lingual surfaces of molars and premolars, while a slight expansion is observed on the buccal sides of these same teeth. TRIOS 3 reveals a deviation pattern similar to that of Emerald S. TRIOS 4, on the other hand, performs slightly better than both Emerald S and TRIOS 3. Primescan and Medit i700 stand out with their lower contraction and expansion levels compared to the other scanners. It's also important to note that the green surfaces on the maps indicate deviations ranging ±10 µm.

In this study, no significant difference was found between the precisions of different IOS. In a similar recent study, six different IOS were evaluated, among them TRIOS 3, Omnicam, Primescan, and Emerald S, similar to the presented study. Researchers have reported that there is no difference between the precision values of different scanners, which is consistent with our study. However, in another study, it was reported that the sensitivity of TRIOS 3 was higher when comparing IOSs, including TRIOS 3 and Emerald S. This may be due to the fact that scans are performed under different conditions, operator-related factors, and differences in dental models. Furthermore, the use of IOSs was found to be more susceptible to errors when measuring longer distances compared to shorter ones.[30,34] Notably, these disparities are often statistically significant, making their underlying causes difficult to pinpoint. Factors potentially impacting accuracy can include the inherent measurement sensitivity of the IOS, image construction techniques, the software algorithm used in the 3D rendering process, the selected scanning protocol, and any bias introduced by the operator.[26]

In this study, the manufacturer-recommended scanning paths were adhered to for each respective IOS, with no alternative scanning paths being evaluated. Previous in vitro research has suggested that the scanning path does not significantly affect the accuracy of quadrant scans. However, it has been observed that the accuracy of complete-arch scans can be dependent on the scanning path. Furthermore, manufacturer guidelines have been found to produce better outcomes than individualized scanning protocols.[35,36]

Different factors can influence the accuracy of IOSs, including intraoral conditions (such as temperature, relative humidity, and lighting), the skill and scanning pattern of the operator, characteristics of the scanner unit (scanning head, light source, and receiver), the speed/up-to-date of the computer software, and the specifics of the scanning area (anterior/posterior, scan length, area, and surface characteristics).[18,35]

Our in vitro study to evaluate IOS accuracy has some limitations. These restrictions include the inability to fully imitate intraoral conditions such as saliva, limited mouth opening, intraoral light environment, patient's jaw mobility, and contrast color difference due to teeth and gums.

Future research should explore the exact location of the prepared teeth or implant being scanned, with a focus on developing a standardized method for the evaluation and comparison of various digital scanning systems. In addition, performance under in vivo conditions should be assessed for a more comprehensive understanding.

Conclusion

While trueness varied across all the scanners studied, precision displayed pleasing consistency. Notably, the Medit i700 and Primescan IOS outperformed others in terms of trueness, a difference that was statistically significant ($p<0.05$). Despite the observed differences among the six IOSs, the trueness of the selected scanners was within clinically acceptable limits. However, the choice of scanner extends beyond accuracy and should take into account factors like scanning time, scan head size, and user learning curve. Lastly, it's important to consider that while accuracy is important, it's not the only factor that determines the utility of an intraoral scanner. Ease of use, patient comfort, integration with other dental software, and cost are also significant considerations.

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

1. Chandran DT, Jagger DC, Jagger RG, Barbour ME. Two- and three-dimensional accuracy of dental impression materials: effects of storage time and moisture contamination. Biomed Mater Eng. 2010;20(5):243–249. doi:10.3233/bme-2010-0638.
2. Seo K, Kim S. A new method to evaluate trueness and precision of digital and conventional impression techniques for complete dental arch. Appl Sci. 2021;11(10):4612. doi:10.3390/app11104612.
3. Damodara EK, Litaker MS, Rahemtulla F, McCracken MS. A randomized clinical trial to compare diagnostic casts made using plastic and metal trays. J Prosthet Dent. 2010;104(6):364–371. doi:10.1016/s0022-3913(10)60167-9.
4. DeLong R, Heinzen M, Hodges JS, Ko CC, Douglas WH. Accuracy of a system for creating 3D computer models of dental arches. J Dent Res. 2003;82(6):438–442. doi:10.1177/154405910308200607.
5. Emir F, Piskin B, Sipahi C. Effect of dental technician disparities on the 3-dimensional accuracy of definitive casts. J Prosthet Dent. 2017;117(3):410–418. doi:10.1016/j.prosdent.2016.06.008.
6. Mandelli F, Gherlone E, Gastaldi G, Ferrari M. Evaluation of the accuracy of extraoral laboratory scanners with a single-tooth abutment model: A 3D analysis. JPR. 2017;61(4):363–370. doi:10.1016/j.jpor.2016.09.002.
7. Ting-shu S, Jian S. Intraoral digital impression technique: a review. J Prosthodont. 2015;24(4):313–321. doi:10.1111/jopr.12218.
8. Shimizu S, Shinya A, Kuroda S, Gomi H. The accuracy of the CAD system using intraoral and extraoral scanners for designing of fixed dental prostheses. Dent Mater J. 2017;36(4):402–407. doi:10.4012/dmj.2016-326.
9. Vandeweghe S, Vervack V, Vanhove C, Dierens M, Jimbo R, De Bruyn H. Accuracy of optical dental digitizers: an in vitro study. IJPRD. 2015;35(1):115–121. doi:10.11607/prd.2185.
10. Bohner LOL, Canto GDL, Marció BS, Laganá DC, Sesma N, Neto PT. Computer-aided analysis of digital dental impressions obtained from intraoral and extraoral scanners. J Prosthet Dent. 2017;118(5):617–623. doi:10.1016/j.prosdent.2016.11.018.
11. de Villaumbrosia PG, Martínez-Rus F, García-Orejas A, Salido MP, Pradíes G. In vitro comparison of the accuracy (trueness and precision) of six extraoral dental scanners with different scanning technologies. J Prosthet Dent. 2016;116(4):543–550. e1. doi:10.1016/j.prosdent.2016.01.025.
12. Imburgia M, Logozzo S, Hauschild U, Veronesi G, Mangano C, Mangano FG. Accuracy of four intraoral scanners in oral implantology: a comparative in vitro study. BMC oral health. 2017;17:1–13. doi:10.1186/s12903-017-0383-4.
13. Kuhr F, Schmidt A, Rehmann P, Wöstmann B. A new method for assessing the accuracy of full arch impressions in patients. J Dent. 2016;55:68–74. doi:10.1016/j.jdent.2016.10.002.
14. Park HR, Park JM, Chun YS, Lee KN, Kim M. Changes in views on digital intraoral scanners among dental hygienists after training in digital impression taking. BMC oral health. 2015;15:1–7. doi:10.1186/s12903-015-0140-5.
15. Rutkūnas V, Gečiauskaitė A, Jegelevičius D, Vaitiekūnas M. Accuracy of digital implant impressions with intraoral scanners. A systematic review. Eur J Oral Implantol. 2017;10(Suppl 1):101–120.
16. Stefanelli LV, Franchina A, Pranno A, Pellegrino G, Ferri A, Pranno N, et al. Use of intraoral scanners for full dental arches: could different strategies or overlapping software affect accuracy? IJERPH. 2021;18(19):9946. doi:10.3390/ijerph18199946.
17. Amornvit P, Rokaya D, Sanohkan S. Comparison of accuracy of current ten intraoral scanners. Biomed Res Int. 2021;2021(1):2673040. doi:10.1155/2021/2673040.
18. ISO. Accuracy (trueness and precision) of measurement methods and results—part 1: General principles and definitions. ISO. 1994.
19. Giuliodori G, Rappelli G, Aquilanti L. Intraoral scans of full dental arches: An in vitro measurement study of the accuracy of different intraoral scanners. IJERPH. 2023;20(6):4776. doi:10.3390/ijerph20064776.
20. Mangano F, Gandolfi A, Luongo G, Logozzo S. Intraoral scanners in dentistry: a review of the current literature. BMC oral health. 2017;17:1–11. doi:10.1186/s12903-017-0442-x.
21. Renne W, Ludlow M, Fryml J, Schurch Z, Mennito A, Kessler R, et al. Evaluation of the accuracy of 7 digital scanners: An in vitro analysis based on 3-dimensional comparisons. J Prosthet Dent. 2017;118(1):36–42. doi:10.1016/j.prosdent.2016.09.024.
22. Wang X, Zhang F, Ma D, Ye X, Zheng X, Ren R, et al. Evaluation of the accuracy of seven intraoral scanners for the full dentate and partially edentulous complete-arch mandibular casts: An in vitro comparison. Heliyon. 2024;10(10):e31063. doi:10.1016/j.heliyon.2024.e31063.
23. Schmalzl J, Róth I, Borbély J, Hermann P, Vecsei B. The impact of software updates on accuracy of intraoral scanners. BMC Oral Health. 2023;23(1):219. doi:10.1186/s12903-023-02926-y.
24. Medina-Sotomayor P, Pascual-Moscardo A, Camps I. Accuracy of 4 digital scanning systems on prepared teeth digitally isolated from a complete dental arch. J Prosthet Dent. 2019;121(5):811–820. doi:10.1016/j.prosdent.2018.08.020.
25. Nedelcu R, Olsson P, Nyström I, Rydén J, Thor A. Accuracy and precision of 3 intraoral scanners and accuracy of conventional impressions: A novel in vivo analysis method. J Dent. 2018;69:110–118. doi:10.1016/j.jdent.2017.12.006.
26. Winkler J, Gkantidis N. Trueness and precision of intraoral scanners in the maxillary dental arch: an in vivo analysis. Sci Rep. 2020;10(1):1172. doi:10.1038/s41598-020-58075-7.
27. Atieh MA, Ritter AV, Ko CC, Duqum I. Accuracy evaluation of intraoral optical impressions: a clinical study using a reference appliance. J Prosthet Dent. 2017;118(3):400–405. doi:10.1016/j.prosdent.2016.10.022.
28. Ender A, Mehl A. In-vitro evaluation of the accuracy of conventional and digital methods of obtaining full-arch dental impressions. Quintessence Int. 2015;46(1):9–17. doi:10.3290/j.qi.a32244.
29. Güth JF, Keul C, Stimmelmayr M, Beuer F, Edelhoff D. Accuracy of digital models obtained by direct and indirect data capturing. Clin Oral Investig. 2013;17:1201–1208. doi:10.1007/s00784-012-0795-0.
30. Malik J, Rodriguez J, Weisbloom M, Petridis H. Comparison of accuracy between a conventional and two digital intraoral impression techniques. Int J Prosthodont. 2018;31(3):107–113. doi:10.11607/ijp.5643.
31. Luthardt R, Loos R, Quaas S. Accuracy of intraoral data acquisition in comparison to the conventional impression. Int J Comput Dent. 2005;8(4):283–294.
32. Mehl A, Ender A, Mörmann W, Attin T. Accuracy testing of a new intraoral 3D camera. Int J Comput Dent. 2009;12(1):11–28. doi:10.5167/uzh-18814.
33. Ender A, Zimmermann M, Attin T, Mehl A. In vivo precision

of conventional and digital methods for obtaining quadrant dental impressions. Clin Oral Investig. 2016;20:1495–1504. doi:10.1007/s00784-015-1641-y.

34. Kaewbuasa N, Ongthiemsak C. Effect of different arch widths on the accuracy of three intraoral scanners. J Adv Prosthodont. 2021;13(4):205. doi:10.4047/jap.2021.13.4.205.

35. Kernen F, Schlager S, Alvarez VS, Mehrhof J, Vach K, Kohal R, et al. Accuracy of intraoral scans: An in vivo study of different scanning devices. J Prosthet Dent. 2022;128(6):1303–1309. doi:10.1016/j.prosdent.2021.03.007.

36. Latham J, Ludlow M, Mennito A, Kelly A, Evans Z, Renne W. Effect of scan pattern on complete-arch scans with 4 digital scanners. J Prosthet Dent. 2020;123(1):85–95. doi:10.1016/j.prosdent.2019.02.008.

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ORIGINAL RESEARCH ARTICLE

Comparative Analysis of Data Efficiency Between Conventional Periapical Radiography and Digital Subtraction Radiography in Chronic Periodontitis Patients

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Abstract

Purpose: Advancements in technology have driven a shift towards digital techniques alongside conventional screening methods in dental radiology and across medical disciplines. This study aims to compare the efficacy of two radiographic techniques, periapical radiography and digital subtraction radiography, in assessing bone recovery processes.
Materials and Methods: Sixty mandibular premolar and molar regions in eighteen chronic periodontitis patients undergoing flap surgery were examined pre- and post-operatively using both periapical radiographs and digital subtraction radiography. Periodontal surgery outcomes were monitored by recording periodontal index, pocket depth, and gingival recession preoperatively (baseline) and at the 3rd and 6th months postoperatively. Standardized parallel periapical radiographs and via digital subtraction radiography images were analyzed by different observers to evaluate changes in alveolar bones and assess surgical outcomes.
Results: Results showed significant reductions in index values and pocket depths, along with an increase in gingival recession. Intraobserver consistency was found to be good and fair, while interobserver consistency was poor across the 0-3, 3-6, and 0-6 month periods. Radiographic evaluation demonstrated a statistically significant increase in digital subtraction radiography data compared to conventional radiography in defect recovery throughout the follow-up period.
Conclusions: This study demonstrated that the digital subtraction radiography technique is more efficient in detecting minimal changes in mineralised tissues that cannot be clearly traced by conventional radiographic techniques.

Keywords: Chronic Periodontitis; Dental; Digital substraction; Radiography

Introduction

Periodontal diseases, characterized by progressive destruction of periodontal supporting tissues, are among the most common inflammatory diseases in society, caused by certain microorganisms present in the oral cavity.[1–3] The level and mineral density of alveolar bone are maintained by a balance between bone formation and resorption regulated by local and systemic factors. Disruption of the balance between the host and microorganisms can lead to a situation where bone resorption exceeds bone formation, resulting in a decrease in bone height and/or density.[4]

Early diagnosis, monitoring, and evaluation of treatment outcomes play a crucial role in improving the clinical outcomes of periodontal disease.[2] In the context of periodontal diseases, radiographic methods are often used in addition to clinical methods to determine the presence and extent of bone loss. However, radiographs may not detect small amounts of alveolar bone loss.[5] Gröndahl et al.[6] reported that radiographs are insufficient for diagnosing early-stage periodontal diseases and measuring bone defect amounts in the buccal and lingual regions of teeth. Long-term follow-up of periodontal diseases is crucial for determining the disease progression. However, there are debates regarding the ability of radiographs to accurately detect small lesions with clinical significance.[7] Van der Stelt et al.[8] argued that there may be limitations in detecting small bone lesions due to structural noise in periapical radiographs, which could affect the visual detection of anatomical structures with

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diagnostic importance.Despite these limitations, radiographs are valuable for periodontal diagnosis. However, to enable radiographic follow-up in long-term studies, standard imaging conditions must be repeatable. Many researchers working on periodontal disease have addressed this issue by using devices to stabilize the X-ray tube, object, and film for evaluations at different times in the same patient.[9,10] Nowadays, in addition to methodological repeatability, three-dimensional imaging techniques, computer programs, and artificial intelligence applications have been introduced to track changes in alveolar bone level and density over time.[1,11,12] One of the image evaluation techniques used to detect changes in alveolar bone level and density is digital subtraction technique.

Digital subtraction radiography (DSR) is one of the methods that enhances the detectability of existing bone changes by aligning and subtracting images obtained at different times, thereby eliminating structural noise observed on radiographs.[13] DSR minimizes distractions from background images, enabling the eye to perceive actual changes between two images, facilitating the detection of early mineral changes in tissues and their monitoring.[9]

The purpose of this study is to monitor bone healing using the DSR technique after periodontal flap surgery in cases of chronic periodontitis with vertical bone defects and to compare the effectiveness of this technique with radiographic data. Additionally, the study aims to determine the extent to which the DSR technique is effective for routine clinical applications.

Material and Methods

Study Population

The study was conducted in accordance with the principles outlined in the Declaration of Helsinki and received approval from the Ethics Committee of Medical, Surgical and Pharmaceutical Research at Hacettepe University (IRB Approval No: LUT04/65, 2005). Informed consent was obtained from all participants after detailed explanation of the diagnostic, treatment, and follow-up procedures.

The study included 18 patients aged 18-60 years diagnosed with chronic periodontal disease at the Department of Oral Diagnosis and Radiology, Faculty of Dentistry, Hacettepe University who were scheduled for flap surgery. Patients with no systemic diseases affecting bone metabolism, diagnosed with chronic periodontal disease, and who had undergone initial periodontal treatment were included in the study. Due to ease of radiographic visualization and indication for flap surgery, teeth with vertical bone defects classified as subclasses B (4–6 mm) and C (7 mm and greater) according to Tarnow and Fletcher's[14] classification were followed. The use of parallel technique for radiography was preferred for its importance in detecting alveolar bone defect sizes and monitoring bone development after flap surgery.[15]

Periodontal Treatment Procedure

Periodontal pocket depth (PD) and gingival recession (GR) were assessed preoperatively and at the 3rd and 6th months postoperatively to evaluate the periodontal health of the patients. Gingival index (GI), plaque index (PI), and bleeding indexes (BI) were recorded with reference to maxillary right molars, left central and premolars, mandibular right central and premolars, and left molars before surgery to assess overall periodontal status.[4] Patients diagnosed with chronic periodontitis underwent oral hygiene education and scaling procedures at the Department of Periodontology. Oral hygiene status of the patients was monitored for 4 weeks, and all patients were deemed ready for periodontal flap surgery. Flap surgeries were performed under local anesthesia in the mandibular premolar and molar regions planned for the study. After sulcular incisions, full-thickness periodontal flaps were raised, followed by subgingival scaling and root planing. No resective bone surgery was performed. Patients were recalled for suture removal after one week, and no postoperative complications were observed. Treatments in areas outside the scope of the research design were completed over time.

Radiographic Imaging Procedure

Periapical radiographs of the periodontal surgical sites were obtained by the same operator at the preoperative, 3rd, and 6th postoperative months. All imaging and processing conditions were standardized to avoid any limitations in evaluating and analyzing radiographs. The parallel technique was used for imaging to ensure standardization and minimize distortion. A total of 180 periapical radiographs obtained from 60 sites (before and 3rd and 6th months after surgery) were obtained in the Department of Oral Diagnosis and Radiology using a Gendex (Kavo Dental Co., Lake Zurich, IL) periapical X-ray machine, Kodak ektaspeed film (Eastman Kodak Co., Rochester, NY, EUA), 80 KVp, 10 mA, 0.34 s exposure time. A 40 cm long cone was used to fix the focal spot object distance and to apply the parallel technique correctly. XCP (Dentsply Rinn Co., Elgin, Ill) film holders were used to place the film in the patient's mouth in the same position each time and to keep the object-film distance constant. In order to ensure consistent biting from the same position and occlusal closure during all examinations, occlusal stents were prepared using cold resin material (Dentalon Plus, Kulzer GmbH, Germany) for the patients.[16] These stents, obtained during preoperative imaging, were disinfected and stored for use in the 3rd and 6th-month follow-up imaging sessions.[17] Following the completion of preoperative and postoperative 3rd and 6th month imaging, all films were processed under identical and optimal conditions using a Dürr Dental DL 24 automatic developing device (Dürr Dental GmbH & Co. KG. Bietigheim-Bissingen). Subsequently, radiographs were digitized at 300 dpi with 8-bit resolution using an Epson Expression 10000XL (Epson, USA) scanner equipped with a high-resolution transparency unit, and saved in Tagged Image File Format (TIFF).[18–20] Efforts were made to standardize factors potentially impacting density, contrast, and geometry of the pre- and post-operative radiographs.

Image Processing Procedure:

To detect alveolar bone changes in radiographs obtained from surgically treated areas, digital subtraction processing was applied between preoperative (0) and 3-month follow-up radiographs, between 0 and 6-month follow-up radiographs, and between 3 and 6-month follow-up radiographs using Emago Advanced Diagnostic Radiography 2006 version 5.0 (Oral Diagnostic Systems, Amsterdam, Netherlands). Although imaging conditions were standardized, an advanced subtraction process was preferred to eliminate minor angular and density differences.[11,12,21,22] In the subtraction process, corresponding pixels in radiographs with the same imaging geometry and density were subtracted from each other. As a result, areas with the same grayscale value in both images appeared empty, while regions with different pixel values appeared lighter or darker. After the subtraction process, dark areas indicated material loss in the follow-up image, whereas light areas indicated material gain (Figure 1).

The radiographs included in the study and the obtained subtraction images were evaluated by an expert radiologist (Y.Y.) with 30 years of experience and an expert periodontologist (X.X.) with 15 years of experience in terms of alveolar bone change amounts in the flap-operated areas, based on three parameters: "alveolar bone loss present", "no change in the alveolar bone", and "alveolar bone gain present" Evaluators were blinded to the time period and patient identity of the images. These assessments were repeated one month later to determine intra-observer consistency.

Intra-observer and inter-observer consistency were tested with radiographs and subtraction images.

Bone changes in the periodontal surgical areas were quantitatively evaluated as pixel grayscale values through histogram measurements on subtraction images.[19] For measurement, three points from the base of the bone defect, one point from the top, and one control point unrelated to the surgical area were selected, and pixel grayscale values were measured. The average grayscale value of the four regions obtained from the periodontal bone defect area (average of 4 test points (ATP)) was calculated. Ensuring that the selected points corresponded to the same point in all subtraction images was achieved using a millimeteric transparent grid placed on the computer screen. The grayscale value of the region identified as the control point (CP) on the subtraction image was subtracted from the average grayscale value of the surgical area and used as a parameter for radiographic density change.[19]

Statistical analysis

In the general oral and periodontal surgical areas, parameters PD, GR, GI, PI, and BI were collected to assess and follow up on the periodontal status throughout the treatment duration. Statistical analysis of these parameters was conducted using the Friedman Test. The changes in the same parameters within 0-3 months, 3-6 months, and 0-6 months intervals were evaluated using the Wilcoxon Signed Rank test. Data obtained from radiographs and subtraction images of sixty periodontal bone defect sites, through observer assessments, were assessed for inter-observer and intra-observer consistency using Kappa statistical analysis. According to Kappa analysis, a κ value ranging from 0.81 to 1.00 indicates excellent agreement, 0.61 to 0.80 indicates good agreement, 0.41 to 0.60 indicates moderate agreement, 0.21 to 0.40 indicates weak agreement, and $\kappa < 0.20$ indicates poor agreement.[23] Spearsman's rho test was employed to examine the relationship between the first and second assessments of the observers and inter-observer assessments. The change in the grayscale values obtained from the subtraction images of periodontal surgery sites over time was statistically analysed by Student paired-t test. Furthermore, Spearman's rho test was utilized to evaluate the statistical relationship between the measurement averages of periodontal defect fillings over time and observer assessments.

Results

The changes in gingival index (GI), plaque index (PI), periodontal pocket depth (PD), gingival recession (GR), and bleeding index (BI) evaluations performed to determine the periodontal health of patients before and at 3rd and 6th months after treatment within time periods are presented in Table 1, while the statistical information indicating the changes in time intervals is shown in Table 2. A statistically significant decrease was observed in GI and PD values during follow-up examinations ($p \leq 0.001$). However, there was a non-significant decrease in PI values ($p>0.05$). When GR was evaluated, a statistically significant decrease was detected between 0-3 and 3-6 month controls ($p<0.05$), but the amount of recession observed between 0-6 months was not significant ($p>0.05$). No statistically significant changes were observed in BI across all time intervals ($p>0.05$).

Descriptive statistical analysis regarding the assessment of areas with periodontal bone defects by observers is presented in Table 3.

One hundred and eighty radiographs and subtraction images obtained from sixty periodontal surgical sites were visually evaluated by an dentomaxillofacial radiology specialist (1G) and a periodontology specialist (2G). The intra- and inter-observer consistencies of observers were tested using Kappa analysis, and the κ values are shown in Table 4. In the evaluation of radiographs, moderate intra-observer consistency ($0.40<\kappa<0.60$) was observed for the 1st observer and good consistency ($0.61<\kappa<0.80$) for the 2nd Observer across 0-3, 3-6, and 0-6 month periods. However, inter-observer consistency was weak ($\kappa<0.40$) in both readings. In the evaluation of subtraction images, good intra-observer consistency ($0.61<\kappa<0.80$) was found for the 1st observer, while moderate consistency ($0.40<\kappa<0.60$) was observed for the 2nd observer. Inter-observer consistency was weak ($\kappa<0.40$) in the 1st reading and moderate ($0.40<\kappa<0.60$) in the 0-6 month period in the 2nd reading (Table 4).

Table 1. Changes in Gingival Index, Plaque Index, Periodontal Pocket Depth, Gingival Recession, and Bleeding Index by Months

		Pretreatment	3rd Month	6th Month
GI	n	60	60	60
	mean	0,98	0,82	0,71
	SD	0,37	0,40	0,46
PI	n	60	60	60
	mean	0,70	0,67	0,61
	SD	0,30	0,27	0,43
PD	n	42	42	42
	mean	5,79	4,38	3,79
	SD	1,89	1,94	1,88
GR	n	42	42	42
	mean	1,21	2,4	2,36
	SD	1,46	2,07	2,21
BI	n	42	42	42
	mean	0,43	0,38	0,40
	SD	0,50	0,49	0,50

Friedman Test SD: Standard Deviation. GI: Gingival Index, PI: Plaque Index, PD: Periodontal Pocket Depth, GR: Gingival Recession, BI: Bleeding Index *Indicates the differences between the groups (p<0.05)

Table 2. Changes in Gingival Index, Plaque Index, Periodontal Pocket Depth, Gingival Recession, and Bleeding Index by Time Periods

Time Period (month)	0 - 3	3 - 6	0 - 6
GI	0.0001*	0.0001*	0.0001*
PI	0.81	0.06	0.10
PD	0.001*	0.0001*	0.001*
GR	0.002*	0.003*	0.68
BI	0.62	0.78	0.74

Wilcoxon Signed Rank test, GI: Gingival Index, PI: Plaque Index, PD: Periodontal Pocket Depth, GR: Gingival Recession, BI: Bleeding Index *Indicates the differences between the groups (p<0.05)

Significant positive correlations were found between the 1st and 2nd readings of radiographs and subtraction images for both observers throughout all time intervals ($p<0.05$) (Table 5). Both observers assessed alveolar bone changes, in the direction of increase during all time periods and with both evaluation materials.

The measurements of alveolar bone defect changes performed with DSR software were statistically evaluated according to time periods. When the radiographic density change parameters obtained from the DSR images of alveolar bone defect areas were evaluated at intervals of 6 months, a statistically significant increase in bone was detected ($p \leq 0.02$) (Table 6).

When examining the correlation between radiographic density change parameters obtained from DSR measurements and observer readings, differences were found across time intervals (Table 7). Statistically significant positive correlations were observed between observer evaluations at 0–3 and 0–6 months and radiographic density change parameters ($p < 0.05$). However, during the 3-6 month period, a randomly positive correlation was identified.

Intraclass Correlation Coefficients test was used to test the reliability of the researcher conducting the DSR software measurements, and the measurement reliability was found to be 0.99.

Table 3. Observer Evaluations of Radiographs and Subtraction Images in Time Periods

		CONVENTIONAL				SUBTRACTION			
Time Period (month)	Assessment Parameters	1G1	1G2	2G1	2G2	1G1	1G2	2G1	2G2
0 - 3	Alveolar Bone Loss	13	19	6	6	22	22	17	13
	No Change In Alveolar Bone	21	19	31	33	17	17	33	30
	Alveolar Bone Gain	26	22	23	21	21	21	10	17
3 - 6	Alveolar Bone Loss	4	3	0	0	8	9	1	1
	No Change In Alveolar Bone	20	36	49	54	11	20	50	49
	Alveolar Bone Gain	36	21	11	6	41	31	9	10
0 - 6	Alveolar Bone Loss	11	16	5	6	13	13	18	13
	No Change In Alveolar Bone	10	14	28	29	10	13	22	22
	Alveolar Bone Gain	39	30	27	25	37	34	20	25

Descriptive Statistic 1G 1: 1st Observer 1st Reading, 1G 2: 1st Observer 2nd Reading, 2G 1: 2nd Observer 1st Reading, 2G 2: 2nd Observer 2nd Reading

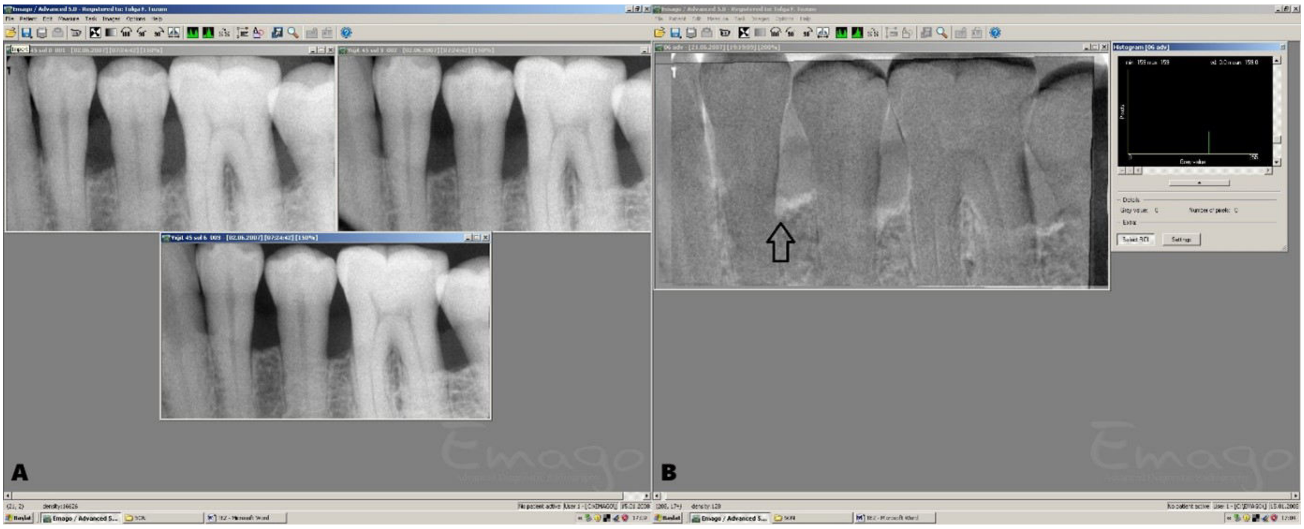

Figure 1. A. Periapical radiographs obtained at pretreatment, 3rd, 6th months. B. Digital Subtraction Radiography image; alveolar bone gain (arrow)

Table 4. Intra- and Inter-Observer Consistency Table

	CONVENTIONAL			SUBTRACTION		
Time Period (month)	0 - 3	3 - 6	0 - 6	0 - 3	3 - 6	0 - 6
1G1 - 1G2	0.47	0.34	0.54	0.62	0.48	0.61
2G1 - 2G2	0.67	0.44	0.65	0.43	0.56	0.52
1G1 - 2G1	0.26	Not Valued	0.29	0.38	0.10	0.30
1G2 - 2G2	0.30	Not Valued	0.28	0.36	0.21	0.58

Kappa statistical analysis, 0.81 - 1.00 excellent agreement, 0.61 - 0.80 good agreement, 0.41 - 0.60 moderate agreement, 0.21 - 0.40 weak agreement, $\kappa < 0.20$ poor agreement 1G 1: 1st Observer 1st Reading, 1G 2: 1st Observer 2nd Reading, 2G 1: 2nd Observer 1st Reading, 2G 2: 2nd Observer 2nd Reading

Discussion

This study evaluated the efficacy of DSR in detecting alveolar bone changes after treatment in individuals undergoing periodontal surgery due to chronic periodontal disease. Although radiographs are considered the primary diagnostic tool for detecting bone changes, their effectiveness in detecting early interproximal bone changes is debatable due to artifacts and imaging techniques. The parallel radiography technique provides the most accurate measurement of alveolar bone loss, but doubts about personal interpretation differences and the inability of radiographs to detect minor changes in alveolar bone density have led to the development and use of effective DSR software for comparing changes in images taken at periodic intervals and demonstrating minimal changes in alveolar bone density.[7] The DSR analysis is influenced by angular differences in imaging due to the method of overlaying and subtracting radiographic images obtained at different times. To minimize these differences, the obtained images should have the same imaging parameters and geometry. For this purpose, the use of acrylic or silicone stents is recommended to ensure the repeatability of geometric parameters for standardization.[17?]

In their study evaluating postoperative changes for the long-term survival of movable partial denture abutment teeth, Watanabe et al[11] utilized the DSR imaging technique and found no periodontal changes in the abutment teeth during long-term follow-up. However, in this study where non-standardized images were used, although the DSR program could correct the angle and density differences between images obtained at different times, they also reported that differences in angulation that may occur in non-standardized radiographs could lead to errors in DSR images.[11] In our study, imaging of periodontal surgical areas was conducted using the parallel technique in accordance with the literature. Imaging was performed with standard imaging parameters, and film holders and prepared occlusal stents specifically for the patient were used to ensure geometric standardization. Custom-made occlusal stents and film holders were utilized for geometric standardization purposes. To prevent any influence from minimal geometric and density differences, advanced features of the DSR program were also employed. Consequently, any potential errors due to angulation or density differences were completely eliminated. The primary limitation of DSR utilization is the standardization of imaging parameters, particularly geometry. Although the advanced features of the program partly mitigate this necessity, standardization of imaging geometry remains essential.

In their study evaluating the efficacy of Digital Subtraction Radiography (DSR) in detecting periodontal bone losses compared to radiographic methods, Nummikoski et al[24] reported that DSR exhibited higher diagnostic accuracy in detecting alveolar crestal bone

Table 5. Evaluation of Alveolar Bone Changes in Periodontal Surgical Sites by Observers

		CONVENTIONAL			SUBTRACTION		
Time Period (Month)		0 - 3	3 - 6	0 - 6	0 - 3	3 - 6	0 - 6
1G1 - 1G2	r	0,40	0.46	0.59	0.70	0.64	0.76
	p	0.001**	0.000**	0.000**	0.000**	0.000**	0.000**
2G1 - 2G2	r	0.71	0.47	0.69	0.55	0.59	0.72
	p	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
1G1 - 2G1	r	0.38	0.32	0.47	0.54	0.31	0.68
	p	0.003**	0.01*	0.000**	0.000**	0.01*	0.000**
1G2 - 2G2	r	0.36	0.28	0.46	0.51	0.40	0.76
	p	0.005**	0.03*	0.000**	0.000**	0.001**	0.000**

Spearsman's rho test, 1G 1: 1st Observer 1st Reading, 1G 2: 1st Observer 2nd Reading, 2G 1: 2nd Observer 1st Reading, 2G 2: 2nd Observer 2nd Reading ** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

Table 6. Evaluation of the radiographic density change parameters of the alveolar bone defect region according to control periods

Time period (Month)		**0 - 3**	**3 - 6**	**0 - 6**
Average Test Points (ATP)	n	60	60	60
	mean	125.27	129.04	131.35
	SD	19.74	21.58	23.37
Control Points (CP)	n	60	60	60
	mean	124.93	129.18	123.86
	SD	9.86	8.52	9.11
ATP- CP	n	60	60	60
	mean	0.34	0.14	7.49*
	SD	22.81	20.57	24.96*

Student paired-t test Mean: Mean, SD: Standard deviation, Ctrl: Control point *Indicates the differences between the groups ($p \leq 0.02$)

losses compared to periapical radiographs. They demonstrated that DSR is an important and effective method in the diagnosis and monitoring of advancing periodontal lesions in routine clinical practice. They also mentioned that simple imaging standardization can be achieved with radiographs without the need for personalized stents or cephalostats. However, they noted that the use of X-ray guiding devices enhances image accuracy in the DSR technique.[24] In their study evaluating the survival rates of removable partial denture abutment teeth and changes in periodontal conditions in patients with and without type 2 diabetes, Watanabe et al[12] utilized Digital Subtraction Radiography (DSR) to assess bone density. They reported that DSR analysis confirmed evidence of decreased bone density at the apex of the alveolar bone of the denture-supporting teeth five years after the placement of partial dentures in patients with type 2 diabetes who received regular treatment. Okano et al[25] evaluated alveolar bone changes through quantitative analysis using DSR at the 1st, 3rd, and 6th months post-therapy following initial periodontal treatment (curettage and root planing). They found a significant monotonic increase in the grayscale value difference of fifteen crestal bone regions over time, with a significant difference observed between the 1st and 3rd months as well as between the 3rd and 6th months. Additionally, they observed a monotonic increase in pixel count in the crestal bone region over time, with a significant increase in pixel count between the 1st and 3rd months, although no statistically significant increase was detected between the 3rd and 6th months. Consequently, they argued that DSR is a repeatable and numerical method for evaluating the outcomes of periodontal treatment.[25] The results obtained from quantitative measurements using DSR in our study are consistent with those in the literature. Evaluation of grayscale value changes in the alveolar bone defect areas included in the study, both preoperatively and at 3rd and 6th months postoperatively, revealed a significant increase in density change over time; however, pairwise comparisons did not reveal a statistically significant increase between the 3rd and 6th months (Table 6). Although there are studies in the literature demonstrating that DSR technique is diagnostically more effective and accurate compared to conventional radiography techniques, Bittar-Cortez et al[19] conducted a study in 2006 where they evaluated peri-implant bone density changes by performing histogram (mean grayscale value) measurements on digitized conventional radiography and DSR, yielding quite different results. Their study concluded that maxillary and mandibular bone morphologies did not affect radiographic density. Furthermore, they indicated no significant difference in measurements between digital conventional radiography and DSR. They mentioned that implant surrounding bone density could be evaluated as mean grayscale value through histogram measurement in both DSR and digital conventional radiography techniques. The researchers argued that the use of a time-consuming and expensive technique like DSR was meaningless. However, they also stated that the chosen method could influence the obtained result, and the DSR technique might be more sensitive in areas with mineral loss around implants.18 In their in vitro studies, Wenzel and Sewerin[26], Janssen et al[27] stated that DSR's numerical measurements were highly accurate in evaluating artificial periodontal bone defects. However, Bittar-Cortez et al[19] argued that this result would decrease in vivo due to standardization difficulties between reference and follow-up radiographs and changes in irradiation parameters. In our study, bone defect areas treated surgically were evaluated with histogram measurements consistent with the study by Bittar-Cortez et al[19], and it was concluded that DSR technique is an effective method for detecting bone healing. It has been observed that DSR, when adhered to with sensitivity to standardization conditions and fully implemented program content, is highly beneficial for research purposes, although it may not be suitable for routine clinical practices.

In our study, in addition to quantitative measurements conducted with DSR, radiographs and subtraction images were reviewed by a dentomaxillofacial radiologist and a periodontologist to evaluate how alveolar changes were interpreted. The intraobserver consistency of the dentomaxillofacial radiologist participating in the study was found to be moderate in detecting alveolar bone changes in radiographs, while consistency in interpreting subtraction images was determined to be good. The periodontologist observer's consistency in radiograph evaluation was good, whereas consistency in interpreting subtraction images was moderate. The good consistency of the periodontology specialist in detecting alveolar bone changes in radiographs was attributed to the high specificity of perception in the studied area, while the high consistency of the radiology specialist in DSR was attributed to the ability of radiology expertise to provide a general perspective that is not specific to the region but adaptable to different areas and techniques. Interobserver consistency was found to be weak for repeatable radiograph readings. However, when subtraction images were evaluated, it was noteworthy that the interobserver consistency for alveolar bone changes in the 0–6 month time frame was weak in the first reading but reached a moderate level in the second reading. It was concluded that the DSR method is more effective in reaching consensus among evaluators (Table 4).

In their study investigating observer reliability during the evaluation of color-coded DSR for assessing changes in alveolar bones,

Table 7. Evaluation of the radiographic density change parameters of the alveolar bone defect region with observer assesments according to control periods

		CONVENTIONAL				SUBTRACTION			
Time Period (month)		**1G1**	**1G2**	**2G1**	**2G2**	**1G1**	**1G2**	**2G1**	**2G2**
0 - 3	r	0,27	0.55	0.52	0.35	0.71	0.62	0.47	0.70
	p	0.03*	0.001**	0.001**	0.001**	0.001**	0.001**	0.001**	0.001**
3 - 6	r	0.24	0.50	0.23	0.24	0.52	0.45	0.36	0.22
	p	0.07	0.001**	0.07	0.06	0.001**	0.001**	0.001**	0.08
0 - 6	r	0.26	0.38	0.31	0.27	0.67	0.61	0.56	0.68
	p	0.04*	0.001**	0.01**	0.03*	0.001**	0.001**	0.001**	0.001**

Spearsman's rho test, 1G 1: 1st Observer 1st Reading, 1G 2: 1st Observer 2nd Reading, 2G 1: 2nd Observer 1st Reading, 2G 2: 2nd Observer 2nd Reading ** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

Shi et al [28] found a significantly high level of intra-observer agreement, while inter-observer agreement was notably high in the second assessments of observers. The increase in agreement during the second assessment was attributed to observers' increased familiarity with black-and-white images and their enhanced experience in evaluating color-coded images during the second assessment. Similarly, our study also demonstrates an increase in both intra- and inter-observer agreement during the second assessment, particularly in DSR images. In their study, Cury et al [29] compared the effectiveness of DSR and radiographic evaluation in detecting periodontal bone changes occurring during long-term monitoring of class II furcation defects. They observed a low inter-observer agreement rate in radiographic evaluations. Alignment between DSR images and radiographic evaluations was found to be low for each observer. Consequently, conventional radiographic evaluations for the diagnosis and monitoring of class II furcation defects in mandibular molars were shown to be more subjective and less accurate compared to DSR images. Consistent with the findings of Cury et al [29] intra-observer agreement in our study was higher in DSR images compared to conventional radiographs, while inter-observer agreement was weak (Table 4).

Nicopoulou-Karayianni et al [16] utilized radiographic and DSR images to evaluate the effect of root canal treatment on periapical lesions and tested observer agreement. When DSR images were evaluated, both inter- and intra-observer agreements were found to be statistically significant compared to conventional radiographs. This study demonstrated better observer agreement in DSR images, consistent with our study results. [16] In our study, the correlation between the first and second readings of the same observer, as well as the correlation between the readings of the first and second observers, was examined. Across all time intervals, significant positive correlations were found between the assessments of two observers in the evaluation of radiographs and DSR images (Table 5). Observers made similar assessments of the datasets. This finding was consistent with the study by Bittar-Cortez et al. [19] Both observers assessed alveolar bone changes, in the direction of increase during all time periods and with both evaluation materials (Table 3). Furthermore, our study assessed the correlation between histogram measurements (mean grayscale value) obtained through DSR and observer evaluations. Statistically significant positive correlations were detected between observer assessments at 0–3 and 0–6 months and changes in radiographic density parameters ($p < 0.05$). However, a sporadic positive correlation was observed during the 3-6 month period. It was concluded that observer evaluations yielded similar results to DSR histogram measurements (Table 7).

In our study, gingival index (GI), plaque index (PI), periodontal pocket depth (PD), gingival recession (GR), and bleeding index (BI) were recorded for the purpose of monitoring oral hygiene control and periodontal health before and after periodontal surgery, and the changes in these indexes over time were evaluated (Table 1). It was observed that there was a statistically significant decrease in GI and PI over time. Hochstetter et al [30] in their study on oral hygiene education conducted on 58 preschool children, reported a statistically significant decrease in GI and PI indexes in the group receiving oral hygiene education. Hugoson et al [31] evaluated PI and GI in their study testing the effectiveness of three different preventive dental health programs in four hundred patients. As a result, they found a decrease in PI and GI values over a two-month period. [31] In our study, it was observed that after oral hygiene motivation, patients' index values rapidly decreased and continued to decrease as long as patient follow-up continued. Gaspirc and Skaleric [32] used GI, PI, BI, clinical attachment level, and PD parameters in their study comparing periodontal flap surgery performed with Er: YAG laser and modified Widmann flap surgery, which we also used as parameters. They reported that both treatments resulted in a significant decrease in GI, PI, BI, and PD parameters over time, while there was an increase in clinical attachment level gain. [32] In our research, a decrease in GI, PI, BI, PD, and increase in GR values over time were observed, and the increase observed in GR was thought to be related to the selected incision type. No significant change was observed in the BI value (Table 2).

Conclusion

Radiographic examination is a necessary and practical method to detect osseous changes caused by periodontitis and to evaluate the long-term outcomes of periodontal treatment. However, due to factors such as observer experience, assessment, and imaging conditions, minimal tissue changes may be overlooked in radiographs. In cases where precise evaluation is required, as demonstrated in our study, DSR can provide quantitative data, enabling a more objective assessment of the examined area. However, the need for standardization in the imaging geometry and parameters of DSR complicates its routine clinical use.

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Writing—original draft preparation : A.A
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Conflict of Interest

The authors declare no conflicts of interest.

Ethics Approval

The study was conducted in accordance with the principles outlined in the Declaration of Helsinki and received approval from the Ethics Committee of Medical, Surgical and Pharmaceutical Research at Hacettepe University (IRB Approval No: LUT04/65, 2005).

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References

1. Chang HJ, Lee SJ, Yong TH, Shin NY, Jang BG, Kim JE, et al. Deep learning hybrid method to automatically diagnose periodontal bone loss and stage periodontitis. Sci Rep. 2020;10(1):7531. doi:10.1038/s41598-020-64509-z.
2. Kim J, Lee HS, Song IS, Jung KH. DeNTNet: Deep Neural Transfer Network for the detection of periodontal bone loss using panoramic dental radiographs. Sci Rep. 2019;9(1):17615. doi:10.1038/s41598-019-53758-2.
3. Tonetti MS, Jepsen S, Jin L, Otomo-Corgel J. Impact of the global burden of periodontal diseases on health, nutrition and wellbeing of mankind: A call for global action. J Clin Periodontol. 2017;44(5):456–462. doi:10.1111/jcpe.12732.
4. Carranza F, Newman M, Takei H. Clinical Periodontology, Ed. Ke-9 [Generic]. W.B. Saunders Co, Philadelphia; 2002.
5. White SC, Pharoah MJ. Oral radiology: principles and interpretation. Elsevier Health Sciences; 2013.
6. Gröndahl HG, Gröndahl K. Subtraction radiography for the diagnosis of periodontal bone lesions. Oral Surg Oral Med Oral Pathol. 1983;55(2):208–213. doi:10.1016/0030-4220(83)90180-9.
7. Gröndahl K, Gröndahl H, Wennstrom J, Heijl L. Examiner agreement in estimating changes in periodontal bone from conventional and subtraction radiographs. J Clin Periodontol. 1987;14(2):74–79. doi:10.1111/j.1600-051x.1987.tb00945.x.
8. Van der Stelt P, Van der Linden L, Geraets W, Alons C. Digitized pattern recognition in the diagnosis of periodontal bone defects. J Clin Periodontol. 1985;12(10):822–827. doi:10.1111/j.1600-051x.1985.tb01359.x.
9. Reddy MS, Jeffcoat MK. Digital subtraction radiography. Dent Clin North Am. 1993;37(4):553–565. doi:10.1016/S0011-8532(22)00241-5.
10. Webber RL, Ruttimann UE, Grondahl HG. X-ray image subtraction as a basis for assessment of periodontal changes. J Prosthodont Res. 1982;17(5):509–511. doi:10.1111/j.1600-0765.1982.tb02041.x.
11. Watanabe C, Wada J, Mizutani K, Nagayama T, Uchida H, Shibata Y, et al. Radiographic predictive factors for 10-year survival of removable partial denture abutment teeth: Alveolar bone level and density. J Prosthodont Res. 2022;67(3):437–443. doi:10.2186/jpr.JPR_D_22_00034.
12. Watanabe C, Wada J, Nagayama T, Uchida H, Mizutani K, Foxton RM, et al. Long-term observation of periodontal condition following placement of removable partial dentures with rigid retainers and major connector in patients with/without diabetes: A retrospective study. J Prosthodont Res. 2022;66(1):117–123. doi:10.2186/jpr.JPR_D_20_00288.
13. Lee SS, Huh YJ, Kim KY, Heo MS, Choi SC, Koak JY, et al. Development and evaluation of digital subtraction radiography computer program. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2004;98(4):471–475. doi:10.1016/j.tripleo.2004.03.013.
14. Tarnow D, Fletcher P. Classification of the vertical component of furcation involvement. J Periodontol. 1984;55(5):283–284. doi:10.1902/jop.1984.55.5.283.
15. Aass AM, Tollefsen T, Gjermo P. A cohort study of radiographic alveolar bone loss during adolescence. J Clin Periodontol. 1994;21(2):133–138. doi:10.1111/j.1600-051x.1994.tb00291.x.
16. Nicopoulou-Karayianni K, Bragger U, Patrikiou A, Stassinakis A, Lang N. Image processing for enhanced observer agreement in the evaluation of periapical bone changes. Int Endod J. 2002;35(7):615–622. doi:10.1046/j.1365-2591.2002.00526.x.
17. Yoshioka T, Kobayashi C, Suda H, Sasaki T. An observation of the healing process of periapical lesions by digital subtraction radiography. J Endod. 2002;28(8):589–591. doi:10.1097/00004770-200208000-00006.
18. Bittar-Cortez J, Passeri L, de Almeida S, Haiter-Neto F. Comparison of peri-implant bone level assessment in digitized conventional radiographs and digital subtraction images. DMFR. 2006;35(4):258–262. doi:10.1259/dmfr/84778143.
19. Bittar-Cortez JA, Passeri LA, Bóscolo FN, Haiter-Neto F. Comparison of hard tissue density changes around implants assessed in digitized conventional radiographs and subtraction images. Clin Oral Implants Res. 2006;17(5):560–564. doi:10.1111/j.1600-0501.2006.01256.x.
20. Gegler A, Mahl C, Fontanella V. Reproducibility of and file format effect on digital subtraction radiography of simulated external root resorptions. DMFR. 2006;35(1):10–13. doi:10.1259/dmfr/86879455.
21. Dunn S, Van der Stelt P, Ponce A, Fenesy K, Shah S. A comparison of two registration techniques for digital subtraction radiography. DMFR. 1993;22(2):77–80. doi:10.1259/dmfr.22.2.8375559.
22. Zacharaki E, Matsopoulos G, Asvestas P, Nikita K, Grondahl K, Grondahl H. A digital subtraction radiography scheme based on automatic multiresolution registration. DMFR. 2004;33(6):379–390. doi:10.1259/dmfr/21571843.
23. Alpar R. Spor bilimlerinde uygulamalı istatistik. Nobel; 2006.
24. Nummikoski PV, Steffensen B, Hamilton K, Brent Dove S. Clinical validation of a new subtraction radiography technique for periodontal bone loss detection. J Periodontol. 2000;71(4):598–605. doi:10.1902/jop.2000.71.4.598.
25. Okano T, Mera T, Ohki M, Ishikawa I, Yamada N. Digital subtraction of radiograph in evaluating alveolar bone changes after initial periodontal therapy. Oral Surg Oral Med Oral Pathol. 1990;69(2):258–262. doi:10.1016/0030-4220(90)90338-s.
26. Wenzel A, Sewerin I. Sources of noise in digital subtraction radiography. Oral Surg Oral Med Oral Pathol. 1991;71(4):503–508. doi:10.1016/0030-4220(91)90441-e.
27. Janssen P, van Palenstein Helderman W, Van Aken J. The detection of in vitro produced periodontal bone lesions by conventional radiography and photographic subtraction radiography using observers and quantitative digital subtraction radiography. J Clin Periodontol. 1989;16(6):335–341. doi:10.1111/j.1600-051x.1989.tb00001.x.
28. Shi X, Eklund I, Tronje G, Welander U, Stamatakis H, Engström P, et al. Comparison of observer reliability in assessing alveolar

bone changes from color-coded with subtraction radiographs. DMFR. 1999;28(1):31–36. doi:10.1038/sj.dmfr.4600401.

29. Cury PR, Araujo NS, Bowie J, Sallum EA, Jeffcoat MK. Comparison between subtraction radiography and conventional radiographic interpretation during long-term evaluation of periodontal therapy in Class II furcation defects. J Periodontol. 2004;75(8):1145–1149. doi:10.1902/jop.2004.75.8.1145.
30. Hochstetter AS, Lombardo MJ, D'eramo L, Piovano S, Bordoni N. Effectiveness of a preventive educational programme on the oral health of preschool children. Promot Educ. 2007;14(3):155–158. doi:10.1177/175797590701400304.
31. Hugoson A, Lundgren D, Asklöw B, Borgklint G. Effect of three different dental health preventive programmes on young adult individuals: a randomized, blinded, parallel group, controlled evaluation of oral hygiene behaviour on plaque and gingivitis. J Clin Periodontol. 2007;34(5):407–415. doi:10.1111/j.1600-051X.2007.001069.x.
32. Gaspirc B, Skaleric U. Clinical evaluation of periodontal surgical treatment with an Er: YAG laser: 5-year results. J Periodontol. 2007;78(10):1864–1871. doi:10.1902/jop.2007.070054.

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ORIGINAL RESEARCH ARTICLE

Oral Health Knowledge, Attitudes and Behaviors in Dental and Oral Health Program Students: A Descriptive Cross-Sectional Study

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Abstract

Purpose: The objective of this study was to assess the oral health attitudes, knowledge, and behaviors of students in dental and oral and dental health programs before and after periodontology clinical training, and to investigate the correlations between these variables and sociodemographic factors.
Materials and Methods: In this study conducted at the end of the spring semester in 2022, we utilized the Turkish version of the Hiroshima University Dental Behavioral Inventory (HU-DBI). Sociodemographic data, oral hygiene practices, and smoking habits were collected through a questionnaire. Higher HU-DBI scores reflect improved oral health attitudes and behaviors. Non-normally distributed data were analyzed with Mann-Whitney U and Kruskal-Wallis H tests, and categorical data with Pearson's chi-square and Bonferroni Z tests, using $p < 0.05$ for significance.
Results: This study involved 295 students: 151 preclinical dental, 76 clinical dental, 34 preclinical, and 34 clinical oral and dental health program students. In all groups, female participants were more numerous than male participants ($p < 0.05$). Across all participants, females had higher overall HU-DBI scores ($p < 0.05$). Clinical dental students had significantly higher HU-DBI scores (7.25 ± 1.63) than preclinical dental students (6 ± 1.57). No significant difference was found between preclinical (6.38 ± 1.41) and clinical oral and dental health program students (6.62 ± 2.09). There was no statistically significant difference in the overall HU-DBI scores between oral and dental health program students and dental students. No significant correlations were found with other sociodemographic factors, such as parental education, alcohol, or cigarette use.
Conclusions: Integrating preventive dentistry components into the early-stage curriculum may facilitate an earlier enhancement of fundamental knowledge and awareness among future dentists and auxiliary personnel in the oral and dental health field, irrespective of sociodemographic factors.

Keywords: Dental student; Education; Health; Knowledge; Oral hygiene

Introduction

Maintaining oral health is a crucial aspect of an individual's overall health and general welfare. However, the prevalence of oral diseases remains a significant societal concern. The state of the oral cavity is influenced by an individual's attitudes toward oral health. The behavior and attitudes of oral health care providers towards their oral health can potentially impact their ability to deliver effective oral health care, thus influencing the oral health outcomes of their patients. Dental care providers must exemplify proper oral hygiene practices by upholding their oral health and serving as role models for their patients. It is reasonable to assert that dental students undergo a process of developing and adapting their oral health-related behaviors and attitudes throughout their undergraduate education. This development has the potential to impact the oral health of their future patients.[1]

The Hiroshima University-Dental Behavioral Inventory (HU-DBI), developed by Kawamura, was designed to evaluate individuals' oral health behaviors and attitudes, particularly concerning tooth brushing. This inventory comprises twenty dichotomous responses, categorized as agree or disagree.[2] The HU-DBI demonstrates favorable test-retest reliability, rendering it valuable not only for comprehending patients but also for prognosticating clinical outcomes.[2,3] In contrast, the utilization of this assessment revealed notable disparities in oral health practices across nations, primarily attributable to variations in health education systems and cultural distinctions.[4–8] Furthermore, the research findings indicate a positive correlation between the level of education and

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improvements in oral health behavior and attitudes.[9–12]

In many dentistry faculties in Turkey, students of oral and dental health programs, who are educated to be auxiliary personnel in the oral and dental health field, receive clinical education alongside dental students. The heightened level of awareness exhibited by oral and dental health program students, who play a crucial role in delivering oral health services alongside dentists, is related to the order and continuity of the clinical workflow. A healthy continuation of the workflow necessitates teamwork and the sharing of responsibilities among all dental staff working alongside the dentist. The training of the staff who assist the dentist at the patient's bedside will have a favorable impact on the overall quality of service.[13]

Nevertheless, a comprehensive investigation assessing the oral health attitudes and behaviors of oral and dental health program students has not yet been conducted.

This study constitutes the first evaluation of oral health-related attitudes and behaviors among dental students and oral and dental health program students, conducted both before and after periodontology clinical training. Moreover, the objective of this study is to assess the possible associations between these attitudes and behaviors and sociodemographic factors.

Material and Methods

Study design and participants

This study was conducted in the Department of Periodontology from February to May 2023. The study, approved by the Ethics Committee for Non-Pharmaceutical and Medical Device Clinical Research (Decision no: 2022/241), was conducted in compliance with the protocols outlined in the 1975 Declaration of Helsinki, as amended in 2013. All subjects who volunteered to participate in the study provided written and verbal consent. This study was conducted and reported using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) standards for cross-sectional studies.[14]

This cross-sectional study comprised all students who agreed to participate in the study and were enrolled in the spring semester of the 2022-2023 academic year at the Faculty of Dentistry and Oral and Dental Health Program. A total of 295 students consented to participate in the research study. The participants were assessed by categorizing them into four distinct groups according to their educational background and clinical involvement: (1) preclinical dental students, (2) clinical dental students, (3) preclinical oral and dental health program students, and (4) clinical oral and dental health program students. During the completion of the questionnaire, the students were instructed to remain seated in the classroom if they were willing to participate. The students were provided with an explanation of the study's goal, and a signed agreement was obtained from each individual before they filled out the questionnaire.

Based on the outcomes of the nationwide examination for university admissions, students are entitled to enroll in the Faculty of Dentistry and Oral and Dental Health Program. The dentistry curriculum spans five years, with the initial three years dedicated to preclinical training and the subsequent two years focused on clinical training. During the preclinical phase of their education, students are required to participate in basic science lectures and engage in laboratory courses. From the fourth year onwards, students are responsible for administering care to patients. Periodontics theoretical training is provided in the third and fourth years. The completion of clinical training occurs at the end of the fifth year.

The two-year curriculum of the oral and dental health program, which trains assistant personnel for dentists and does not authorize intraoral applications on patients (unlike dental hygienists), is preclinical in the first year and clinical in the second year. By the end of the first year, students will have completed the basic theoretical periodontology courses.

Questionnaire instrument

The questionnaire was used to collect information about the sociodemographic characteristics of the participants, including gender, parental education level, and place of residence. Additionally, the participants were asked about their smoking and oral hygiene habits.

Evaluation of oral health behaviors and attitudes of individuals

The oral health behaviors and attitudes of the individuals participating in the study were measured using the HU-DBI questionnaire translated into Turkish by Yıldız et al.[15]. The HU-DBI is a questionnaire consisting of 20 questions about tooth brushing habits. When determining the HU-DBI scores, one point was given for each response that agreed with items 4, 9, 11, 12, 16, and 19, and one point was given for each response that disagreed with items 2, 6, 8, 10, 14, and 15. The highest possible HU-DBI score was 12, with higher levels suggesting superior oral health behavior[2]. The score for oral health knowledge was influenced by items 2, 8, 10, 15, and 19. Similarly, the score for oral health attitudes was influenced by items 6, 11, and 14. Lastly, the score for oral health behaviors was influenced by items 4, 9, 12, and 16.[16]

Statistical analysis

Considering the HU-DBI results of the reference study, this study was completed with 295 participants with 95% confidence ($1-\alpha$), f = 0.351 effect size, and as a result of post hoc power analysis, the power of the test ($1-\beta$) was obtained as 100%.[17] The data were examined using statistical software (SPSS version 23, IBM, Armonk, NY). The normality of the data was assessed using the Kolmogorov-Smirnov and Shapiro-Wilk tests. The Mann-Whitney U test was used to compare pairs of non-normally distributed data. Three or more categories of non-normally distributed data were compared using the Kruskal-Wallis H test, and multiple comparisons were examined using Dunn's test. Pearson's chi-square test was used to compare categorical data, and the Bonferroni corrected Z test was used to examine multiple comparisons. The analysis results were reported in the form of frequency (percentages) for categorical variables, means ± standard deviations for quantitative variables, and medians (minima – maxima) for quantitative variables. The study accepted a statistical significance value of $p < 0.05$.

Results

Sociodemographic data

The study was completed with the participation of a total of 295 students. The distribution of students across different levels of dentistry and oral and dental health programs was as follows: 151 preclinical dental students (1st, 2nd, and 3rd level) constituted 51.1% of the total, 76 clinical dental students (4th and 5th level) accounted for 25.7%, 34 preclinical oral and dental health program students (1st grade) included 11.4%, and 34 clinical oral and dental health program students (2nd grade) also constituted 11.4% of the total student population. The mean ages of the preclinical dental students, clinical dental students, preclinical oral and dental health program students, and clinical oral and dental health program students were 20.52, 23.03, 19.53, and 20.85 years, respectively.

Table 1 presents the distribution of the students' demographic characteristics by educational background. Within each group, the

Table 1. The distribution of demographic characteristics by educational backgrounds

Participants		Dental students n (%)[X]	Oral and dental health program students n (%)[X]	P value
Gender	Male	71 (31.2)	10 (14.7)	0.001*
	Female	156 (68.7)	58 (85.2)	
Place of Residence	Urban	213 (93.8)	58 (85.2)	0.001*
	Semi-rural	11 (4.8)	5 (7.3)	
	Rural	3 (1.3)	5 (7.3)	
Mother Education Level	Illiterate/ Primary school	84 (36.9)a	42 (61.7)b	0.001*
	Secondary school	27 (11.8)[a]	19 (32.7)[b]	
	High school	59 (25.9)[a]	5 (7.3)[b]	
	University	57 (25.1)[a]	2 (2.9)[b]	
Father Education Level	Illiterate/ Primary school	42 (18.5)a	29 (42.6)b	0.001*
	Secondary school	25 (11.0)	14 20.5)	
	High school	42 (18.5)	18 (26.4)	
	University	118 (51.9)[a]	7 (10.2)[b]	

*p<0.05, chi-square test, there is no difference between groups with the same letter

number of female participants was statistically significantly higher compared to the number of male participants ($p < 0.05$). The educational levels of the mothers of dental students, as well as the educational levels of their fathers and the rates of urbanization, exhibited statistically significant differences when compared to those of oral and dental health program students ($p < 0.05$).

Evaluation of HU-DBI responses

Table 2 displays the HU-DBI statements and the percentage distribution of students who expressed agreement and disagreement with the statements, categorized by group. Notable differences were observed in 6 items (3, 10, 11, 14, 15, and 20) between groups. No significant difference was found between the groups in terms of alcohol use, daily tooth brushing, or dental flossing habits.

Evaluation of HU-DBI scores

The overall HU-DBI scores indicated the highest scores in the clinical dental student group and the lowest in the preclinical dental student group (Table 3). The differences in the overall HU-DBI scores, as well as the HU-DBI knowledge and attitudes indexes between clinical dental students and preclinical dental students, were statistically significant. There was no statistically significant difference in the overall HU-DBI scores or the HU-DBI knowledge, attitudes, and behavior indexes between preclinical oral and dental health program students and clinical dental students, or between these two groups and the other groups. In the HU-DBI behavior index, no significant difference was found among any of the groups.

HU-DBI scores by gender, socio-demographic status, general health behavior, oral hygiene habits

Female students had a significantly higher overall HU-DBI score (6.53 ± 1.68) than male students (6.08 ± 1.85) ($p<0.05$). Students who reported regularly attending dental check-ups (6.92±1.71) and brushing their teeth at least twice a day (2.04±0.65) had significantly higher overall HU-DBI scores ($p<0.05$). The students who consistently reported engaging in daily flossing had a significantly higher overall HU-DBI (6.74 ± 1.54) and knowledge index score (3.28 ± 1.08) ($p < 0.05$). There was no significant relationship between HU-DBI scores and other variables related to sociodemographic status, alcohol, and cigarette use ($p > 0.05$).

Discussion

This study aimed to assess the oral and dental health behaviors and attitudes of students enrolled in dentistry and oral and dental health programs. The results revealed that clinical dental students (7.25 ± 1.63) had the highest HU-DBI score. The overall HU-DBI scores of clinical dental students were significantly higher than those of preclinical dental students (6 ± 1.57). In our study, both dental students and oral and dental health program students were predominantly female. Previous studies have found that the increasing number of female dental students is consistent with global trends.[18–21] This trend is also observable among oral and dental health program students, aligning with previous research conducted on dental hygienist students, a similar professional group.[22]

These findings, indicating that the educational attainment of dental students' parents was considerably higher than that of oral and dental health students' parents, may suggest that dental students tend to come from more educated families. These results are similar to the findings of many other studies.[19,21–23]

Previous research utilizing the HU-DBI scoring system has consistently shown that clinical dental students tend to have higher scores than their preclinical counterparts. This trend has been observed in several countries, including Lithuania, Poland, Croatia, Romania, Jordan, and Turkey.[12,15,24–26] The widely accepted hypothesis regarding this difference suggests that dental education enhances students' knowledge of oral health, which positively influences their attitudes and behaviors.[16] In a study conducted in Estonia, no significant difference was observed between the overall HU-DBI scores of preclinical and clinical dental students.[27] In the present study, similar to many other studies, the overall HU-DBI scores of dental clinical students were higher than those of preclinical students.[12,15,24–26] Cultural disparities between Western and Eastern societies seem to significantly impact students' attitudes and perceptions regarding oral health behavior. As dental students enter the clinical setting and continue their periodontology education, there is a noticeable improvement in their oral health-related knowledge and attitudes, likely due to increased educational attainment and direct patient interactions.

Kawamura et al.[4] evaluated HU-DBI scores among dental hygiene students, finding that second-grade students had significantly higher scores than first-grade students. In contrast, the present study found no significant difference between the HU-DBI scores of first and second-year students in the oral and dental health program. This could be due to the curriculum, as students complete basic periodontology training by the end of their first year.

In the dental curriculum, basic periodontology training continues into the clinical phase. However, in the curriculum of the oral and dental health program, this training is completed by the end of

Table 2. Students responses to the Hiroshima University Dental Behavior Inventory (HU-DBI)

	Preclinical dental students[X]	Clinical dental students[X]	Preclinical oral and dental health program students[X]	Clinical oral and dental health program students[X]	P*
1. I don't worry much about visiting the dentist					
Agree	108 (71.5)	48 (63.2)	24 (70.6)	30 (88.2)	0.200
Disagree	43 (28.5)	28 (36.8)	10 (29.4)	4 (11.8)	
2. My gums tend to bleed when I brush my teeth					
Agree	27 (17.9)	7 (9.2)	5 (14.7)	7 (20.6)	0.108
Disagree	124 (82.1)	69 (90.8)	29 (85.3)	27 (79.4)	
3. I worry about the color of my teeth					
Agree	73 (48.3)[a]	18 (23.7)[b]	9 (26.5)[a],[b]	13 (38.2)ab	0.002*
Disagree	78 (51.7)	58 (76.3)	25 (73.5)	21 (61.8)	
4. I have noticed some white sticky deposits on my teeth					
Agree	41 (27.2)	14 (18.4)	6 (17.6)	4 (11.8)	0.095*
Disagree	110 (72.8)	62 (81.6)	28 (82.4)	30 (88.2)	
5. I use a child sized toothbrush					
Agree	15 (9.9)	11 (14.5)	5 (14.7)	4 (11.8)	0.582
Disagree	136 (90.1)	65 (85.5)	29 (85.3)	30 (88.2)	
6. I think that I cannot help having false teeth when I am old					
Agree	19 (12.6)	7 (9.2)	3 (8.8)	6 (17.6)	0.065*
Disagree	132 (87.4)	69 (90.8)	31 (91.2)	28 (82.4)	
7. I am bothered by the color of my gums					
Agree	27 (17.9)	6 (7.9)	5 (14.7)	6 (17.6)	0.070*
Disagree	124 (82.1)	70 (92.1)	29 (85.3)	28 (82.4)	
8. I think my teeth are getting worse despite my daily brushing					
Agree	38 (25.2)	10 (13.2)	3 (8.8)	7 (20.6)	0.085*
Disagree	113 (74.8)	66 (86.8)	31 (91.2)	27 (79.4)	
9.I brush each of my teeth carefully					
Agree	106 (70.2)	61 (80.3)	29 (85.3)	29 (85.3)	0.143
Disagree	45 (29.8)	15 (19.7)	5 (14.7)	5 (14.7)	
10. I have never been taught professionally how to brush					
Agree	58 (38.4)[a]	15 (19.7)[a]	9 (26.5)[a],[b]	10 (29.4)[a],[b]	0.033
Disagree	93 (61.6)	61 (80.3)	25 (73.5)	24 (70.6)	
11. I think I can clean my teeth well without using toothpaste					
Agree	23 (15.2)[a],[c]	31 (40.8)[b]	4 (11.8)[c]	8 (23.5)[a],[b],[c]	<0.001
Disagree	128 (84.8)	45 (59.2)	30 (88.2)	26 (76.5)	
12. I often check my teeth in a mirror after brushing					
Agree	140 (92.7)	69 (90.8)	33 (97.1)	33 (97.1)	0.569
Disagree	11 (7.3)	7 (9.2)	1 (2.9)	1 (2.9)	
13. I worry about having bad breath					
Agree	119 (78.8)	57 (75)	21 (61.8)	26 (76.5)	0.325
Disagree	32 (21.2)	19 (25)		8 (23.5)	
14. It is impossible to prevent gum disease with toothbrushing alone					
Agree	117 (77.5)[a]	39 (51.3)[b]	24 (70.6)[a],[b]	23 (67.6)[a],[b]	0.001
Disagree	34 (22.5)	37 (48.7)	10 (29.4)	11 (32.4)	
15. I put off going to the dentist until I have a toothache					
Agree	81 (53.6)[a],[c]	24 (31.6)[b]	23 (67.6)[c]	11 (32.4)[a],[b]	<0.001*
Disagree	70 (46.4)	52 (68.4)	11 (32.4)	23 (67.6)	
16. I have used a dye to see how clean my teeth are					
Agree	3 (2)	2 (2.6)	2 (5.9)	1 (2.9)	0.807
Disagree	148 (98)	74 (97.4)	32 (94.1)	33 (97.1)	
17. I use a toothbrush which has hard bristles					
Agree	34 (22.5)	12 (15.8)	5 (14.7)	9 (26.5)	0.474
Disagree	117 (77.5)	64 (84.2)	29 (85.3)	25 (73.5)	
18. I don't feel I've brushed well unless I brush with strong strokes					
Agree	46 (30.5)	15 (19.7)	9 (26.5)	13 (38.2)	0.290
Disagree	105 (69.5)	61 (80.3)	25 (73.5)	21 (61.8)	
19. I feel I sometimes take too much time to brush my teeth					
Agree	27 (17.9)	20 (26.3)	6 (17.6)	10 (29.4)	0.425
Disagree	124 (82.1)	56 (73.7)	28 (82.4)	24 (70.6)	

20. I have had my dentist tell me that I brush very well					
Agree	47 (31.1)^{a}	48 (63.2)^{b}	15 (44.1)^{a,b}	19 (55.9)^{a,b}	<0.001*
Disagree	104 (68.9)	28 (36.8)	19 (55.9)	15 (44.1)	
Other items evaluated the health behaviors and oral hygiene behaviors of students.					
I drink alcohol atleast once a week					
Agree	2 (1.3)	3 (3.9)	1 (2.9)	0 (0)	0.444
Disagree	149 (98.7)	73 (96.1)	33 (97.1)	34 (100)	
I smoke at least once a week					
Agree	14 (9.3)^{b}	17 (22.4)^{a}	6 (17.6)^{a,b}	9 (26.5)^{a}	0.015*
Disagree	137 (90.7)	59 (77.6)	28 (82.4)	25 (73.5)	
I visit the dentist at least once a year for a check-up					
Agree	82 (54.3)^{a,c}	59 (77.6)^{b}	11 (32.4)^{c}	20 (58.8)^{a,b,c}	<0.001*
Disagree	69 (45.7)	17 (22.4)	23 (67.6)	14 (41.2)	
I floss regularly every day					
Agree	64 (42.4)	40 (52.6)	10 (29.4)	11 (32.4)	0.135
Disagree	87 (57.6)	36 (47.4)	24 (70.6)	23 (67.6)	
I brush my teeth twiceor more a day					
Agree	117 (77.5	57 (75)	25 (73.5)	30 (88.2)	0.130
Disagree	34 (22.5)	19 (25)	9 (26.5)	4 (11.8)	

*p<0.05, chi-square test. There is no difference between groups with the same letter.

the first year. This difference may explain why preclinical dental students have significantly lower HU-DBI scores compared to other groups, while no significant difference is observed among the other groups.

The comparison of the HU-DBI knowledge, behavior, and attitude indexes between clinical and preclinical dental students showed a significant difference in the HU-DBI knowledge and attitude index, with clinical students exhibiting a higher score. However, no significant difference was found in the behavior index. A study was conducted on dental students in Germany, which revealed a notable difference only in the behavioral index, favoring clinical dental students.[20] Conversely, another investigation conducted on dental students in Estonia did not identify any significant distinction between clinical and preclinical dental students.[27]

In the present study, a comparison was made between the responses of clinical and preclinical dental students to HU-DBI questions. The findings revealed that a significantly higher proportion of preclinical dental students expressed concerns regarding the color of their teeth, reported not receiving prior instructions on proper tooth brushing techniques, relied on toothpaste for effective teeth cleaning, believed that gingival health could not be adequately maintained through brushing alone, visited the dentist only because of pain, and had not received prior affirmations from a dentist regarding their brushing proficiency. These differences in responses may be attributable to the completion of basic periodontology training and clinical training.

When the oral and dental health students were compared, it was seen that there was only a difference in item 15. More oral and dental health preclinical students than clinic students stated that they only go to the dentist when they have pain.

This study did not find any statistically significant difference in the HU-DBI scores between participants who consumed alcohol at least once a week and those who did not, consistent with the findings of Riad et al.[20] In the present study, 13.7% of all participants and 13.6% of dentistry students smoked at least once a week. This result is lower than the rate of smokers in previous studies conducted on dentistry students in Turkey.[15,28,29] However, a similar result was obtained from a study conducted in Estonia.[27] In the same previous study, the HU-DBI scores of smokers were significantly lower than those of nonsmokers. In contrast to the findings of the previous study, this study did not observe a significant effect of smoking on HU-DBI scores.

Previous studies have shown a positive correlation between parents' educational level and their children's oral hygiene practices.[30,31] Children with more educated parents tend to have better oral hygiene habits, indicating the significant influence of parental education and knowledge on developing these habits. However, in the present study, no statistically significant difference in HU-DBI scores was found based on the educational level of students' parents (p>0.05). Given that the study included dental and oral and dental health program students who were already educated about oral health, it can be inferred that their HU-DBI scores were not affected by their parents' educational background.

There is a commonly held belief that females have a greater propensity for attending to their physical well-being and maintaining their looks compared to males. A similar expectation is also anticipated about dental appointments and behaviors related to oral health. According to the study conducted by Ostberg et al.[32], it was observed that adolescent girls between the ages of thirteen and eighteen had superior performance on behavioral assessments and displayed a greater inclination toward oral health compared to boys within the same age group. Although it is an expected result that female students have higher HU-DBI scores, some studies do not find a relationship between HU-DBI scores and gender.[20,24,27] In contrast, a study in Romania revealed behavioral and attitude differences between genders among dental students.[25] In the present study, similar to this research, female students' overall HU-DBI scores and HU-DBI knowledge indexes were significantly higher than male students.

The present study aimed to assess dental students and oral and dental health program students in terms of oral health attitudes, knowledge, and behaviors. Additionally, the study attempted to identify the variables that may influence these factors. To our knowledge, no other study has evaluated the oral health knowledge, attitudes, and behaviors of oral and dental health program students before and after periodontology clinical training. Furthermore, there is a lack of investigation into the potential impact of variables such as urbanization and family education level on these outcomes.

The limitations of the study include the lack of a baseline evaluation before the initiation of basic periodontology training and the absence of a separate analysis of HU-DBI scores by class year among dental students. Additionally, the single-center design may restrict the generalizability of the findings to other institutions. The cross-sectional approach further limits the ability to establish causality or assess changes over time. Moreover, reliance on self-reported

Table 3. Comparison of oral health knowledge, attitudes, behaviors and overall HU-DBI score by the groups

		Preclinical dental students^X	Clinical dental students^X	Preclinical oral and dental health program students^X	Clinical oral and dental health program students^X	p*
Overall HU-DBI score	Mean ± SD	6 ± 1.57	7.25 ± 1.63	6.38 ± 1.41	6.62 ± 2.09	<0.001*
	Median(min-max)	6 (2 - 9)^a	7 (3 - 10)^b	6.5 (2 - 11)^{a,b}	7 (2 - 10)^{a,b}	
HU-DBI knowledge index	Mean ± SD	2.83 ± 1.11	3.53 ± 1.04	3 ± 1.04	3.26 ± 1.33	<0.001*
	Median (min-max)	3 (0 - 5)^a	4 (1 - 5)^b	3 (0 - 5)^{a,b}	4 (0 - 5)^{a,b}	
HU-DBI attitudes indexes	Mean ± SD	1.25 ± 0.62	1.8 ± 0.88	1.32 ± 0.53	1.38 ± 0.89	<0.001*
	Median(min-max)	1 (0 - 3)^b	2 (0 - 3)^a	1 (0 - 2)^{a,b}	1 (0 - 3)^{a,b}	
HU-DBI behaviour index	Mean ± SD	1.92 ± 0.7	1.92 ± 0.61	2.06 ± 0.6	1.97 ± 0.52	0.963
	Median(min-max)	2 (0 - 4)	2 (0 - 3)	2 (1 - 4)	2 (1 - 3)	

* $p<0.05$, Kruskal-Wallis H test. There is no difference between groups with the same letter.

data introduces the potential for response bias, as participants may overreport positive behaviors.

Conclusion

This study found that clinical dental students had higher oral health scores than preclinical dental students, underscoring the importance of introducing elements of preventive dentistry into the Turkish dental curriculum at an earlier stage to enhance the foundational knowledge and awareness of future dental professionals. However, there was no significant difference between clinical and preclinical oral and dental health program students. Female students also exhibited higher scores. This research provides insights into factors influencing dental and oral health attitudes among students and suggests the need for further investigation into the effectiveness of oral health education programs.

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Author Contributions

Conceived the concept and the protocol : Z.T.E.
Carried out the collection of data : T.Y.
Responsible for the supervision, data interpretation and critical editing : Z.T.E
Wrote the draft : Z.T.E
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Conflict of Interest

The authors declare that they have no competing interests.

Ethics Approval

The study, approved by the Ethics Committee for Non-Pharmaceutical and Medical Device Clinical Research (Decision no: 2022/241), was conducted in compliance with the protocols outlined in the 1975 Declaration of Helsinki, as amended in 2013

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References

1. Dogan B. Differences in oral health behavior and attitudes between dental and nursing students. Clin Exp Health Sci. 2013;3(1):34. doi:10.5455/musbed.20130102082831.
2. Kawamura M. Dental behavioral science. The relationship between perceptions of oral health and oral status in adults. Hiroshima Daigaku Shigaku Zasshi. 1988;20(2):273–286.
3. Kawamura M, Sasahara H, Kawabata K, Iwamoto Y, Konishi K, Wright FA. Relationship between CPITN and oral health behaviour in Japanese adults. Aust Dent J. 1993;38(5):381–388. doi:10.1111/j.1834-7819.1993.tb05520.x.
4. Kawamura M, Honkala E, Widstrom E, Komabayashi T. Cross-cultural differences of self-reported oral health behaviour in Japanese and Finnish dental students. Int Dent J. 2000;50(1):46–50. doi:10.1111/j.1875-595x.2000.tb00546.x.
5. Kawamura M, Iwamoto Y, Wright FA. A comparison of self-reported dental health attitudes and behavior between selected Japanese and Australian students. J Dent Educ. 1997;61(4):354–360.
6. Kawamura M, Spadafora A, Kim KJ, Komabayashi T. Comparison of United States and Korean dental hygiene students using the Hiroshima university-dental behavioural inventory(HU-DBI). Int Dent J. 2002;52(3):156–162. doi:10.1111/j.1875-595x.2002.tb00621.x.
7. Kawamura M, Yip HK, Hu DY, Komabayashi T. A cross-cultural comparison of dental health attitudes and behaviour among freshman dental students in Japan, Hong Kong and West China. Int Dent J. 2001;51(3):159–163. doi:10.1002/j.1875-595x.2001.tb00833.x.
8. Kim KJ, Komabayashi T, Moon SE, Goo KM, Okada M, Kawamura M. Oral health attitudes/behavior and gingival self-care level of Korean dental hygiene students. J Oral Sci. 2001;43(1):49–53. doi:10.2334/josnusd.43.49.
9. Barrieshi-Nusair K, Alomari Q, Said K. Dental health attitudes and behaviour among dental students in Jordan. Community Dent Health. 2006;23(3):147–151.
10. Polychronopoulou A, Kawamura M. Oral self-care behaviours: comparing Greek and Japanese dental students. Eur J Dent Educ. 2005;9(4):164–170. doi:10.1111/j.1600-0579.2005.00387.x.
11. Polychronopoulou A, Kawamura M, Athanasouli T. Oral self-care behavior among dental school students in Greece. J Oral Sci. 2002;44(2):73–78. doi:10.2334/josnusd.44.73.
12. SEN DO, Betul I, YARKAC FU, Elif O. Diş Hekimliği Fakültesi Öğrencilerinin Periodontal Farkındalığı, Ağız Sağlığına Yönelik Tutum ve Davranışlarının Değerlendirilmesi. NEU Dent J.

2020;2(1):14–24.
13. Yener O, Torumtay G, Dogan B. Dis hekimliginde yardimci personel egitimi: Dental implantlar ve biyomateryaller üzerine bir pilot calisma. BAUN Sag Bil Derg. 2012;1(2):59–64.
14. von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet. 2007;370(9596):1453–1457. doi:10.1016/S0140-6736(07)61602-X.
15. Yildiz S, Dogan B. Self reported dental health attitudes and behaviour of dental students in Turkey. Eur J Dent. 2011;5(3):253–259. doi:10.1055/s-0039-1698889.
16. Al-Wesabi AA, Abdelgawad F, Sasahara H, El Motayam K. Oral health knowledge, attitude and behaviour of dental students in a private university. BDJ Open. 2019;5:16. doi:10.1038/s41405-019-0024-x.
17. Kawamura M, Ikeda-Nakaoka Y, Sasahara H. An assessment of oral self-care level among Japanese dental hygiene students and general nursing students using the Hiroshima University–Dental Behavioural Inventory (HU-DBI): surveys in 1990/1999. Eur J Dent Educ. 2000;4(2):82–88. doi:10.1034/j.1600-0579.2000.040206.x.
18. Freire Mdo C, Jordao LM, de Paula Ferreira N, de Fatima Nunes M, Queiroz MG, Leles CR. Motivation towards career choice of Brazilian freshman students in a fifteen-year period. J Dent Educ. 2011;75(1):115–21. doi:10.1002/j.0022-0337.2011.75.1.tb05030.x.
19. Knevel RJ, Gussy MG, Farmer J, Karimi L. Nepalese dental hygiene and dental students' career choice motivation and plans after graduation: a descriptive cross-sectional comparison. BMC Med Educ. 2015;15:219. doi:10.1186/s12909-015-0500-5.
20. Riad A, Buchbender M, Howaldt HP, Klugar M, Krsek M, Attia S. Oral Health Knowledge, Attitudes, and Behaviors (KAB) of German Dental Students: Descriptive Cross-Sectional Study. Front Med (Lausanne). 2022;9:852660. doi:10.3389/fmed.2022.852660.
21. Tanalp J, Ilguy D, Dikbas I, Oktay I. Demographic profile and future expectations of students enrolled in a Turkish private dental school. J Dent Educ. 2012;76(6):800–809. doi:10.1002/j.0022-0337.2012.76.6.tb05316.x.
22. Knevel R, Gussy MG, Farmer J, Karimi L. Perception of Nepalese dental hygiene and dentistry students towards the dental hygienists profession. Int J Dent Hyg. 2017;15(3):219–228. doi:10.1111/idh.12192.
23. Marino RJ, Morgan MV, Winning T, Thomson WM, Marshall RI, Gotjamanos T, et al. Sociodemographic backgrounds and career decisions of Australian and New Zealand dental students. J Dent Educ. 2006;70(2):169–178. doi:10.1002/j.0022-0337.2006.70.2.tb04073.x.
24. Badovinac A, Bozic D, Vucinac I, Vesligaj J, Vrazic D, Plancak D. Oral health attitudes and behavior of dental students at the University of Zagreb, Croatia. J Dent Educ. 2013;77(9):1171–1178. doi:10.1002/j.0022-0337.2013.77.9.tb05589.x.
25. Dumitrescu AL, Kawamura M, Sasahara H. An assessment of oral self-care among Romanian dental students using the Hiroshima University–Dental Behavioural Inventory. Oral Health Prev Dent. 2007;5(2):95–100.
26. Pacauskiene IM, Smailiene D, Siudikienė J, Savanevskyte J, Nedzelskiene I. Self-reported oral health behavior and attitudes of dental and technology students in Lithuania. Stomatologija. 2014;16(2):65–71.
27. Riad A, Pold A, Olak J, Howaldt HP, Klugar M, Krsek M, et al. Estonian Dental Students' Oral Health-Related Knowledge, Attitudes and Behaviours (KAB): National Survey-Based Study. Int J Environ Res Public Health. 2022;19(3):1908. doi:10.3390/ijerph19031908.
28. Gurlek O, Baser U, Beklen A, Guncu GN, Hakki SS, Haytac MC, et al. The rate of tobacco smoking among dental school students in Turkey. Ege univ dis hekim fak derg. 2019;40(3):185–191. doi:10.5505/eudfd.2019.49379.
29. Peker I, Alkurt MT. Oral Health Attitudes and Behavior among a Group of Turkish Dental Students. Eur J Dent. 2009;3(1):24–31. doi:10.1055/s-0039-1697402.
30. Al Mejmaj DI, Nimbeni SB, Alrashidi RM. Association between Demographic Factors Parental Oral Health Knowledge and their Influences on the Dietary and Oral Hygiene Practices followed by Parents in Children of 2-6 Years in Buraidah City Saudi Arabia: A Pilot Study. Int J Clin Pediatr Dent. 2022;15(4):407–411. doi:10.5005/jp-journals-10005-2409.
31. Chen L, Hong J, Xiong D, Zhang L, Li Y, Huang S, et al. Are parents' education levels associated with either their oral health knowledge or their children's oral health behaviors? A survey of 8446 families in Wuhan. BMC Oral Health. 2020;20(1):203. doi:10.1186/s12903-020-01186-4.
32. Ostberg AL, Halling A, Lindblad U. Gender differences in knowledge, attitude, behavior and perceived oral health among adolescents. Acta Odontol Scand. 1999;57(4):231–236. doi:10.1080/000163599428832.

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ORIGINAL RESEARCH ARTICLE

Determination of Gingival Phenotype and Gingival Recession Type in Patients Postorthodontic Treatment

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Abstract

Purpose: Gingival recession is a commonly reported symptom following orthodontic treatment, for which identification is crucial to therapeutic management. This study aimed to determine the frequency of recession occurring after orthodontic treatment, assess the gingival phenotype in patients with recession, and investigate the various types of recession.

Materials and Methods: This study involved 80 patients aged 18-65 years who had completed fixed orthodontic treatment, and they were categorized into two groups based on the presence of gingival recession. Periodontal indices were obtained for all patients. Patients with gingival recession had assessments taken for gingival recession depth, gingival recession width, gingival tissue thickness, and keratinized gingival width. Statistical analyses were performed with a significance level of $p<0.05$ to compare participants with and without gingival recession.

Results: Patients with gingival recession exhibited significantly lower rates of gingivitis than those without gingival recession. Tooth number 31 exhibited the highest incidence of gingival recession, at 31.2%. Gingival recession was observed in 93.5% of Cairo Class 1 patients. Among the participants, 51.9% had a thin gingival phenotype, while 48.1% had a thick phenotype.

Conclusions: To minimize the risk of gingival recession and maintain periodontal health, the study highlights the need for careful evaluation and preventive actions throughout and following orthodontic treatment.

Keywords: Gingival recession; Gingivitis; Orthodontics

Introduction

The apical displacement of the gingival margin concerning the cementoenamel junction is known as gingival recession.[1] Gingival recession during orthodontic tipping and translational motions might result from a narrowed mandibular symphysis, a narrower free gingival margin, inadequate plaque control, and aggressive tooth brushing.[2] The gingival phenotype, which includes the gingiva's thickness and the keratinized tissue's width, determines the periodontal phenotype. Gingival thickness can be assessed and classified as either thick or thin, based on direct measurements following the criteria established by Seibert and Lindhe.[3] Furthermore, maintaining at least 2 mm of keratinized gingiva and 1 mm of attached gingiva is essential for preserving periodontal health and stability.[4]

In order to arrange orthodontic therapy for any malocclusion, it is necessary to ascertain the kind and order of tooth movements. This can include comprehensive orthodontic treatment, which focuses on correcting the malocclusion completely, or adjunctive orthodontic treatment, which moves teeth to improve a particular aspect of the occlusion to support other dental procedures meant to control disease and restore function.[5] Orthodontic therapy can correct tooth misalignment resulting from periodontitis, but it may also have adverse consequences on periodontal soft tissues, including gingivitis, gingival enlargement, and gingival recession.[6] Applying too much pressure on the periodontal ligament might result in crushing, restricted blood flow, deterioration, and delayed movement of the tooth. Applying a moderate amount of force slows down the process of bone resorption caused by ligament strangling. On the other hand, applying a modest amount of force leads to reduced blood supply but still allows for both bone resorption and tooth movement to occur simultaneously.[5] During orthodontic therapy, gingival recession can be significantly influenced by the direction of tooth movement and the thickness of the gingiva.[7] The prevalence of gingival recession during orthodontic treatment is significantly related to gingival tissue biotype, the depth of attached tissue, pro-inclination, considerable maxillary expansion, and vestibular inclination tooth movement.[8] Dorfman et al. (1978) indicated that gingival recession is mostly noticed in teeth with a greater degree of inclination compared to teeth with a lesser degree of inclination.[9] Alterations in the position of the lower incisors, particularly an extreme forward inclination, following orthodontic treatment, might potentially contribute to the occurrence of

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gingival recession.[10] More severe gingival recession is more likely when there is incisor retroclination with mesial basal connections and a decrease in the sagittal intermaxillary angle.[11] Contrary to non-proclined teeth, mandibular incisors that are proclined did not exhibit a higher likelihood of gingival recession throughout a five-year period of observation.[12] Similarly, in another study, the change in lower incisor inclination during treatment did not affect the development of labial gingival recessions in a patient; similarly.[13] Irrespective of the orthodontic treatment approach, having more keratinized gingival height, a wider mandibular symphysis, and a larger intercanine width after treatment are linked to a lower likelihood of developing gingival recession. On the other hand, a greater arch depth is associated with a higher risk of gingival recession. Moreover, opting for nonextraction therapy is linked to a higher probability of experiencing gingival recession.[14] There was no association between gingival recession and pretreatment angle classification, ANB angle, overjet, overbite, arch width, or mandibular divergence.[15]

Orthodontic treatment has many consequences. The study's null hypothesis is that there is no relationship between posttreatment gingival phenotype and gingival recession and no differences among different types of gingival recession in patients who underwent orthodontic treatment. This study aimed to determine the posttreatment gingival recession status, gingival phenotype (if gingival recession was present), and type of recession in patients who underwent orthodontic treatment.

Material and Methods

Study settings

The Bolu Abant Izzet Baysal University Clinical Research Ethics Committee authorized the protocol (2022/167), and the study was carried out in compliance with the Declaration of Helsinki. Each participant was thoroughly informed about the study's aims, the questionnaire, and the principles of the Helsinki Declaration[16], and subsequently provided written informed consent. Information regarding compliance with the STROBE guidelines for cross-sectional studies is provided. The research focused on individuals with gingival recession and was conducted at the Periodontology Department of the Faculty of Dentistry from July 2022 to January 2024.

Study population calculations

The power analysis conducted using the G Power program (G * Power 3.1 software, Heinrich Heine University, Germany) for the t-test determined that a minimum of 80 participants in total, with 40 participants in each subgroup, were required to achieve a power level of 0.85 (1-β), an effect size of 0.60 (d), and a margin of error (α) of 0.05.

Eligibility criteria

Inclusion criteria
Patients aged 18-65 years who had completed fixed orthodontic treatment were included in the study.

Exclusion criteria
Exclusion criteria included uncontrolled diabetes, use of radiotherapy, chemotherapy, or immunosuppressants, tobacco use, pregnancy and lactation, and any etiology of gingival recession other than orthodontic treatment. The study did not include patients involved in Invisalign (Align Technology, Arizona, USA) functional or lingual fixed orthodontics.

Study design

The study comprised a cohort of eighty patients aged eighteen to sixty-five who had just completed treatment at the Orthodontic Clinic. The patients were categorized into two groups based on the presence of gingival recession: a group with gingival recession (n = 40) and a group without gingival recession (n = 40). Information about demographic characteristics (age, sex), anthropometric measurements (height and weight), and health status (systemic status and medication use) was obtained from the patients.

Measurement of periodontal status and gingival recession

A single calibrated examiner (T.S.) conducted the clinical oral examination, including teeth evaluation. The evaluation performed on all subjects included the following measurements: plaque index[17], gingival index[18], bleeding on probing[19], clinical attachment level, and probing pocket depth. The probing measurements were done using a manual UNC-15 periodontal probe (PCP15; Hu-Friedy, Chicago, IL, USA) at each tooth. The gingival and plaque indices were assessed using a scale ranging from zero to three. The occurrence or non-occurrence of bleeding was assessed for each tooth following probing. The probing depth, assessed at six locations in each tooth, is defined as the distance from the bottom of the gingival sulcus to the edge of the gingival margin. In the group with gingival recession, the Cairo classification[20], gingival thickness (mm), keratinized gingival width (mm), gingival recession depth (mm), gingival recession width (mm), presence/absence of enamel-cementum junction (+/-), and presence/absence of cervical step (+/-) were determined.

The gingiva was anesthetized using a topical anesthetic. An endodontic file size 06 with a rubber stop/caliper was inserted perpendicularly at a point centered between the gingival margin and the mucogingival junction. This measurement was taken with a periodontal probe. The width of the keratinized gingiva was determined by measuring the distance from the mucogingival junction to the free gingival margin, extending from the most apical point of the margin to the mucogingival edge.

Statistical method

The statistical analyses were conducted using IBM SPSS Statistics (Version 26.0, Armonk, NY: IBM Corp.). Categorical data were presented as numbers and percentages. Independent sample t-tests were used to compare measurement data, as well as age, height, and weight, between the two groups. Statistical significance was set at $p<0.05$.

Results

Demographic characteristics

The age, sex, height, and weight distribution were similar between the groups with and without gingival recession. A total of 27.5% of the patients were male, and 72.5% were female (Table 1).

Periodontal indices and condition

Patients with gingival recession had a significant difference in periodontal health and gingivitis compared to those without this condition ($p<0.05$). Patients without gingival recession had a higher rate of gingivitis compared to those with gingival recession.

A statistically significant difference was observed between the groups concerning the gingival index, bleeding on probing, gingival recession, and attachment loss ($p<0.05$). There was no statistically

Table 1. Demographic characteristics of patients

		f	%
Gender	Male	22	27.5
	Female	58	72.5
	N	Median (Min./Max.)	Mean±S.d.
Age	80	20(18/58)	21.28±6.35
Height	80	168(153/187)	167.83±8.44
Weight	80	58.5(42/100)	60.76±11.83

f: frequency, Frequency and descriptive analysis used for demographic characteristics of patients.

significant difference between the groups regarding the plaque index or probing depth (p>0.05) (Table 2).

Gingival recession status

In the gingival recession group, 77 teeth from 40 patients were examined. The results indicated that the highest number of teeth with recession were tooth 31 (31.2%), tooth 41 (20.8%), and tooth 42 (13%). When the seventy-seven teeth were evaluated using the Cairo Classification, 93.5% were in Cairo Class 1, 5.2% were in Cairo Class 2, and 1.3% were in Cairo Class 3. Assessment of gingival thickness showed that 51.9% of patients had a thickness of 1mm, 41.6% had a thickness of 2mm, 5.2% had a thickness of 3mm, and 1.3% had a thickness of 4mm. Upon evaluating the gingival biotype classification, 51.9% of the patients were categorized as having a thin biotype, while 48.1% had a thick biotype. Regarding the identifiable cemento-enamel junction classification, 84.4% of the patients fell into Category A, and 15.6% into Category B. When the root surface step was evaluated, 45.5% of the patients were in the plus category, and 54.5% were in the minus category (Table 3).

The mean gingival recession depth of the 77 teeth examined in patients with gingival recession was 1.55±1.10 mm. The mean gingival recession width was 2.79±0.86 mm. The mean width of the keratinized gingiva was 3.53±1.96 mm (Table 4).

Discussion

The objectives of this research were to determine the incidence of gingival recession following orthodontic treatment, evaluate the gingival phenotype in patients experiencing recession, and examine the different types of recession. The study's null hypothesis posits no association between post-treatment gingival phenotype and gingival recession, nor are there any differences among various types of gingival recession in patients who have undergone orthodontic treatment. In this study, gingival recession after orthodontics was mostly seen in teeth 31, 41, and 42, Cairo 1 classification, and a thin gingival phenotype.

Orthodontic treatment can adversely affect mucogingival conditions. Patients with a thin gingival phenotype may experience recession problems as a result of labial tooth movement, namely the forward positioning of mandibular incisors. Postorthodontic tooth position changes can arise from non-passive retention devices, leading to increased recession defects and root exposure.[21] A comprehensive analysis of seven trials revealed no association between the movement of the mandibular incisor teeth produced by dental appliances and the occurrence of gingival recession. Contributing factors to gingival recession following orthodontic tipping and translation movements include a thinner free gingival margin, a narrow mandibular symphysis, poor plaque control, and vigorous tooth brushing.[2] In their study, Rankeme et al. (2013) documented a rise in the occurrence of gingival recession on both the labial/buccal and lingual/palatinal of the teeth following orthodontic therapy.[22] Gebistorf et al. (2018) found that there was a rise in the occurrence of labial/buccal gingival recession after orthodontic treatment. Specifically, 54.5% of the participants reported at least one site of recession, while 10.2% had multiple recession sites following the treatment.[23] After undergoing treatment with fixed orthodontic appliances, two hundred fifty-one individuals had a significant increase in gingival recession in another study.[24] Sandhu et al. (2018) observed a notable rise in gingival recession among thirty-eight patients who underwent fixed orthodontic treatment.[25] In another study, the average gingival recession scores were 0.19 before and 0.383 after treatment.[26] After completing the therapy, adults saw a significant increase in the average levels of visible gingival inflammation and recession. On the other hand, teenagers exhibited similar increases in visible plaque and inflammation.[27] In addition, another study discovered that the occurrence of gingival recession after orthodontic treatment was 10.3%.[11] An analysis of sixteen research found that 10 of them documented a significant occurrence of gingival recession after orthodontic treatment.[15] However, there is insufficient evidence to suggest that fixed orthodontic treatment might cause or elevate the likelihood of gingival recession in another research investigation.[28] There was no noticeable rise in the average number of teeth experiencing gingival recession over the duration of therapy. Nevertheless, the frequency of gingival recession with a depth above 0.1 mm increased from 21% prior to treatment to 35% following the therapy. Only 2.8% of the participants had a gingival recession depth that was above 2 mm, while 5% of patients with previous gingival recession showed improvement.[29] In this study, gingival recession was observed in 77 teeth of the 80 patients.

Orthodontic therapy and the subsequent retention period provide a potential risk of developing labial gingival recession, with mandibular incisors being particularly vulnerable in individuals undergoing orthodontic treatment.[12] Gingival recession is most prevalent in the upper and lower teeth due to the majority of orthodontic tooth movements occurring in these regions.[30] Sawan et al. (2017) reported that 87% of patients exhibited gingival recession in at least one upper or lower anterior tooth following orthodontic expansion or extraction.[14] In a different study, maxillary and mandible canine teeth were observed to have the highest percentage of occurrence of gingival recession after orthodontic treatment.[24] This study showed that teeth numbers 31, 41, and 42 had the highest levels of gingival recession.

The inclination of the lower incisors at the end of treatment did not affect the occurrence of labial gingival recession or any changes in the height of the clinical crown in patients.[31] Studies on animals often demonstrate that incisors that are displaced show more gingival recession than control teeth. Clinical studies indicate that teeth that are more proclined than less proclined, untreated teeth, and incisors that relocate out the osseous membrane of the alveolar process may be related to a higher risk of gingival recession.[32] Gingival recession and tooth inclination were significantly correlated; gingival recession increased by around 0.2 mm for every 1° increase in labial tooth inclination.[33] In contrast to patients with normal incisor inclination, those whose lower incisors proclined more than 95° after orthodontic therapy showed an apical migration of the gingival zenith.[10] The degree of extent of proclination of the mandibular central incisors during fixed appliance therapy did not show any correlation with the gingival recession in this study.[11,34]

According to Sandhu et al. (2018), following fixed orthodontic treatment, the gingival biotype was unchanged.[25] Böke et al. (2014) conducted a study involving 251 patients with fixed orthodontic appliances, showing that orthodontic treatment had no significant impact on gingival biotype values.[24] The change in the values of gingival biotypes before and after treatment does not show a meaningful difference in another study.[27] Conversely, Kumar et al. (2020) observed that the gingival biotype was present in both the maxillary and mandibular arches, noting an increase in the thick gingival biotype and a decrease in the thin maxillary biotype.[26] When examining the gingival biotype categorization of patients

Table 2. Comparison of indices of patients according to groups

		N	Median (Min/Max)	Mean±S.D.	p
Plaque Index	No gingival recession	40	0.20 (0.0 /2.00)	0.30±0.45	0.441
	Gingival recession	40	0.10 (0.0/2.05)	0.23±0.38	
Gingival Index	No gingival recession	40	0.02 (0.0/2.00)	0.22±0.48	0.011*
	Gingival recession	40	0.00 (0.00/0.20)	0.02±0.04	
Probing Depth	No gingival recession	40	2.03 (0.04/2.90)	1.99±0.54	0.896
	Gingival recession	40	2.01 (0.20/3.00)	2.01±0.52	
Bleeding on Probing	No gingival recession	40	9.0% (0.0%/80.0%)	15.59%±17.85%	0.025*
	Gingival recession	39	3.0% (0.0%/58.0%)	7.67%±12.36%	
Clinical Attachment level	No gingival recession	40	2.01(0.0/2.90)	1.91±0.65	0.028*
	Gingival recession	40	2.04 (1.43/3.20)	2.17±0.37	

Min: minimum, Max: maximum, S.D.: standard deviation *:p<0.05 İndependent sample t test used for comparing the effects of the gingival recession on indices

Table 3. Assessment of gingival recession

		f	%
Tooth number	13	1	1.3
	14	1	1.3
	23	2	2.6
	26	2	2.6
	31	24	31.2
	32	6	7.8
	33	4	5.2
	34	1	1.3
	41	16	20.8
	42	10	13.0
	43	6	7.8
	44	2	2.6
	45	1	1.3
	46	1	1.3
Cairo classification	1	72	93.5
	2	4	5.2
	3	1	1.3
Gingival thickness	1	40	51.9
	2	32	41.6
	3	4	5.2
	4	1	1.3
Gingival biotype	Thin	40	51.9
	Thick	37	48.1
Cemento-enamel junction (A/B)	A	65	84.4
	B	12	15.6
Root surface step (+/-)	Plus	35	45.5
	Minus	42	54.5

f: frequency, Frequency analysis used for showing assessment of gingival recession

Table 4. Evaluation of the etiology of recession in patients with gingival recession

	Median (Min/Max)	Mean±S.D.
Gingival Recession Depth	1(0.5/8.0)	1.55±1.10
Gingival Recession Width	3(1/5)	2.79±0.86
Keratinized Gingival Width	3(0/8)	3.53±1.96

Min: minimum, Max: maximum, s.d.: standard deviation Descriptive analysis was used to evaluate the etiology of gingival recession in patients with this condition.

with gingival recession in this study, it was found that 51.9% had the thin biotype, whereas 48.1% had the thick biotype.

It has been argued that a minimum band of keratinized tissue (2 mm) may be essential for preventing gingival recession development/progression.[4] Dorfman et al. (1978) stated that gingival recession is mostly noticed in teeth that are more inclined forward compared to teeth that are less inclined forward.[9] In another study, a significant increase in the height of the keratinized gingiva was observed after treatment.[14] Abdelhafez et al. (2021) reported a difference in the amount of keratinized gingiva in patients who underwent orthodontic treatment compared to those who did not.[35] Contrary to these findings, there was no difference in the initial amount of keratinized gingiva between teeth that developed gingival recession and those with unchanged gingival margin positions (3.00 ± 0.61 mm and 3.5 ± 0.86 mm, respectively).[36] In this study, the mean keratinized gingival width was 3.53±1.96 mm.

Böke et al. (2014) reported a significant post-treatment increase in visible plaque and inflammation among patients with fixed orthodontic appliances.[24] After undergoing treatment with fixed orthodontic equipment, a considerable rise in visible plaque, visible inflammation, and gingival recession is observed in the patient. Specifically, visible plaque rose from 2.95 mm to 5.94 mm, and visible inflammation from 2.86 mm to 10.52 mm.[25] Some studies revealed that the average visible plaque and inflammation significantly increased during orthodontic treatment.[26,27] Furthermore, persons who had previously had orthodontic treatment had a lower prevalence of periodontitis.[37] Although fixed orthodontic treatment increases visible plaque and inflammation, gingival recession appears to correlate with lower gingival index values and reduced bleeding, possibly indicating a protective factor against periodontitis.

This study's limitations include being done at a single institution and having a very small sample size of 80 patients, which may limit the findings' generalizability. The cross-sectional design limits the ability to establish causal relationships, necessitating cautious interpretation of the results. Future studies should be designed as multi-center trials with larger sample sizes to enhance the generalizability and robustness of the findings.

Conclusion

This study underscores the significant impact of orthodontic treatment on periodontal health, gingival recession, and gingival biotype. These findings emphasize the need for diligent monitoring and preventive strategies during and after orthodontic therapy to reduce the risk of gingival recession and support periodontal health.

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Author Contributions

Found study idea/hypothesis : T.S.
Study design : T.S.
Collected data : T.S.
Analysis and/or interpretation of results : T.S.
Wrote article : T.S.
Critical review. : T.S.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethics Approval

The Bolu Abant Izzet Baysal University Clinical Research Ethics Committee authorized the protocol (2022/167), and the study was carried out in compliance with the Declaration of Helsinki. Each participant was thoroughly informed about the study's aims, the questionnaire, and the principles of the Helsinki Declaration, and subsequently provided written informed consent.

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References

1. Periodontology AAo. Glossary of Periodontal Terms. American Academy of Periodontology; 1992.
2. Aziz T, Flores-Mir C. A systematic review of the association between appliance-induced labial movement of mandibular incisors and gingival recession. Aust Orthod J. 2011;27(1):33–39. doi:10.2478/aoj-2011-0007.
3. Lindhe J. Textbook of Clinical Periodontology. John Wiley & Sons, Limited; 1989.
4. Lang NP, Löe H. The relationship between the width of keratinized gingiva and gingival health. J Periodontol. 1972;43(10):623–627. doi:10.1902/jop.1972.43.10.623.
5. Ong MM, Wang HL. Periodontic and orthodontic treatment in adults. Am J Orthod Dentofacial Orthop. 2002;122(4):420–428. doi:10.1067/mod.2002.126597.
6. Liu Y, Li CX, Nie J, Mi CB, Li YM. Interactions between Orthodontic Treatment and Gingival Tissue. Chin J Dent Res. 2023;26(1):11–18. doi:10.3290/j.cjdr.b3978667.
7. Kim DM, Neiva R. Periodontal soft tissue non-root coverage procedures: a systematic review from the AAP Regeneration Workshop. J Periodontol. 2015;86(2 Suppl):S56–572. doi:10.1902/jop.2015.130684.
8. Saravanan R, Neelofar Begum A, Helen Gracy M. Orthodontic Treatment Induced Gingival Recession- A Review on Impact and Treatment Outcomes. IJRAMR. 2021;2(8):81–84.
9. Dorfman HS. Mucogingival changes resulting from mandibular incisor tooth movement. Am J Orthod. 1978;74(3):286–297. doi:10.1016/0002-9416(78)90204-x.
10. Ciavarella D, Tepedino M, Gallo C, Montaruli G, Zhurakivska K, Coppola L, et al. Post-orthodontic position of lower incisors and gingival recession: A retrospective study. J Clin Exp Dent. 2017;9(12):e1425–e1430. doi:10.4317/jced.54261.
11. Vasconcelos G, Kjellsen K, Preus H, Vandevska-Radunovic V, Hansen BF. Prevalence and severity of vestibular recession in mandibular incisors after orthodontic treatment. Angle Orthod. 2012;82(1):42–47. doi:10.2319/021411-108.1.
12. Renkema AM, Fudalej PS, Renkema AA, Abbas F, Bronkhorst E, Katsaros C. Gingival labial recessions in orthodontically treated and untreated individuals: a case - control study. J Clin Periodontol. 2013;40(6):631–637. doi:10.1111/jcpe.12105.
13. Renkema AM, Fudalej PS, Renkema A, Bronkhorst E, Katsaros C. Gingival recessions and the change of inclination of mandibular incisors during orthodontic treatment. Eur J Orthod. 2013;35(2):249–255. doi:10.1093/ejo/cjs045.
14. Sawan NM, Ghoneima A, Stewart K, Liu S. Risk factors contributing to gingival recession among patients undergoing different orthodontic treatment modalities. Interv Med Appl Sci. 2018;10(1):19–26. doi:10.1556/1646.9.2017.42.
15. Cadenas de Llano-Pérula M, Castro AB, Danneels M, Schelfhout A, Teughels W, Willems G. Risk factors for gingival recessions after orthodontic treatment: a systematic review. Eur J Orthod. 2023;45(5):528–544. doi:10.1093/ejo/cjad026.
16. Emanuel EJ. Reconsidering the Declaration of Helsinki. Lancet. 2013;381(9877):1532–1533. doi:10.1016/s0140-6736(13)60970-8.
17. Silness J, Löe H. Periodontal Disease in Pregnancy II. Correlation Between Oral Hygiene and Periodontal Condition. Acta Odontologica Scandinavica. 1964;22(1):121–135. doi:10.3109/00016356408993968.
18. Loe H, Silness J. PERIODONTAL DISEASE IN PREGNANCY. I. PREVALENCE AND SEVERITY. Acta Odontol Scand. 1963;21:533–551. doi:10.3109/00016356309011240.
19. Ainamo J, Bay I. Problems and proposals for recording gingivitis and plaque. Int Dent J. 1975;25(4):229–235.
20. Cairo F, Nieri M, Cincinelli S, Mervelt J, Pagliaro U. The interproximal clinical attachment level to classify gingival recessions and predict root coverage outcomes: an explorative and reliability study. J Clin Periodontol. 2011;38(7):661–666. doi:10.1111/j.1600-051X.2011.01732.x.
21. Jepsen K, Sculean A, Jepsen S. Complications and treatment errors involving periodontal tissues related to orthodontic therapy. Periodontol 2000. 2023;92(1):135–158. doi:10.1111/prd.12484.
22. Renkema AM, Fudalej PS, Renkema A, Kiekens R, Katsaros C. Development of labial gingival recessions in orthodontically treated patients. Am J Orthod Dentofacial Orthop. 2013;143(2):206–212. doi:10.1016/j.ajodo.2012.09.018.
23. Gebistorf M, Mijuskovic M, Pandis N, Fudalej PS, Katsaros C. Gingival recession in orthodontic patients 10 to 15 years posttreatment: A retrospective cohort study. Am J Orthod Dentofacial Orthop. 2018;153(5):645–655. doi:10.1016/j.ajodo.2017.08.020.
24. Boke F, Gazioglu C, Akkaya S, Akkaya M. Relationship between orthodontic treatment and gingival health: A retrospective study. Eur J Dent. 2014;8(3):373–380. doi:10.4103/1305-7456.137651.
25. Kumar V, Singh P, Arora VK, Kaur S, Sarin S, Singh H. Assessment of Effect of Orthodontic Treatment on Gingival Health: A Clinical Study. J Pharm Bioallied Sci. 2018;6(6):5–7. doi:10.4103/jpbs.JPBS_589_20.
26. Kumar V, Singh P, Arora VK, Kaur S, Sarin S, Singh H. Assessment of Effect of Fixed Orthodontic Treatment on Gingival Health: An Observational Study. J Pharm Bioallied Sci. 2021;13(Suppl 1):S425–s428. doi:10.4103/jpbs.JPBS_589_20.
27. Karacaoglu F, Gazioglu C, Akkaya S, Akkaya M. Are the effects of fixed orthodontic treatment on gingival health similar in adolescents and young adults. J Biomed Sci. 2016;6(1):5. doi:10.4172/2254-609X.100049.
28. Crego-Ruiz M, Jorba-García A. Assessment of the periodontal health status and gingival recession during orthodontic treatment with clear aligners and fixed appliances: A systematic review and meta-analysis. Med Oral Patol Oral Cir Bucal. 2023;28(4):e330–e340. doi:10.4317/medoral.25760.
29. Melsen B, Allais D. Factors of importance for the development of dehiscences during labial movement of mandibu-

lar incisors: a retrospective study of adult orthodontic patients. Am J Orthod Dentofac Orthop. 2005;127(5):552–561. doi:10.1016/j.ajodo.2003.12.026.

30. Randhawa GK. Correlation between Orthodontic Treatment and Periodontitis- A Clinical Study. J Adv Med Dent Scie Res. 2018;6(1):110–113. doi:10.21276/jamdsr.
31. Renkema AM, Navratilova Z, Mazurova K, Katsaros C, Fudalej PS. Gingival labial recessions and the post-treatment proclination of mandibular incisors. Eur J Orthod. 2015;37(5):508–513. doi:10.1093/ejo/cju073.
32. Joss-Vassalli I, Grebenstein C, Topouzelis N, Sculean A, Katsaros C. Orthodontic therapy and gingival recession: a systematic review. Orthod Craniofac Res. 2010;13(3):127–141. doi:10.1111/j.1601-6343.2010.01491.x.
33. Lee JB, Baek SJ, Kim M, Pang EK. Correlation analysis of gingival recession after orthodontic treatment in the anterior region: an evaluation of soft and hard tissues. J Periodontal Implant Sci. 2020;50(3):146–158. doi:10.5051/jpis.2020.50.3.146.
34. Djeu G, Hayes C, Zawaideh S. Correlation between mandibular central incisor proclination and gingival recession during fixed appliance therapy. Angle Orthod. 2002;72(3):238–245.
35. Abdelhafez RS, Talib AA, Al-Taani DS. The effect of orthodontic treatment on the periodontium and soft tissue esthetics in adult patients. Clin Exp Dent Res. 2022;8(1):410–420. doi:10.1002/cre2.480.
36. Closs LQ, Branco P, Rizzatto SD, Raveli DB, Rösing CK. Gingival margin alterations and the pre-orthodontic treatment amount of keratinized gingiva. Braz Oral Res. 2007;21(1):58–63. doi:10.1590/s1806-83242007000100010.
37. Sim HY, Kim HS, Jung DU, Lee H, Lee JW, Han K, et al. Association between orthodontic treatment and periodontal diseases: Results from a national survey. Angle Orthod. 2017;87(5):651–657. doi:10.2319/030317-162.1.

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CASE REPORT

Three-Year Outcomes of Combined Autotransplantation and Regenerative Endodontic Treatment of an Immature Tooth: A Case Report

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Abstract

Autotransplantation and regenerative endodontic treatment are biologically based dental treatment modalities. Autotransplantation may be a more affordable alternative to implants for patients who experience tooth loss at a young age. Regenerative endodontic treatment is also an alternative to routine endodontic treatment as it can allow the regeneration of necrotic or inflamed pulp tissue. The aim of this case is to report a successful 3-year treatment outcome in an immature tooth using a combination of autotransplantation and regenerative endodontic treatment. An 18-year-old female patient with complaints of severe pain and mobility at 37. The patient's medical history revealed no systemic disease. Clinical and radiographic examination revealed that 37 had undergone root canal treatment 3 years ago. Retreatment of the root canal was initiated, but the symptoms did not improve despite interm treatment. After surgical consultation, it was decided to extract 37. For autotransplantation, 38 was extracted atraumatically and autotransplanted into the socket of 37 and splinted for 2 weeks. Regenerative endodontic treatment was planned due to the radiolucency observed in the periapical area of the tooth at the 6-month follow-up. Regenerative endodontic treatment was performed on the autotransplanted tooth using platelet-rich fibrin obtained from the patient's own blood. The tooth remained asymptomatic and functional for 3 years. Root development continued and periapical healing was complete at 6 months. The tooth showed a positive response to pulp sensitivity tests at the 1-year follow-up. The combination of autotransplantation and regenerative endodontic treatment can be considered as a long-term treatment option for immature teeth.

Keywords: Autotransplantation; Platelet-rich fibrin; Regeneration; Revascularisation; Vital pulp therapy

Introduction

While the primary goal of conservative dentistry is to preserve natural teeth, tooth extraction may be necessary in some cases. Replacement of lost teeth is essential to restore chewing function and aesthetic appearance. Implant-supported prostheses or autotransplantation may be considered as alternatives to traditional prostheses to replace extracted teeth.[1] Dental implants are not a suitable option before the completion of growth, typically up to the age of 19 years in females and 21 years in males, as they cannot follow craniofacial growth and maintain their position during ongoing development.[2,3] However, tooth loss due to trauma or decay is more common in young adults.[4,5] Therefore, autotransplantation can be an excellent alternative for these patients. Autotransplantation involves the surgical repositioning of a tooth from the same patient to replace a missing tooth. It can be thought of as the controlled extraction of a tooth followed by its reinsertion into the extraction socket, either naturally or under the control of the dentist. The preservation of the attached gingiva in its natural shape provides better aesthetic results and preservation of proprioception, which are the main advantages of the procedure.[6,7] It also has a lower rate of bone resorption and is relatively less expensive than implants.[8]

The use of dental autotransplantation was first introduced into dentistry by M.L. Hale in 1954, and the basic principles are still used today.[9] Initially, the treatment was not widely accepted due to a success rate of around 50%.[10,11] However, in the last fifteen years, with the recognition of the need for atraumatic extraction and endodontic treatment during the procedure, success rates have increased and the popularity of the procedure has grown. Today, tooth transplantation is considered an alternative treatment to implants for replacing edentulous areas. However, many factors influence the success and survival of the tooth. These include the stage of root completion, tooth type, surgical technique, recipient site preparation, use of perioperative systemic antibiotics, and type and

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duration of splinting.[10] It has been reported that open apex teeth may allow neurovascular growth after tooth transplantation, leading to improved vitality and survival rates.[12] Another clinical trial reported survival rates of 94% and 84% in teeth with incomplete and complete root formation, respectively.[13]

Regenerative endodontic treatment, like dental autotransplantation, is a biologically based dental treatment for dental tissue loss in young adults and children.[14] Regenerative endodontic treatment, also known as revascularisation, aims to treat inflamed or necrotic open apex permanent teeth by respecting the biology of the pulp-dentine complex.[15] In open apex permanent teeth, the primary goal of regenerative endodontics is to eliminate symptoms and heal periapical lesions, with the additional goals of maintaining or regaining vitality and promoting root development.[16]

Regenerative endodontics requires three main components: stem cells capable of differentiating into odontoblast-like cells, growth factors that direct the differentiation of stem cells into odontoblast-like cells, and scaffold structures necessary to organise these cells in the right place in three dimensions.[17] Therefore, materials such as calcium hydroxide, MTA, Biodentin and EDTA, which induce the release of growth factors from the root canal, are preferred in regenerative endodontic treatments.[18] The most common method of scaffolding is to induce periapical bleeding with a sterile instrument and form a blood clot in the canal.[19] However, since periapical bleeding may not always be transported into the canal and the erythrocytes in the clot may become necrotic over time, the use of autogenous platelet concentrates obtained by centrifugation of the patient's own blood, such as platelet-rich plasma (PRP) and platelet-rich fibrin (PRF), has become widespread.[20,21]

Variable results have been reported in studies of both regenerative endodontic treatment and autotransplantation procedures.[18,22] However, when reviewing the current literature, the number of studies evaluating the results of regenerative endodontic treatment in immature teeth where autotransplantation procedures have been performed is quite limited.[14,23] The aim of this study is to report the 3-year results of a case where autotransplantation and regenerative endodontic treatment were performed.

Case Report

An 18-year-old female patient presented to the Endodontics Department of the Marmara University Faculty of Dentistry with severe pain and mobility in tooth 37. Her medical history revealed that tooth 37 had undergone root canal treatment three years previously. Radiographs showed a large periapical lesion extending to the inferior alveolar nerve associated with the previous root canal treatment (Figures 1-2). It was decided to repeat the root canal treatment due to chronic apical periodontitis. Despite two interim applications of calcium hydroxide over a period of 3 months, no improvement in symptoms was observed. After a surgical consultation, it was decided to extract teeth 37 and 38 and to transplant tooth 38 to replace tooth 37.

Other treatment options recommended to the patient included implant placement and fixed prosthesis. However, after discussing the benefits, risks and long-term outcomes of each option, the patient opted for autotransplantation because she wanted to retain a natural tooth and avoid the need for prosthetics or implants. This decision was influenced by the patient's preference for a biological solution that could restore function and aesthetics with a more natural outcome. After a detailed explanation of the procedure and possible complications, the patient was informed and signed a consent form. For the autotransplantation procedure, tooth 38 was extracted atraumatically under local anaesthesia and preserved in 0.9% isotonic sodium chloride solution to maintain the vitality of the periodontal ligament. The atraumatic tooth extraction was performed by an oral surgeon with more than 5 years of experience, during which time he gained extensive expertise in various surgical procedures. An inferior alveolar nerve block technique was used for local anaesthesia, and a solution of 4% articaine with epinephrine(1:100,000) was selected for the procedure. Tooth 37 was extracted and after curettage of the extraction socket, the recipient site for the transplanted tooth was prepared with surgical drills. Tooth 38 was placed in the socket and finger pressure was applied for 3 minutes. The occlusal relationship with the opposing arch was then assessed to avoid premature contact. After placement of tooth 38 in the socket, 4/0 non-absorbable monofilament sutures were selected for stabilisation. (Ethicon, Johnson & Johnson, USA) (Fig. 3). Follow-up appointment was scheduled for 2 weeks later.

At the follow-up visit, the sutures were removed and tooth mobility was checked. According to the Miller classification, mobility, which was recorded as class 3 after autotransplantation, was recorded as class 1 at the follow-up visit. Periodontal probing revealed no pockets deeper than 3 mm. As there were no clinical or radiographic problems (no pain or sensitivity to percussion and palpation, absence of periapical radiolucency, normal periodontal ligament width and healthy bone structure observed on radiographs), the patient was scheduled for routine follow-up every 3 months for the first year. At the 6-month follow-up, the patient presented with pain on chewing. Radiographic examination revealed radiolucency in the periapical area of the tooth. Clinically, the tissues surrounding the tooth were assessed by percussion and palpation tests, which revealed mild to moderate tenderness. Thermal tests (application of cold and heat) and electrical pulp tests were performed to assess the vitality of the tooth, and these tests confirmed that the tooth was non-vital. Radiographic examination showed the presence of a periapical radiolucent area at the root apex, indicating chronic apical infection. The diagnosis of chronic apical periodontitis was confirmed based on the combination of clinical and radiographic findings. Considering the patient's age, regenerative endodontic treatment was planned and a consent form was signed after explaining the possible risks.

After cavity preparation under the rubber-dam isolation, the working length was determined radiographically. The root canals were prepared and enlarged up to size 30 with a 0.4 taper with rotary insturments(Smart Gold, EndoArt, Inci Dental, Turkey) under irrigation with 2.5% sodium hypochlorite. (Microvem, Altun Sterilization & Medical, Turkey) Final irrigation with 17% EDTA (Microvem, Altun Sterilization & Medical, Turkey). Calcium hydroxide (Vision, WP Dental, Germany) was placed in the canal and the patient was scheduled for a second appointment three weeks later.(Fig.4) At the second appointment, the regenerative treatment was started as the patient reported no discomfort. The root canal was irrigated with 10 mL of 2.5% NaOCl and 10 mL of 17% EDTA with sonic activation (EDDY, VDW, Germany) under rubber dam isolation. The canal was then rinsed with distilled water and dried. Ten millilitres of blood was taken from the patient and centrifuged at 2700 rpm for 12 minutes to obtain a PRF membrane. The PRF membrane obtained was placed in the canal as a small strip and compressed. A 3-4 mm layer of mineral trioxide aggregate (MTA) (BioMTA, Cerkamed, Poland) was applied and sealed with glass ionomer cement (RubyLiner, Inci Dental, Turkey) (Fig. 5). The permanent composite restoration was completed one month later. This was due to the patient's location out of town.

The patient was recalled every three months for the first year for radiographic examination and clinical symptom assessment. Initial examinations revealed no pain to percussion or palpation, but the tooth was unresponsive to cold and electrical pulp tests. Healing of the periapical area was observed at three months, with enlargement of the apex at six months (Figs 6-7). Follow-up examinations showed that the tooth was functional and asymptomatic. And no aesthetic discolouration was observed as a result of the MTA application. At one year, radiographs showed complete healing of the apical lesion with continued hard tissue deposition (Fig. 8). In addition, the tooth responded positively to sensitivity testing. After 36 months of follow-up, the tooth remained asymptomatic and

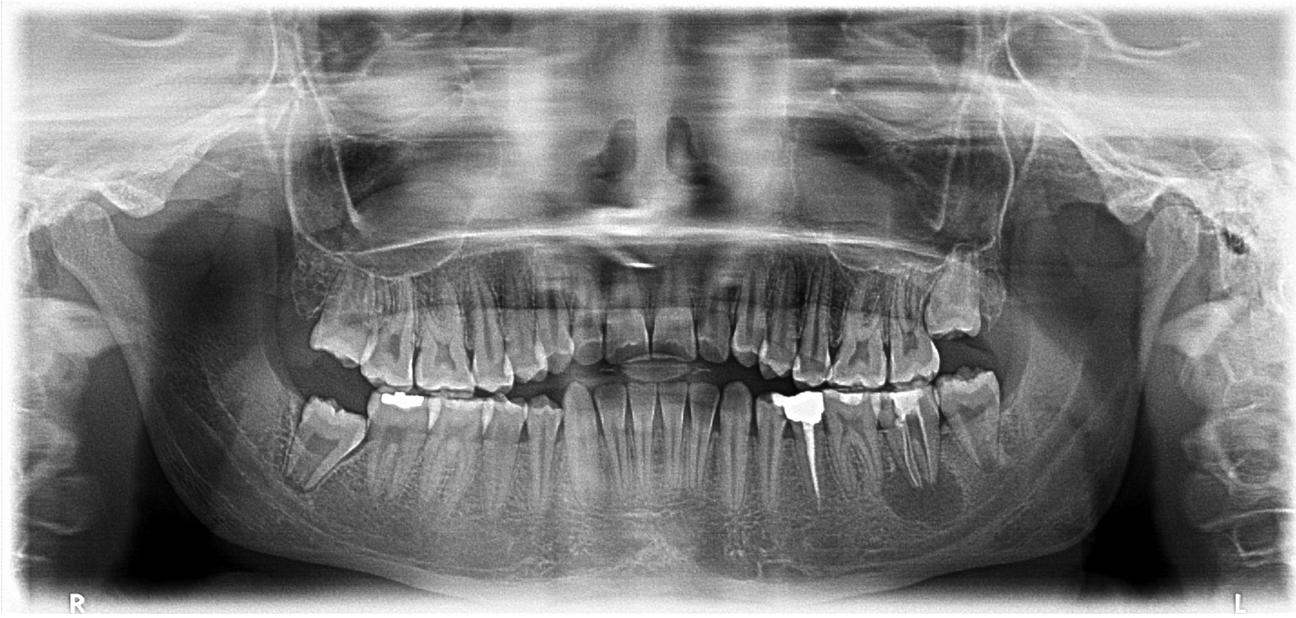

Figure 1. Diagnostic panoramic radiograph

Figure 2. Diagnostic periapical radiograph

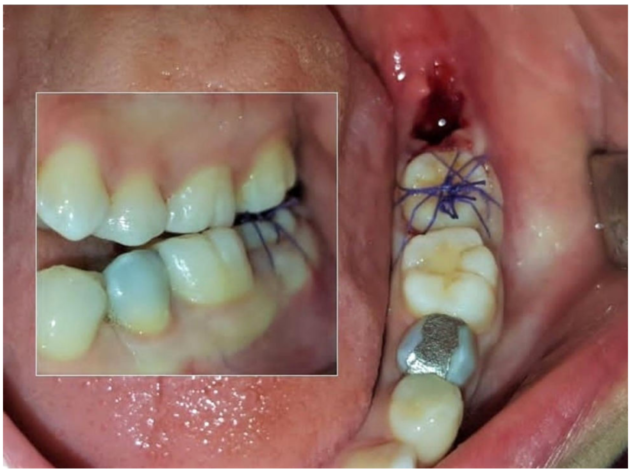

Figure 3. Splinted with sutures for stabilisation

Figure 4. 6-month post-autotransplantation (after the application of calcium hydroxide.)

functional in the oral cavity. There was no evidence of pain or sensitivity to percussion, palpation or biting. The tooth continued to respond to thermal and electrical sensitivity testing. Radiographs showed complete healing of the apical lesion and a normal periodontal ligament in all directions of the root (Fig. 9).

Discussion

Dental autotransplantation and regenerative endodontic treatment are biologically based treatments that are particularly useful for treating tooth loss at a young age.[14] Autotransplantation is a technique that has been continuously developed and supported by valid clinical studies to date.[6,24,25] Although there are many studies on teeth with complete root development, there are not enough studies on teeth with incomplete root development to confirm the success of this technique. However, survival rates reported in recent meta-analyses are over 95%, suggesting that autotransplantation should be considered a predictable long-term technique for open apex teeth.[13,23]

Figure 5. Placement of MTA

Figure 6. 3-month follow-up radiograph

Figure 7. 6-month follow-up radiograph

Figure 8. 12-month follow-up radiograph

Figure 9. 36-month follow-up radiograph

In this case, tooth 37, which could not be treated despite root canal treatment and application of calcium hydroxide, was extracted and tooth 38, with an open apex, was transplanted in its place, followed by regenerative endodontic therapy. Calcium hydroxide was applied twice over a three-month period to ensure complete disinfection of the infected root canals. The first application aimed to eliminate most of the bacteria in the canal, while the second application focused on eradicating any remaining bacterial biofilms and infections. The literature suggests that calcium hydroxide has a long-lasting antibacterial effect and is effective in eliminating residual bacteria. In addition, multiple applications improve infection control and aid the healing process.[26] As there was no response to treatment, it was decided to discontinue the root canal treatment and proceed with autotransplantation therapy.

Pulpal vitality is considered one of the key criteria for successful autotransplantation. In their studies, Northway et al.[27] reported that transplanted open apex teeth should respond positively to sensitivity tests within 2 to 4 months. Czochrowska et al.[28] found positive responses to pulp vitality tests in all immature apex teeth they transplanted. Nagori et al.[29] also reported positive responses to electrical pulp tests in transplanted open apex teeth. In this case, the transplanted tooth did not respond to vitality tests and became symptomatic within 6 months. Regenerative treatment was therefore the treatment of choice.

According to the American Association of Endodontics (AAE) guidelines, the primary goal of regenerative endodontic procedures is to treat apical periodontitis. Secondary goals include standardizing root wall thickness and length and achieving vitality.[30,31] Stem cells, growth factors and natural or artificial scaffolds play a role in regenerative treatments. PRF is a potential scaffold that controls inflammatory responses and promotes growth and regeneration.[32] By acting as a depot for tissue healing elements, PRF increases the formation of new hard and soft tissue in the canal area.[33] The clinical advantages of MTA placement over PRF, with its excellent coronal sealing and biocompatibility properties, have been demonstrated.[34] In this case, PRF obtained by centrifugation of the patient's blood was used and covered with MTA. The settings chosen to obtain the PRF membrane were optimised to preserve the biocompatibility and coagulation properties of the fibrin structure. PRF was obtained by centrifugation at 2700 rpm for 12 minutes. These settings help to maintain the biological activity and cellular components of the PRF, promoting the formation of an optimal fibrin matrix that supports tissue healing. Similar centrifugation speeds and durations have been reported in the literature to provide the highest biological efficacy of the PRF membrane.[35]

Clinical and radiological evaluations were performed at 3, 6, 12 and 36 months after the regeneration procedure; the tooth was asymptomatic and functional. In addition, complete periapical healing was observed at 6 months and root formation continued. At the 1-year follow-up, the tooth was found to respond positively to pulp sensitivity tests.

No root resorption was observed during the follow-up period. This can be attributed to the use of atraumatic extraction techniques and careful preservation of periodontal ligament cells, which played a crucial role in maintaining the vitality of the transplanted tooth and helping to prevent inflammatory root resorption.[36] During the transplantation process, careful and atraumatic extraction of the tooth, together with preservation of the root surfaces and minimisation of the time before transplantation, helps to maintain the vitality of the periodontal cells. Keeping the tooth in a moist environment and preventing further desiccation of the cells also contributes to the success of the procedure. Similar studies have shown that preserving periodontal ligament cells has a protective effect against root resorption and ankylosis, emphasising the importance of these factors in the long-term success of the graft.[37–39] Additionally, the use of nonabsorbable sutures during the procedure, combined with proper stabilization techniques to avoid excessive force, may have minimized the risk of root resorption. Studies have indicated that applying sutures for stabilization after autotransplantation, especially for short-term use, enhances pulp healing and reduces the risk of inflammatory root resorption when compared to rigid splinting techniques. These findings suggest that less rigid stabilization methods, such as sutures, are beneficial for promoting healing while minimizing complications like root resorption.[40,41] In this case, the tooth was placed with minimal pressure and stabilised with non-resorbable sutures.

In addition, the biocompatible materials used in the root canal treatment, particularly mineral trioxide aggregate (MTA), may have contributed to the prevention of resorption by promoting healing and minimising inflammation. Similar findings have been reported in the existing literature, where the use of biocompatible materials and appropriate stabilisation techniques have been shown to positively influence the healing process and reduce the risk of resorption.[42–44]

The success achieved through the use of appropriate surgical techniques, careful preservation of the periodontal ligament and the use of biocompatible materials is promising for future treatment procedures. This study demonstrates that autotransplantation and regenerative endodontic treatment can be valuable clinical options for managing tooth loss, particularly in young patients. The use of MTA and PRF membranes in this approach optimises infection control and tissue healing, allowing the transplanted tooth to regain functionality. The primary clinical contribution of this study is to demonstrate that biocompatible materials and appropriate stabilisation techniques significantly improve the long-term success of autotransplantation procedures.

However, the study has some limitations. It is a single case report, which limits the generalisability of the findings. Further clinical studies are needed to evaluate factors such as patient age, root development status and surgical techniques in a broader patient population. In addition, the success rate of autotransplantation and the factors influencing it should be investigated in larger clinical trials and randomised controlled trials to validate these findings.

Conclusion

Despite its limitations, this study presents a successful three-year follow-up of the autotransplantation technique performed on an immature tooth followed by regenerative endodontic treatment. This technique can be recommended, especially for patients in the growth and development phase; however, in these cases, the combination of success criteria and the determination of the necessary follow-up period are essential, along with a clear surgical protocol to evaluate the effectiveness of the technique.

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References

1. Srivastava S, Gupta K, Dubey S, Singh A. Guided autotransplantation of tooth: An innovative approach. Natl J Maxillofac Surg. 2022;13(Suppl 1):S136–s139. doi:10.4103/njms.NJMS_169_20.
2. Gilijamse M, Baart JA, Wolff J, Sándor GK, Forouzanfar T. Tooth autotransplantation in the anterior maxilla and mandible: retrospective results in young patients. Oral Surg Oral Med Oral Pathol Oral Radiol. 2016;122(6):e187–e192. doi:10.1016/j.oooo.2016.06.013.
3. Tsukiboshi M. Autotransplantation of teeth: requirements for predictable success. Dent Traumatol. 2002;18(4):157–180. doi:10.1034/j.1600-9657.2002.00118.x.
4. Barman J, Kalita C, Baruah R, Choudhury K. Tooth Loss and Its Risk Factors Among the Young Adults in the Kamrup (Metro) District of Assam: An Epidemiological Study. JIAPHD. 2022;20(2):159–167. doi:10.4103/jiaphd.jiaphd_136_21.
5. Nashkova S, Dimova C. Traumatic dental injuries: etiology, prevalence and possible outcomes. IJSR. 2022;1(4):27–29. doi:10.35120/medisij010427n.
6. Ong D, Itskovich Y, Dance G. Autotransplantation: a viable treatment option for adolescent patients with significantly compromised teeth. Aust Dent J. 2016;61(4):396–407. doi:10.1111/adj.12420.
7. Srivastava S, Gupta K, Dubey S, Singh A. Guided autotransplan-

tation of tooth: An innovative approach. Natl J Maxillofac Surg. 2022;13(Suppl 1):S136. doi:10.4103/njms.NJMS_169_20.
8. Jang Y, Choi YJ, Lee SJ, Roh BD, Park SH, Kim E. Prognostic factors for clinical outcomes in autotransplantation of teeth with complete root formation: survival analysis for up to 12 years. J Endod. 2016;42(2):198–205. doi:10.1016/j.joen.2015.10.021.
9. Verweij J, Jongkees F, Moin DA, Wismeijer D, Van Merkesteyn J. Autotransplantation of teeth using computer-aided rapid prototyping of a three-dimensional replica of the donor tooth: a systematic literature review. Int J Oral Maxillofac Surg. 2017;46(11):1466–1474. doi:10.1016/j.ijom.2017.04.008.
10. Almpani K, Papageorgiou SN, Papadopoulos MA. Autotransplantation of teeth in humans: a systematic review and meta-analysis. Clin Oral Investig. 2015;19:1157–1179. doi:10.1007/s00784-015-1473-9.
11. Schmidt SK, Cleverly DG. Tooth autotransplantation: an overview and case study. Northwest Dent. 2012;91(4):29–34.
12. Singh AK, Khanal N, Acharya N, Hasan MR, Saito T. What are the complications, success and survival rates for autotransplanted teeth? An overview of systematic reviews and metanalyses. In: Healthcare. vol. 10. MDPI;. p. 835. doi:10.3390/healthcare10050835.
13. Lundberg T, Isaksson S. A clinical follow-up study of 278 autotransplanted teeth. Br J Oral Maxillofac Surg. 1996;34(2):181–185. doi:10.1016/s0266-4356(96)90374-5.
14. EzEldeen M, De Piero MNSP, Xu L, Driesen RB, Wyatt J, Van Gorp G, et al. Multimodal Imaging of Dental Pulp Healing Patterns following Tooth Autotransplantation And Regenerative Endodontic Treatment. J Endod. 2023. doi:10.1016/j.joen.2023.06.003.
15. Turk T, Cicconetti A, Di Nardo D, Miccoli G, Coppola S, Bhandi S, et al. Nonsurgical retreatment using regenerative endodontic protocols: a case report. J Contemp Dent Pract. 2020;21(11):1275–1278. doi:10.5005/jp-journals-10024-2909.
16. Galler K, Krastl G, Simon S, Van Gorp G, Meschi N, Vahedi B, et al. European Society of Endodontology position statement: Revitalization procedures. Int Endod J. 2016;49(8):717–723. doi:10.1111/iej.12629.
17. Murray PE, Garcia-Godoy F, Hargreaves KM. Regenerative endodontics: a review of current status and a call for action. J Endod. 2007;33(4):377–390. doi:10.1016/j.joen.2006.09.013.
18. Cehreli ZC, Unverdi GE, Ballikaya E. Deciduous tooth pulp autotransplantation for the regenerative endodontic treatment of permanent teeth with pulp necrosis: a case series. J Endod. 2022;48(5):669–674. doi:10.1016/j.joen.2022.01.015.
19. Lovelace TW, Henry MA, Hargreaves KM, Diogenes A. Evaluation of the delivery of mesenchymal stem cells into the root canal space of necrotic immature teeth after clinical regenerative endodontic procedure. J Endod. 2011;37(2):133–138. doi:10.1016/j.joen.2010.10.009.
20. Martin G, Ricucci D, Gibbs JL, Lin LM. Histological findings of revascularized/revitalized immature permanent molar with apical periodontitis using platelet-rich plasma. J Endod. 2013;39(1):138–144. doi:10.1016/j.joen.2012.09.015.
21. Torabinejad M, Milan M, Shabahang S, Wright KR, Faras H. Histologic examination of teeth with necrotic pulps and periapical lesions treated with 2 scaffolds: an animal investigation. J Endod. 2015;41(6):846–852. doi:10.1016/j.joen.2015.01.026.
22. Plotino G, Abella Sans F, Duggal MS, Grande NM, Krastl G, Nagendrababu V, et al. Present status and future directions: Surgical extrusion, intentional replantation and tooth autotransplantation. Int Endod J. 2022;55:827–842. doi:10.1111/iej.13723.
23. Sicilia-Pasos J, Kewalramani N, Pena-Cardelles JF, Salgado-Peralvo AO, Madrigal-Martinez-Pereda C, Lopez-Carpintero A. Autotransplantation of teeth with incomplete root formation: systematic review and meta-analysis. Clin Oral Investig. 2022;26(5):3795–3805. doi:10.1007/s00784-022-04435-8.
24. Park JH, Tai K, Hayashi D. Tooth autotransplantation as a treatment option: a review. J Clin Pediatr Dent. 2010;35(2):129–135. doi:10.17796/jcpd.35.2.97816254u2140x88.
25. Yoshino K, Kariya N, Namura D, Noji I, Mitsuhashi K, Kimura H, et al. A retrospective survey of autotransplantation of teeth in dental clinics. J Oral Rehabil. 2012;39(1):37–43. doi:10.1111/j.1365-2842.2011.02234.x.
26. Bergenholtz G, Torneck C, Kishen A. Inter-appointment medication with calcium hydroxide in routine cases of root canal therapy. The Root Canal Biofilm. 2015:303–325. doi:10.1007/978-3-662-47415-0_10.
27. Northway W. Autogenic dental transplants. Am J Orthod Dentofacial Orthop. 2002;121(6):592–593. doi:10.1067/mod.2002.124795.
28. Czochrowska EM, Stenvik A, Bjercke B, Zachrisson BU. Outcome of tooth transplantation: survival and success rates 17-41 years posttreatment. Am J Orthod Dentofacial Orthop. 2002;121(2):110–119. doi:10.1067/mod.2002.119979.
29. Nagori SA, Bhutia O, Roychoudhury A, Pandey RM. Immediate autotransplantation of third molars: an experience of 57 cases. Oral Surg Oral Med Oral Pathol Oral Radiol. 2014;118(4):400–407. doi:10.1016/j.oooo.2014.05.011.
30. Arslan H, Ahmed HMA, Şahin Y, Yıldız ED, Gündoğdu EC, Güven Y, et al. Regenerative endodontic procedures in necrotic mature teeth with periapical radiolucencies: a preliminary randomized clinical study. J Endod. 2019;45(7):863–872. doi:10.1016/j.joen.2019.04.005.
31. Geisler TM. Clinical considerations for regenerative endodontic procedures. Dent Clin North Am. 2012;56(3):603–626. doi:10.1016/j.cden.2012.05.010.
32. Das S, Srivastava R, Thosar NR, Khubchandani M, Ragit R, Malviya N. Regenerative Endodontics-Reviving the Pulp the Natural Way: A Case Report. Cureus. 2023;15(3). doi:10.7759/cureus.36587.
33. Lin LM, Shimizu E, Gibbs JL, Loghin S, Ricucci D. Histologic and histobacteriologic observations of failed revascularization/revitalization therapy: a case report. J Endod. 2014;40(2):291–295. doi:10.1016/j.joen.2013.08.024.
34. Torabinejad M, Higa RK, McKendry DJ, Ford TRP. Dye leakage of four root end filling materials: effects of blood contamination. J Endod. 1994;20(4):159–163. doi:10.1016/S0099-2399(06)80326-2.
35. Choukroun J, Adda F, Schoeffer C, Vervelle A. PRF: an opportunity in perio-implantology. Implantodontie. 2000;42:55–62.
36. Galler KM, Grätz EM, Widbiller M, Buchalla W, Knüttel H. Pathophysiological mechanisms of root resorption after dental trauma: a systematic scoping review. BMC Oral Health. 2021;21:1–14. doi:10.1186/s12903-021-01510-6.
37. Martin K, Nathwani S, Bunyan R. Autotransplantation of teeth: an evidence-based approach. Br Dent J. 2018;224(11):861–864. doi:10.1038/sj.bdj.2018.432.
38. Suwanapong T, Waikakul A, Boonsiriseth K, Ruangsawasdi N. Pre-and peri-operative factors influence autogenous tooth transplantation healing in insufficient bone sites. BMC Oral Health. 2021;21:1–10. doi:10.1186/s12903-021-01686-x.
39. Zhu W, Zhang Q, Zhang Y, Cen L, Wang J. PDL regeneration via cell homing in delayed replantation of avulsed teeth. J Transl Med. 2015;13:1–11. doi:10.1186/s12967-015-0719-2.
40. Gupta R, Tomer A, Pyasi S. An In Vitro Analysis of Fracture Strength of Various Bulk Fill Flow able Composite Resins. J Med Sci. 2018;17(2):40–44.
41. Krishna Prasada L, Suhas AKP. Splinting of Traumatized Tooth-A Systematic Review. RGUHS J Dent Sci. 2023;15(1):17–23. doi:10.26463/rjds.15_1_19.
42. Güzeler I, Uysal S, Cehreli ZC. Management of trauma-induced inflammatory root resorption using mineral trioxide aggregate obturation: two-year follow up. Dent Traumatol. 2010;26(6):501–504. doi:10.1111/j.1600-9657.2010.00932.x.
43. Pace R, Giuliani V, Pagavino G. Mineral trioxide aggregate

in the treatment of external invasive resorption: a case report. Int Endod J. 2008;41(3):258–266. doi:10.1111/j.1365-2591.2007.01338.x.

44. Perić T, Marković D, Petrović B. Mineral trioxide aggregate for the treatment of external root resorption in an avulsed immature tooth-ten years of follow-up. Srp Arh Celok Lek. 2020;148(3-4):231–235. doi:10.2298/SARH190111103P.