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Aims and Scope

Cumhuriyet Dental Journal (CDJ) is an international journal dedicated to the latest advancement of dentistry. The aim of this journal is to provide a platform for scientists and academicians all over the world to promote, share, and discuss various new issues and developments in different areas of dentistry.

CDJ publishes original research papers, reviews, and case reports within clinical dentistry, on all basic science aspects of structure, chemistry, developmental biology, physiology and pathology of relevant tissues, as well as on microbiology, biomaterials and the behavioral sciences as they relate to dentistry.

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INDEXING

CUMHURIYET DENAL JOURNAL

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To achieve open access to scholarly journal literature, we recommend two complementary strategies.

I. Self-Archiving: First, scholars need the tools and assistance to deposit their refereed journal articles in open electronic archives, a practice commonly called, self-archiving. When these archives conform to standards created by the Open Archives Initiative, then search engines and other tools can treat the separate archives as one. Users then need not know which archives exist or where they are located in order to find and make use of their contents.

II. Open-access Journals: Second, scholars need the means to launch a new generation of journals committed to open access, and to help existing journals that elect to make the transition to open access. Because journal articles should be disseminated as widely as possible, these new journals will no longer invoke copyright to restrict access to and use of the material they publish. Instead they will use copyright and other tools to ensure permanent open access to all the articles they publish. Because price is a barrier to access, these new journals will not charge subscription or access fees, and will turn to other methods for covering their expenses. There are many alternative sources of funds for this purpose, including the foundations and governments that fund research, the universities and laboratories that employ researchers, endowments set up by discipline or institution, friends of the cause of open access, profits from the sale of add-ons to the basic texts, funds freed up by the demise or cancellation of journals charging traditional subscription or access fees, or even contributions from the researchers themselves. There is no need to favor one of these solutions over the others for all disciplines or nations, and no need to stop looking for other.

Open access to peer-reviewed journal literature is the goal. Self-archiving (I.) and a new generation of open-access journals (II.) are the ways to attain this goal. They are not only direct and effective means to this end, they are within the reach of scholars themselves, immediately, and need not wait on changes brought about by markets or legislation. While we endorse the two strategies just outlined, we also encourage experimentation with further ways to make the transition from the present methods of dissemination to open access. Flexibility, experimentation, and adaptation to local circumstances are the best ways to assure that progress in diverse settings will be rapid, secure, and long-lived.

The Open Society Institute, the foundation network founded by philanthropist George Soros, is committed to providing initial help and funding to realize this goal. It will use its resources and influence to extend and promote institutional self-archiving, to launch new open-access journals, and to help an open-access journal system become economically self-sustaining. While the Open Society Institute's commitment and resources are substantial, this initiative is very much in need of other organizations to lend their effort and resources.

We invite governments, universities, libraries, journal editors, publishers, foundations, learned societies, professional associations, and individual scholars who share our vision to join us in the task of removing the barriers to open access and building a future in which research and education in every part of the world are that much morefree to flourish. Submitting a paper to CDJ is free of charges. In addition, CDJ has not have article processing charges.

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Original research

THE EFFECT OF DIFFERENT ACID TREATMENTS ON SHEAR BOND STRENGTH BETWEEN MONOLITHIC ZIRCONIA AND DENTIN SURFACE

ABSTRACT

Objective: The aim of this study is to evaluate the effect of dentin surface treatments with citric, tartaric, phosphoric, and boric acids on the bonding strength of monolithic zirconia.

Materials and Methods: A hundred human molar teeth were randomly divided into subsets (n=10) based on acid treatment modalities and thermocycling procedure. Monolithic zirconia superstructures were fabricated using CAD/CAM system in the final dimensions of 7 mm in diameter and 3 mm in thickness. After application of acid treatments to dentin surface, shear bond strength test was performed to assess the effectiveness of surface modifications that were also examined using a scanning electron microscope.

Results: The study groups were ranked respectively as (citric acid>tartaric acid>phosphoric acid>boric acid>control) for the set of groups without thermocycling and (citric acid>tartaric acid) and (phosphoric acid>boric acid>control) for the set of thermocycling groups ($p<0.05$) based on highest value. The bonding strength of tartaric acid group was not significantly different from the bonding strength of phosphoric acid group ($p>0.05$).

Conclusions: In both procedures with and without thermal cycling; based on order of efficacy, citric, tartaric, phosphoric, and boric acids were more effective in improving the shear bond strength between monolithic zirconia and dentin surface. The thermal cycling procedure decreased the bonding strength in all the groups.

Keywords: Boric acid, citric acid, phosphoric acids, zirconium oxide, dentin, shear strength.

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INTRODUCTION

Zirconia is preferred by clinicians over recent years in dentistry. As a result of the introduction of computer-aided design and computer aided manufacturing (CAD/CAM) technology to dental laboratories and clinics, the use of zirconia material for the production of prosthesis has rapidly increased.[1] This material provides good success in prosthetic rehabilitation because of its advantages including biocompatibility, high fracture toughness, and esthetic properties.[2,3] Thus, the use of zirconia material has led to high mechanical strength and good esthetic outcome for patients. Veneering of zirconia frameworks is a conventional method used by the dental technicians.[4] With this technique, veneered zirconia provides natural appearing because of its white color but chipping or delamination of the feldspathic porcelain layer over the zirconia framework is the most common complication of this restoration.[5] Therefore, full-contour zirconia has been presented as an alternative to conventionally veneered zirconia.

Monolithic zirconia enables to produce high strength prosthesis with reasonable esthetic results, time and cost as a new alternative dental prosthetic treatment. In addition, due to the use of anatomic contour zirconia, major complication of conventionally veneered zirconia has been eliminated.[6] Monolithic zirconia restorations have a higher fracture strength when compared to the maximal occlusal forces (383.6 in women - 545.7 N in men) in the posterior location of the mouth.[7,8] For the long-term success of monolithic zirconia restoration in posterior region of the mouth, minimum occlusal thickness should be 0.7 mm for implant-supported restorations and 0.5 mm for tooth-supported restorations to endure the chewing forces.[2,9] This is an important advantage in the clinical situations including limited interarch distance, the need for preservation of tooth structure, and inadequate clinical crown length.[10]

Sufficient bonding strength between zirconia material and dentin surface is an important matter for successful functioning of a ceramic restoration.[11] For the luting of zirconia restorations, resin cements are preferred for their advantageous mechanical and adhesive features compared to conventional cements. Providing a strong bonding with resin cement depends on chemical type of bonding and micromechanical retention to the material surface.[12] In the literature, researchers have aimed to improve retention of zirconia crowns with the surface treatment of zirconia with grinding, sandblasting, airborne-particle abrasion, acid and laser etching, silanization, or a combination of these methods.[3-15] On the other hand, modification of dentin surfaces may improve the bonding strength of zirconina ceramics.[16] Data about the efficacy of acid treatments in terms of improving the bonding strength between dentin surface and zirconia are limited.

Retention of monolithic zirconia to abutment teeth should be adequate to withstand the masticatory forces especially in the case of reduced clinical crown length.[17] However, there is still no consensus on the improving bonding strength between monolithic zirconia and dentin surface if there is a reduced clinical crown length. The aim of this study was to evaluate the effect of dentin treatments with citric, tartaric, phosphoric and boric acids on the bonding strength of monolithic zirconia. The null hypothesis was that the shear bond strength of the monolithic zirconia that was bonded to dentin surface after surface modifications with citric, tartaric, phosphoric and boric acids would not be altered by acid etching process.

MATERIAL AND METHODS

The study was approved by the Committee on Human Research of (No: 2016-12/11). A hundred human permanent mandibular molar teeth extracted due to clinical reasons were used in this study. Teeth were free of restoration, caries, and cracks. After having been scraped of any residual tissue tags, they were kept at +4°C in 0.9% saline solution during the whole study. Occlusal enamel of each molar tooth was separated into the crowns parallel to the occlusal surface and middle-dentin surface was exposed with a precision low-speed diamond saw (Isomet 1000, Buehler, Lake Buff, IL, USA). The part of the teeth including the roots was fixed with autopolymerizing acrylic resin (Meliodent, Heraeus Kulzer, Wehrheim, Germany) to form 2.5 cm high and 1.5 cm diameter cylinders. Roughness of dentin surfaces was standardized with 600-800 and 1200 grit waterproof polishing papers.

Monolithic zirconia (Katana, Noritake Dental Supply Co. Ltd., Aichi, Japan) superstructures were fabricated using CAD/CAM system (DC40, Yenadent, Ankara, Turkey) in the final dimensions of 7 mm in diameter and 3 mm in thickness in accordance with the ISO 11405 standard. The specimens were sintered to full density in a high-temperature furnace (Protherm; B&D Dental Origin Milling, USA) according to the manufacturer's instructions.

In this study, we determined the optimal concentration and application time of acid agents with a pilot study because of limited information in the literature. For each acid surface treatment modality, 3 acid concentrations (5%, 10%, 15%) were applied to dentin surface at 5 application times (5, 10, 15, 20, 25 s). For every acid agent, 3 pilot groups were selected according to stereomicroscope evaluation of pore structures. In order to determine the optimal concentration and application time, shear bond strength test was performed using universal test device (LF Plus, Lloyd Instruments, Fareham, England) in selected 3 pilot groups. Thus, for every acid surface treatment modality, the optimal concentration and application time were determined after statistical analysis of the data obtained from the pilot groups (Table 1).

Table 1. Concentration and application time of acid treatments.

Groups	Concentration (%)	Application Time (s)
Boric Acid	5	20
Phosphoric Acid	32	15
Tartaric Acid	15	15
Citric Acid	10	25

The examined teeth were divided into two sets, one of which was subject to thermocycling (n=50). Each set was divided randomly into five subgroups according to acid treatment modality: no treatment (control), boric, phosphoric, tartaric, and citric acids (n=10).

Control Group: No treatment

Boric Acid Group: A 5% boric acid solution (Multicell; Wisent, Inc., Quebec, Canada) was prepared and applied to dentin surfaces with burnishing movement using a sponge for 20 s. The specimens were rinsed for 20 s and dried with oil-free compressed air for 10 s.

Phosphoric Acid: Commercially available 32% phosphoric acid gel (Scotchbond Universal Etchant; 3M ESPE Dental Products, MN, USA) was applied to dentin surface for 15 s. The specimens were rinsed for 20 s and dried with oil-free compressed air for 10 s.

Tartaric Acid: A 15% tartaric acid solution (Merck&Co., Inc., NJ, USA) was applied to dentin surface with burnishing movement using a sponge for 15 s. The specimens were rinsed for 20 s and dried with oil-free compressed air for 10 s.

Citric Acid: Dentin surfaces were roughened with 10% citric acid solution (Merck&Co., Inc., NJ, USA) with burnishing movement using a sponge for 25 s. The specimens were rinsed for 20 s and dried with oil-free compressed air for 10 s.

After surface modifications, a self-adhesive resin cement (Panavia SA, Kuraray, Osaka, Japan) was used for the cementation of monolithic zirconia crowns to dentin surfaces. Constant hand pressure was applied by one operator to zirconia specimens during the cementation. Excess resin cement was initially removed from the periphery of the zirconia specimen with an explorer and light cured with a LED curing unit (Smartlite, Dentsply, York, USA) for totally 100 s from 5 different directions. Before the application of shear bond strength test, half of the specimens were stored in the aqueous incubation (Nuve BM 302; Nuve San., Ankara, Turkey) at 37°C for 24 hours and the other half was thermocycled (GM, Gokceler Mechanical, Sivas, Turkey) for 3000 cycles in 5°C and 55°C water baths with a dwell time for 30 s.

The specimens were placed in a universal testing machine (Lloyd LF Plus, Ametek Inc, Lloyd Instruments, Leicester, UK) without drying immediately after the specimens were removed from the distilled water and the shear bond strength was performed at a crosshead speed of 1 mm/min until failure. The shear force was recorded in Newtons (N) and calculated in MPa by considering the cross-sectional area of the monolithic zirconia. The mean and standard deviation were calculated for different groups. The specimens were evaluated using a scanning electron microscope (SEM) (Tescan Mira 3, Brno, Czech Republic) at x5000 magnification after shear bond test to examine how the zirconia specimen detached and how acid treatments produced irregularity on the dentin surface.

Statistical Analysis

The data of shear bond strength were analyzed with two-way ANOVA followed by the Tukey test for pairwise comparisons. Data are presented as the mean plus or minus standard deviation (SD). Differences were considered significant at level of 0.05.

RESULTS

Table 1 shows the optimal concentration and application time for every acid surface treatment modality which determined after statistical analysis of the data obtained from the pilot groups.

Figure 1 shows the values of shear bond strength between monolithic zirconia and dentin surface treated with boric, phosphoric, tartaric, and citric acids.

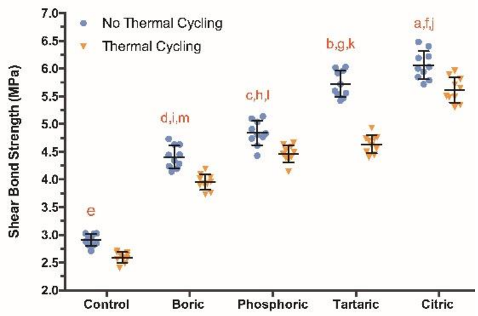

Figure 1. Figure 1. Values of shear bond strength between monolithic zirconia and dentin surface treated with boric, phosphoric, tartaric and citric acids. Data were expressed as mean (midline) and SD (whiskers). a$P<0.05$, citric acid with thermocycling vs. citric acid without thermocycling. b$P<0.05$, boric acid with thermocycling vs. boric acid without thermocycling. c$P<0.05$, phosphoric acid with thermocycling vs. phosphoric acid without thermocycling. d$P<0.05$, boric acid with thermocycling vs. boric acid without thermocycling. e$P<0.05$, control group with thermocycling vs. control group without thermocycling. f$P<0.05$, citric acid vs. other groups with thermocycling. g$P<0.05$, tartaric acid vs. boric and control groups with thermocycling. h$P<0.05$, phosphoric acid vs. boric and control groups with thermocycling. i$P<0.05$, boric acid vs. control group with thermocycling. j$P<0.05$, citric acid vs. other groups without thermocycling. k$P<0.05$, tartaric acid vs. phosphoric, boric, and control groups without thermocycling. l$P<0.05$, phosphoric acid vs. boric and control groups without thermocycling. m$P<0.05$, boric acid vs. control group without thermocycling.

ANOVA and t tests revealed that the bonding strengths of the specimens were significantly different. First, the effect of thermal cycling procedure was compared in all the groups. In all the groups, application of thermocycling procedure provided a significant decrease in the bonding strength between monolithic zirconia and dentin surface ($p<0.05$). In the set of thermocycling group, the bonding strength was significantly higher in the citric acid than the other groups ($p<0.05$). The bonding strength of tartaric acid was significantly higher compared to the boric and control groups ($p<0.05$). The phosphoric acid had significantly higher bond strength compared to boric and control groups ($p<0.05$). The bonding strength of boric acid was significantly higher than that of control group ($p<0.05$). Although the bonding strength of tartaric acid was higher than the bonding strength of the phosphoric acid, this difference was not statistically significant ($p>0.05$).

In the set of the groups without thermocycling, it was significantly higher in the citric acid than the other groups ($p<0.05$). The tartaric acid had significantly higher bonding strength compared to phosphoric, boric and control groups ($p<0.05$). The bonding strength of phosphoric acid was significantly higher in the boric and control groups ($p<0.05$). The boric acid provided a significant increase in the bonding strength compared to control group ($p<0.05$) (Table 2).

Table 2. Shear bond strength values (MPa) for all samples

Groups	No Thermal Cycling		Thermal Cycling	
	Mean	Standard deviation	Mean	Standard deviation
Control	2.907[a]	0.109	2.594[a]	0.097
Boric Acid	4.407[b]	0.204	3.953[b]	0.140
Phosphoric Acid	4.838[c]	0.221	4.465[c]	0.154
Tartaric Acid	5.724[d]	0.238	4.637[c]	0.165
Citric Acid	6.062[e]	0.255	5.613[d]	0.227

*Different lower case letter represents statistical significant among groups, verified by one-way ANOVA and Tukey's test ($p<0.05$).

Figures 2 showed the surface morphology of representative dentin after different treatments observed by a SEM.

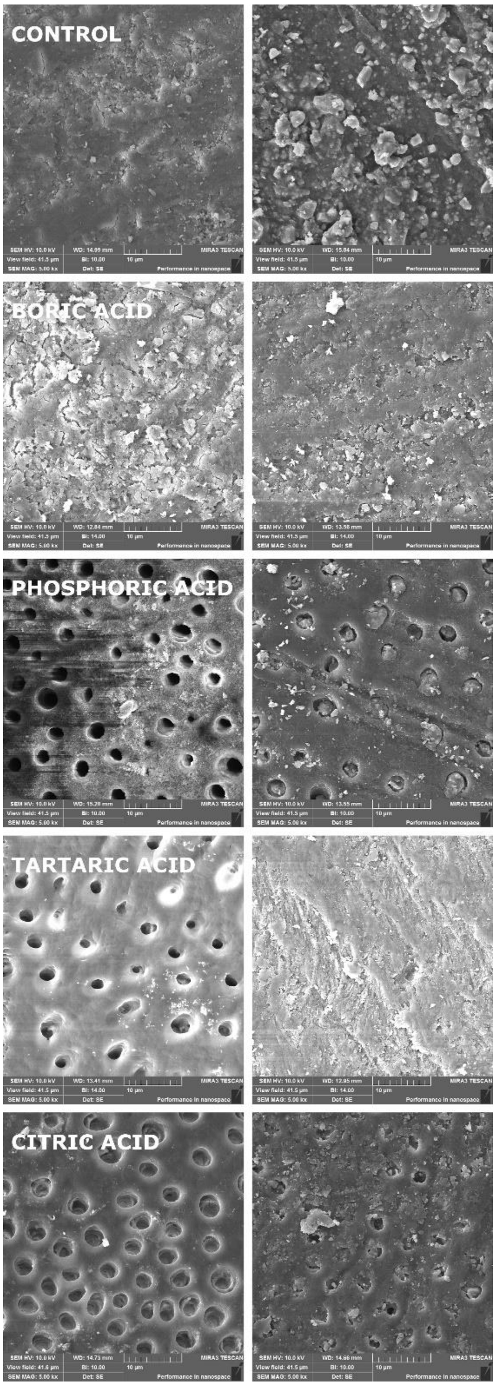

Figure 2. Scanning electron microscope images of dentin surfaces treated by boric, phosphoric, tartaric, and citric acids.

The SEM images showed that the pore structures with regular and deep edges were observed in the citric acid group (%10 for 25 s). In tartaric acid group (15% for 15 s), the pore diameters were smaller than the pores caused by citric acid. It is observed that the pore structures in the phosphoric acid group (32% for 15 s) had irregular edges than the citric acid and they formed with less frequent intervals. In boric acid group (%5 for 20 s), it was observed that the pore diameters were highly smaller, shallow and irregularly distributed than the other acids. In all the groups, it was seen that cements filled in the pore cavities after the SBS test.

DISCUSSION

The results support the rejection of the null hypothesis because all acid treatments significantly increased the bonding strength between monolithic zirconia and dentin surface. This study revealed that (1) thermal cycling procedure decreased the bonding strength in all the groups; (2) application of acid treatments to dentin surface increased bonding strength values; (3) in both procedures with and without thermal cycling; based on order of efficacy, citric, tartaric, phosphoric, and boric acids were more effective in improving the shear bond strength between monolithic zirconia and dentin surface; (4) the most favorable results in bonding strength measurements were obtained with citric acid solution; (5) boric acid provided less success among the acid agents.

Citric acid has been used for many years in root surface treatment applications in periodontology field and in the disinfections of root canals applications in endodontics field.[18,19] Citric acid is a convenient agent for surface treatments due to its erosive character[20]; however, the number of surface treatment studies in prosthodontics field is limited in the literature. Ravikumar *et al*.

evaluated the bonding strength of AH Plus Sealer to root dentin surface treated with EDTA, maleic acid, citric acid and MTAD agent, it was determined that the post-irrigation bonding strength values were not significantly different between citric acid and EDTA groups.[21] Akisue *et al*., compared the shear bond strength of four resin-based sealers to dentin treated with citric acid solution or Er:YAG irradiation. They concluded that RealSeal and 15% citric acid solution achieved the best results regarding the sealer and pretreatment used.[22] Kameyama *et al.*, evaluated the effect of aqueous solutions of 10% citric acid (10-0) or 10% citric acid/3% ferric chloride (10-3) on resin bonding to dentin following irradiation with an Er:YAG laser. They examined that ferric chloride included in an aqueous solution of 10% citric acid (10-3) was effective in acid treatment for bonding 4-META/MMA-TBB resin and dentine. They concluded that ferric chloride in citric acid prevented the denaturing of collagen and prevented the collapse of demineralized collagen network. It is also known that collapse of demineralized collagen was similar between 10-3 and 10-0.[23] Demiryurek *et al.*, evaluated the effects of different surface treatments on the bond strength of a fiber post to dentin. They calculated that irrigation with 10% citric acid increased the push-out bonding strength values 4 times than the control group.[24] In the present study, 10% citric acid treatment for 25 s on the dentin surface achieved the highest bonding strength value. This situation can be explained by the formation of regular and smooth pore structures on the dentin surface by the citric acid treatment and the attachment of the resin cement on the pore structure.

Tartaric acid is incorporated into glass ionomer cements in order to control the setting characteristics and provide easy mixing.[25] The tartaric acid mainly occurs mainly in wine and grapes and this acid is deemed to be extremely erosive to dental hard tissues.[26] Fu *et al.*, investigated the interfacial interaction of tartaric acid with hydroxyapatite and enamel. The authors concluded that the enamel etched with tartaric acid mainly revealed decalcification of the periphery of the enamel rods. Etching of enamel tissue for 30 s may be appropriate for resin-to-enamel bonding via micro-retentive interlocking. Therefore, tartaric acid might be used as an etchant and functional ingredient in self-etching primers.[27] In the present study, the application of 15% tartaric acid agent on the dentin surface for 15 s increased the bonding strength values than the bonding strength values of the control group.

Application of phosphoric acid to dentin surface provides further exposure of dentin tubules and this is beneficial for the penetration of monomer of resin cement.[28] Juloski *et al.*, assessed the effect of preliminary phosphoric acid-etching on shear bond strength (SBS) to enamel and dentin of a self-adhering restorative composite and of a new self-etch adhesive used in combination with the proprietary flowable composite. The authors concluded that phosphoric acid treatment of the substrate before applying Vertise Flow or OptiBond XTR did not significantly change their adhesion potential to enamel and dentin. In their study, SEM observations showed that phosphoric acid pretreatment did not change the etching pattern of self-etching adhesives but just increased the depth of etching.[29] Poggio *et al.*, compared the bond strength of different universal adhesives under three testing conditions; when no pretreatment was applied, after 37% phosphoric acid etching and after glycine application. They suggested that acceptable bond strength values could be obtained with no dentin pretreatment regardless the adhesive system used in reduced sensitivity technique conditions. They also suggested that acid pretreatment should be localized only to enamel.[30]

Alaghehmand *et al*., determined the micro-shear bond strength of composite resin on superficial and deep dentin after conditioning with phosphoric acid and Erbium-Doped Yttrium Aluminum Garnet (Er:YAG) laser. They suggested that laser treatment of dentin surfaces negatively affected the bond strength compared to acid etching. The authors noted that this controversy might be partly due to the heterogeneity of methods for dentin conditioning via laser.[31] Davari *et al.*, investigated the shear bond strength of an etch-and-rinse adhesive system to dentin surfaces following

Er:YAG laser and/or phosphoric acid etching. They concluded that phosphoric acid etching was still an effective dentin pretreatment technique for composite resin restorations[32] In the present study, application of 32% phosphoric acid for 15 s to dentin surface improved the bonding strength of monolithic zirconia specimens but citric and tartaric acids provided more favorable results. This situation may be associated with the fact that citric and tartaric acids more effectively regulated dentin tubules by protecting the hybrid layer on the dentin surface.

Boric acid (BA) is a weak, inorganic acid used in clinical and industrial applications.[33] In dental field, boric acid is used as cavity disinfectant agent because of bacteriostatic and fungistatic properties.[34] In the literature, the use of boric acid in "surface treatment" studies is limited. Ercan *et al.* evaluated the effect of ozone, chlorhexidine and boric acid on shear bond strength between tooth dentin and composite buildups. They suggested that chlorhexidine and boric acid significantly decreased the strength of the bond, and there was significant difference between the shear bond values.[35] Although application of 5% boric acid for 25 s was increased the bonding strength compared to no treatment group in our study, other acids were more successful in terms of enhancing bonding quaility between zirconia and dentin surfaces. This may be due to less-invasive characteristic of boric acid. This characteristic was also observed in SEM observations which pore diameters were smaller and shallow.

Thermal cycling procedure allows understanding the effect of thermal stresses on bonded interfaces of restorative materials. With this procedure, in vivo process can be simulated in laboratory conditions.[36] In present study, thermal cycling procedure was negatively effect to the bonding strength of monolithic zirconia specimens cemented to the dentin surface. Mechanical stresses originated from thermal changes may be affect bonding quality in bonding interfaces.

The authors of the present study are aware that the data of the current trial have to be interpreted within its limitations. For modification of the dentin surface, we used phosphoric acid in gel form. It is known that application of solution form of the agent is more effective than gel form.[37] Nevertheless, the data of the present study should be supported by clinical studies as decreasing in debonding rate of monolithic zirconia crowns can be adequately experienced in oral environment. Further studies maybe helpful to determine the effect of their different concentrations to optimize the potential merit of citric acid for use before the cementation.

In conclusion, the surface treatment by the means of applied acid treatments produces positive changes in the surface morphology of dentin surfaces. The main idea of the present study was to include different acid surface treatments including citric, tartaric, phosphoric and boric acids, and investigation if the bond strength between monolithic zircoina and dentin surface would be affected by different specifications of these acid agents. Current experiments supported that application of citric, tartaric, phosphoric, and boric acids on the dentin surface can increase the shear bond strength between monolithic zirconia and dentin surface. In addition, to the best of the authors' knowledge, there has been no study examining the effect of these acid treatments on the bonding of monolithic zirconia crowns in the same laboratory settings, and the current experiments provided in vitro data about the preferring the appropriate acid treatment for cementation of these crowns.

CONCLUSIONS

Based on the limitations of present study, the following conclusions may be drawn:

1. Application of acid treatments is effective to increase bonding strength between monolithic zirconia and dentin surface.

2. The thermal cycling procedure decreased the bonding strength in all the groups.

3. In both procedures with and without thermal cycling; based on order of efficacy, citric, tartaric, phosphoric, and boric acids were more effective in improving the shear bond strength between monolithic zirconia and dentin surface.

4. Treatment with 10% citric acid of dentin surface for 25 s is suggested cementation process of monolithic zirconia restorations.

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Monolitik Zirkonya Materyalinin Dentine Bağlanma Dayanımı Üzerine Farklı Tür Asit Yüzey Uygulamalarının Etkilerinin Araştırılması

ÖZ

Amaç: *Bu çalışmanın amacı, dentin yüzeyine uygulanan sitrik, tartarik, fosforik ve borik asit uygulamasının, monolitik zirkonyanın bağlanma dayanımına etkisini araştırmaktır.* ***Gereç ve Yöntemler:*** *Bu çalışmada, 100 adet insan dişi rastgele seçim yöntemiyle asit uygulama prosedürleri ve termal yorgunluk işlemlerine göre alt gruplara ayrıldı (n=10). Monolitik zirkonya restorasyonlar, CAD/CAM sistemi kullanılarak 3 mm kalınlığında ve 7 mm çapında üretildi. Dentin yüzeylerine asit uygulaması işleminin ardından, uygulanan asitlerin etkinliğini değerlendirmek üzere makaslama bağlantı dayanım testi uygulandı. Yüzey modifikasyonları taramalı elektron mikroskobu yardımıyla incelendi.* ***Bulgular:*** *Çalışma grupları, termal yorgunluk uygulanmayan gruplar için (sitrik asit> tartarik asit> fosforik asit> borik asit> kontrol) ve termal yorgunluk uygulanan gruplar için (sitrik asit> tartarik asit) ve (fosforik asit> borik asit> kontrol) en yüksek bağlanma değerine göre sıralandı (p<0,05). Termal yorgunluk uygulanan gruplarda; tartarik asit grubu ile fosforik asit grubu arasında bağlantı dayanım değerlerinde istatistiksel olarak anlamlılık saptanamadı (p>0,05).* ***Sonuç:*** *Termal yorgunluk içeren ve içermeyen her iki prosedürde; etkinlik sırasına göre sitrik, tartarik, fosforik ve borik asit uygulaması, monolitik zirkonya ile dentin arasındaki bağlantı dayanımını arttırmada daha başarılı olmuştur. Termal yorgunluk uygulaması tüm gruplarda bağlanma dayanımını azaltmıştır.*

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Original research

DENTIN BOND STRENGTH AND MICROLEAKAGE COMPARISON OF THREE DIFFERENT UNIVERSAL ADHESIVES

ABSTRACT

Objectives: The aim of this study is to evaluate and compare the bond strength and micro-leakage of three different universal adhesive systems applied in self-etch mode to dentin.

Materials and Methods: To evaluate bond strength, the mid-coronal dentin surfaces of forty-five human molar teeth were exposed and randomly assigned into three groups according to the following adhesive application: Single Bond Universal (3M ESPE), Optibond XTR (Kerr), and Tokuyama Universal (Tokuyama Dental) (n=15). The shear bond strength test was performed after composite build-up. Then, the fractured surfaces were evaluated using a scanning electron microscope (SEM). To evaluate micro-leakage, facial class V cavities were prepared to forty-five human premolars and randomly assigned into identical three experimental groups described above (n=15). After composite resin restoration of cavities, the specimens were thermo-cycled for 500 cycles and then immersed in basic fuchsine, sectioned, and examined under a stereo-microscope. Data were evaluated using one-way ANOVA, Tukey's, Chi-square and Mann Whitney U tests.

Results: Among the adhesives, the highest bond strength was achieved in Optibond XTR, while Tokuyama Universal showed the lowest bond strength values ($p<0.05$). In micro-leakage results, no significant difference was reported in occlusal margins among groups. In gingival margins, Optibond XTR showed less leakage compared to Tokuyama and Single Bond Universal ($p<0.05$).

Conclusions: The study findings indicated that two-step universal adhesive system is more successful than one-step universal adhesive systems in bonding to dentin. Considering that bonding plays a major role in the longevity of the restoration, it can be said that the use of two-step universal adhesive systems in dentin can give more successful results.

Keywords: Adhesive systems, dentin bond strength, micro-leakage.

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INTRODUCTION

Owing to the growing patient demand for esthetic restorations and the application of more conservative cavity preparations, direct composite resin materials have become widespread in recent years. There is a direct relation between the success of composite restorations and the effectiveness of the adhesive system used.[1]

Nowadays, adhesive systems are categorized according to their different characteristics. In etch-and-rinse systems, which are among the subgroups of classification according application mode, 30-40% concentration of orthophosphoric acid is applied as a separate step. In this way, collagen is exposed by removing the smear layer completely. The applied resin then flows into the tubules of dentin and polymerizes by entering between the collagen fibers to provide a basis for the hybrid layer. In the clinical environment, it is better to use etch-and-rinse systems with "wet bonding" technique.[2] However, it is not practically possible to leave the dentin moist while drying the enamel and then to determine whether the dentin is sufficiently moist. The problem of dentin moistness, which reduces the spread of adhesive resin between collagen fibrils, has been eliminated with self-etch adhesive systems. Self-etch adhesives are systems that etching and primer application steps are applied simultaneously to enamel and dentin, and do not need a separate etching and rinsing step. However, the acids in self-etching adhesive are not as strong as phosphoric acid. Therefore, they constitute weak enamel bonding and long-term restorations show gaps in the enamel edges.[3] To solve this problem, roughening the enamel edges of the cavity with ortho phosphoric acid before applying self-etch adhesives is recommended.[4] In clinical use, etching the edges of the enamel without overflowing into the dentin is difficult.

Recently, studies aimed to eliminate the disadvantages of multi-step bonding procedures and to ease clinical use have resulted in products called "universal" or "multi-mode".[5] This system provides clinician with many options during use. Thanks to these adhesive systems, the clinician can use etch-and-rinse, self-etch and selective-etch techniques together. This enables the clinician to choose the desired system using an adhesive agent in different situations.

This *in vitro* study aimed to compare the bond strengths and micro-leakage values of three different universal adhesive systems applied in the self-etch mode to dentin. The null hypothesis was that there are no differences between the universal adhesive systems in terms of bond strength and micro-leakage.

MATERIALS AND METHODS

The study was approved by the Non-Interventional Clinical Research Ethics Committee of Sivas Cumhuriyet University under approval number 2018-01/30.

A total of extracted 90 permanent human molar (45) and premolar (45) teeth were used in the study. The extracted teeth were stored in the 2.5% sodium hypochlorite (NaOCI) solution and then in distilled water at room temperature.

Shear Bond Strength (SBS) Test Procedure

For the SBS tests, 45 molars were buried in a silicon mold using self-curing acrylic (IMICRYL Dental, Konya, Turkey). The occlusal thirds of molars were separated with using a water-cooled diamond saw (IsoMet 1000, Buehler, USA). The exposed dentin surfaces were ground with 600 grid silicon carbide abrasive papers and prepared samples were divided randomly into three groups (n=15); Single Bond Universal (3M ESPE, St. Paul, MN, USA), Optibond XTR (Kerr, Orange, CA, USA) and Tokuyama Universal (Tokuyama Dental, Japan). All information about tested adhesive systems are presented in Table 1.

Table 1. Chemical compositions and application procedures of the tested adhesives.

Adhesive/Manufecturer	pH	Composition	Application procedure
Single Bond Universal (3M ESPE, USA)	2.7	10-MDP phosphate monomer, Vitrebond copolymer, HEMA, BISGMA, dimethacrylate resins filler, silane, initiators, ethanol, water	**1.** Apply adhesive to tooth surface by scrubbing action for 20 s. **2.** Dry the adhesive for 5 s. **3.** Light cure for 10 s.
Optibond XTR (Kerr, USA)	2.4	**Primer:** GPDM, HEMA, Dimethacrylate, CQ, water, ethanol, acetone. **Adhesive:** Bis-GMA, HEMA, trifunctional monomer, ethanol, CQ, barium glass filler, fluoride-containing filler, nano-filler.	**1.** Apply the self-etch primer using a micro brush with a scrubbing motion for 20 s. **2.** Air thinning for 5 s. **3.** Shake the adhesive briefly. **4.** Apply the adhesive using a light brushing motion for 15 s and air thin for 5 s. **5.** Light cure for 10 s.
Tokuyama Universal (Tokuyama Dental, Japan)	2.2	**Primer A:** Acetone, 3D-SR monomer, MTU-6, Bis-GMA, TEGDMA, HEMA **Primer B:** Acetone, isopropyl alcohol, water, borate catalyst, peroxide, silane bonding agent	**1.** Mix by dropping one drop of bottles A and B. Scrub to surface with agitation for 20 s. **2.** Air thinning for 5 s.

MDP: 10-methacryloyloxy-decyl-dihydrogen-phosphate; HEMA:-hydroxyethyl methacrylate; BIS-GMA: bisphenol-A-diglycidyl methacrylate; GPDM: glycero-phosphate dimethacrylate; CQ: camphorquinone; 3D-SR: three dimensional surface-reinforcing monomer; MTU-6: 6-methacryloyloxyhexyl 2-thiouracil-5-carboxylate; TEGDMA: triethyleneglycol dimethacrylate.

All of adhesive agents applied in accordance with the manufacturer’s -instructions and polymerized with a LED-curing light (Valo Cordless, Ultradent, South Jordan, USA) for 10 s. A cylindrical plastic tube (4x3 mm) was placed on exposed dentin surface where the adhesive had been applied. Composite resin (Estelite Sigma Quick, Tokuyama, Japan) was built-up and polymerized for 40 s. Then, SBS test was performed using a universal testing machine at 0.5mm/min (LLOYD Instruments, Ametek Inc. England). Obtaind fractured specimens were examined on a stereo-microscope (Nikon SMZ800, Tokyo, Japan) under 25x magnification. The failure modes (cohesive, adhesive, and mixed) were identified for each specimen. After examination of all samples with the stereo-microscope, fractured surfaces were evaluated in detail on SEM analysis (TESCAN MIRA3, Brno, Czech Republic).

Micro-leakage Test Procedure

Class V cavity preparations (4x3x2 mm) without bevels were prepared on the facial surfaces of the 45 premolars with diamond burs underwater cooling. The gingival margin was 1 mm below the cemento-enamel junction. The teeth were then randomly divided into the specified groups as in the bond strength test procedure (n=15). After the bonding agents were applied according to the manufacturer’s instructionspolymerized with the same dental light device for 10 s. All cavities were restored with composite resin. The restorations were then finished and polished (Astropol, Ivoclar Vivadent, USA) under water cooling. After the specimens stored in distilled water for 24 h, thermocycling procedure were applied. This procedure was done with 500 times between 5-55 °C and 30 s of dwell time. The entire surface of specimens of which root apex were closed using sticky wax was applied two layers of nail varnish starting at a distance of 1 mm from the margins. The samples were kept in 0.5% basic fuchsine at room temperature. Samples removed from solution after 24 hours were rinsed under water. Occlusal (enamel) and gingival (cementum) margins of samples that are divided into two parts as mesio-distally using a low-speed diamond disc were evaluated with a stereo-microscope at 40x magnification. The dye infiltration was observed according to the following classification. [6]

0: No infiltration;

1: Dye infiltration at 1/3 of cavity walls;

2: Dye infiltration at 2/3 of cavity walls;

3: Dye infiltration entire or more than 2/3 of the cavity walls;

4: Infiltration involving axial wall.

Statistical Analysis

Data analysis was carried out using SPSS version 22.0 (SPSS Inc., Chicago, IL, USA). One-way ANOVA complemented by post hoc Tukey Test were used for inter-group comparison. The data obtained by counting were assessed by using Chi-square and Mann-Whitney U tests. The value of 0.05 was accepted as statistical significance.

RESULTS

Shear Bond Strength

Values obtained from shear bond strength test and distribution of the fracture modes are given in Table 2 and Table 3, respectively.

Table 2. The maximum, minimum, mean shear bond strength values (Mpa) and standard deviation (SD) of the tested adhesive systems.

Adhesive system	N	Minimum (Mpa)	Maximum (Mpa)	Mean ± SD (Mpa)
Single Bond Universal	15	9.23	16.97	12.66 ± 2.5 [a]
Optibond XTR	15	13.53	21.67	18.57 ± 2.3 [b]
Tokuyama Universal	15	4.01	8.33	5.5 ± 1.3 [c]

[a,b,c]: Values with the different superscript letters are significantly different. ($p<0.05$).

Table 3. Distribution of the fracture modes after shear bond strength (SBS) testing.

Adhesive system	Fracture mode			
	Adhesive	Dentin cohesive	Composite cohesive	Mixed
Single Bond Universal	3	5	2	5
Optibond XTR	-	-	2	13
Tokuyama Universal	14	-	1	-

When the groups are analyzed with one-way variance analysis, the differences were statistically significant (p=0.001). As a result of multiple comparisons between adhesive systems, it was observed that Optibond XTR showed significantly the highest bond strength (p=0.001), while Tokuyama Universal showed significantly the lowest (p=0.001. In the fracture surface analysis, Single Bond Universal showed more cohesive fractures, Optibond XTR had more mixed fractures, and Tokuyama Universal had more adhesive fractures (Table 3).

SEM photographs of the fracture surfaces of the groups are presented in Figure 1.

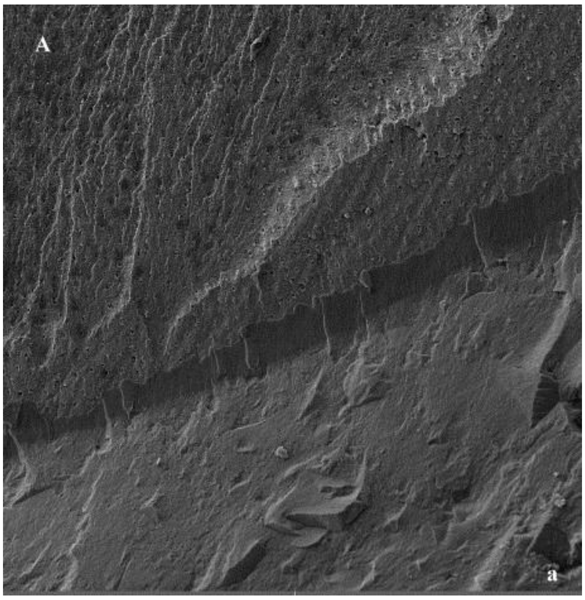

Figure 1. Mixed failure SEM micrograph of Single Bond Universal (A) at 500x (a) magnification.

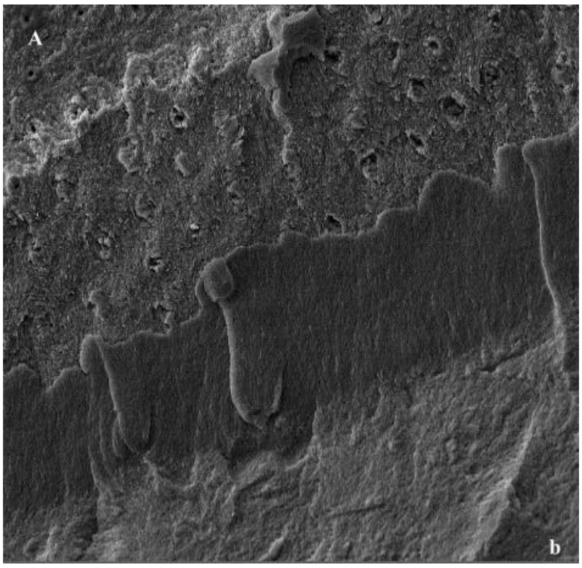

Figure 2. Mixed failure SEM micrograph of Single Bond Universal (A) at 2000x (b) magnification.

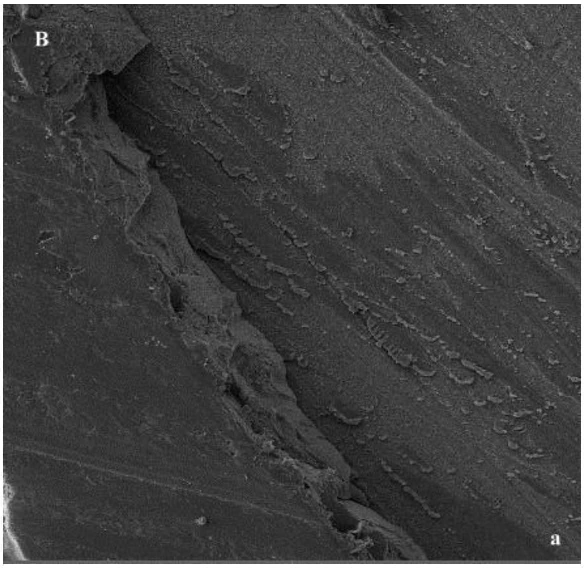

Figure 3. Cohesive failure SEM micrograph of Optibond XTR (B) at 500x (a) magnification.

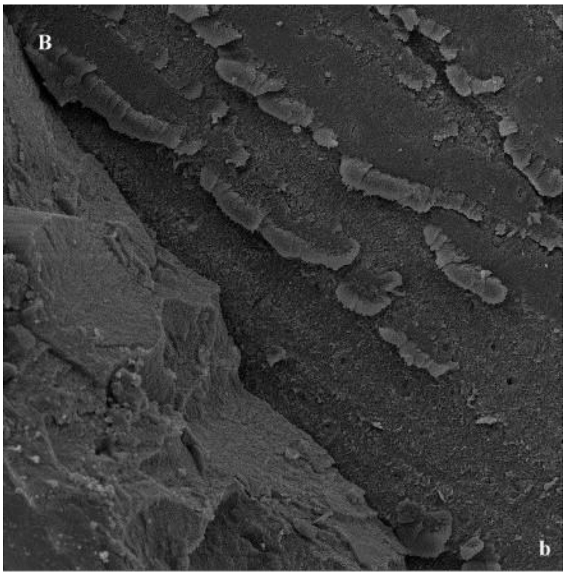

Figure 4. Cohesive failure SEM micrograph of Optibond XTR (B) at 2000x (b) magnification.

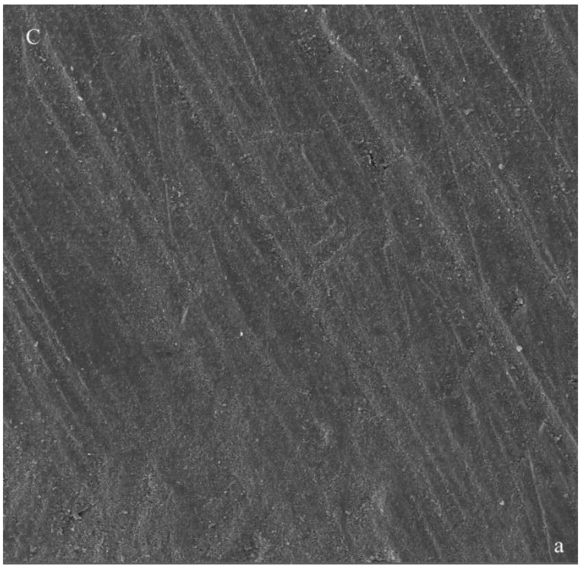

Figure 5. Adhesive failure SEM micrograph of Tokuyama Universal (C) at 500x (a) magnification.

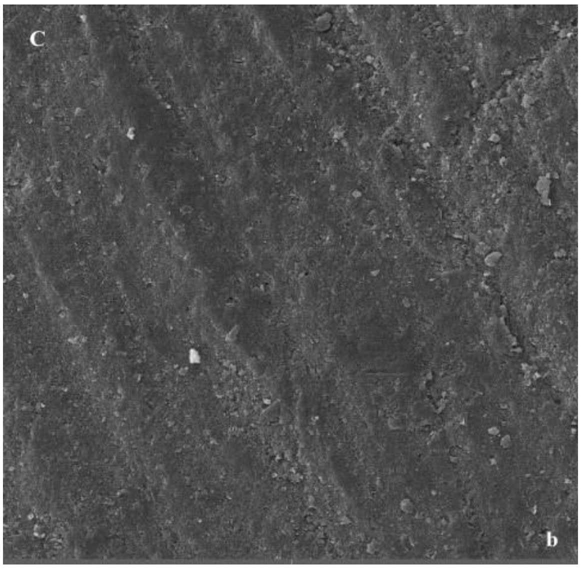

Figure 6. Adhesive failure SEM micrograph of Tokuyama Universal (C) at 2000x (b) magnification.

When the fracture surface of the Single Bond Universal was examined under the SEM, the composite cohesive region, the dentin cohesive region (where the tubules can be clearly seen) and the adhesive layer were observed. In the fractured specimens of Optibond XTR, the composite cohesive region and the dentin surface where the tubules were not clearly visible were observed. Sealed dentin surfaces with detectable adhesive agent and composite residues were visible. When the fracture surface of Tokuyama Universal was examined with the SEM, dentin tubules and adhesive residues appeared to be indistinct.

Microleakage

The occlusal and gingival microleakage scores of the universal adhesive systems are shown in Table 4.

Table 4. Occlusal and gingival microleakage scores.

Adhesive system		Microleakage scores				
		0	**1**	**2**	**3**	**4**
Single Bond Universal	**occlusal**	10	3	2	0	0
	gingival	7	4	1	1	2
Optibond XTR	**occlusal**	14	0	1	0	0
	gingival	10	4	0	0	1
Tokuyama Universal	**occlusal**	8	4	1	2	0
	gingival	4	2	1	2	6

When comparison was made between the mean microleakage scores of different materials at the occlusal margins, Optibond XTR exhibited the least microleakage and Tokuyama Universal showed the most. However, there were no statistically significant differences in microleakage of the occlusal margins between the groups ($p>0.05$). When comparison was made between mean microleakage scores of different materials, Optibond XTR exhibited the least microleakage and Tokuyama Universal exhibited the most microleakage at the gingival margins. Intragroup comparisons revealed that there was a statistically significant difference in microleakage between Optibond XTR and Tokuyama Universal adhesive systems ($p=0.006$). In the evaluation made separately for the occlusal and gingival microleakage, while there was no statistically significant difference between the samples of Single Bond Universal and Optibond XTR groups for both regions ($p>0.05$), Tokuyama Universal showed more microleakage in the gingival than occlusal. ($p=0.02$) ($p<0.05$). Also, all adhesives showed more leakage in the gingival than occlusal margins (Table 5).

Table 5. Statistical values of microleakage levels in occlusal and gingival margins.

	Adhesive system	N	Mean ± SD	Median (minimum-maximum)
Occlusal	**Single Bond Universal**	15	$.4667 \pm 0.74^{a}$	0.00(0.00-2.00)
	Optibond XTR	15	$.1333 \pm 0.51^{a}$	0.00(0.00-2.00)
	Tokuyama Universal	15	$.8000 \pm 1.08^{a}$	0.00(0.00-3.00)
Gingival	**Single Bond Universal**	15	1.1333 ± 1.45^{ab}	1.00(0.00-4.00)
	Optibond XTR	15	$.5333 \pm 1.06^{a}$	0.00(0.00-4.00)
	Tokuyama Universal	15	2.2667 ± 1.75^{b}	3.00(0.00-4.00)

^{a,b}: Values with the different superscript letters are significantly different. ($p<0.05$).

DISCUSSION

Although the production of adhesion systems recently introduced as “universal” adhesives are an exciting step for the development of adhesive dentistry, it remains unclear whether they are suitable for all adhesive procedures. In this study, Optibond XTR showed the highest bonding strength and lowest microleakage values while Tokuyama Universal showed the lowest bonding strength and highest microleakage values. Therefore, the null hypothesis of the study was rejected.

Optibond XTR is a two-step universal adhesive system developed to increase the acidification capacity of the primer. This system has a moderate self-etching primer (pH = 1.6). The primer contains glycerol phosphate dimethacrylate (GPDM) as the monomer and water, ethanol and acetone as the solvent. Shortly after the primer of the adhesive system is applied, the acetone evaporates and the concentration of water and GPDM increases. Due to the increase in GPDM and water concentration, the pH of the primer initially decreases from 2.4 to 1.6.[7,8] Increased acidity of the primer increases the depth of demineralization in dentin. It has been reported that increasing the depth of demineralization in dentin provides better bonding.[9-11] The high bond strength of Optibond XTR can be attributed to strong demineralization and micromechanical locking due to its strong acidity. Also, the fact that GPDM in the Optibond XTR has two polymerizable groups forms a stronger polymerization network and may tend to react more strongly with adhesives and other monomers in the restorative material. This may explain the high bonding performance. Juloski *et al*.[12] examined the bond strength of different adhesive systems used etch-and-rinse and self-etch modes on enamel and dentin. They concluded that Optibond XTR used in self-etch mode gave similar results to etch-and-rinse adhesive systems. Meharry *et al*.[13] compared the shear bond strength of nine different adhesive systems. They reported that Optibond XTR gave high bonding values.

Single Bond Universal is a one-step universal adhesive system with monomer containing methacryloyloxyethyl dihydrogen phosphate (MDP). MDP is a monomer that can acidify enamel and dentin and chemically bond with calcium (Ca) in hydroxyapatite (HAp). This ionic bond of MDP with HAp is highly resistant to hydrolytic degradation. Therefore, chemical bonding between MDP and HAp have critical importance in maintaining the stability of the adhesive layer.[14-16] In addition, more than 50% of the polyalkenoic acid copolymer contained in Single Bond Universal except MDP can be bond with HAp. Munoz *et al.*[17] showed that Single Bond Universal had a lower conversion degree than other groups in their studies comparing the bonding efficiency of eight adhesive systems to dentin. They reported that this is because Vitrebond's high molecular weight prevents monomer convergence during polymerization. They also reported that Vitrebond reduced the bonding strength of the MDP monomer, resulting in low bonding strength. Takamizawa *et al.*[18] compared the effectiveness of various smear layers in dental hard tissues on the fatigue strength and shear bond strength of four different bonding systems. They found that two-step adhesive systems are more successful than one-step adhesive systems regardless of the smear layers and reported that Single Bond Universal has lower bond strength than Optibond XTR. Michaud *et al.*[19] examined the bond strength in various etching proctocols of three different adhesive systems. They concluded that when applied in self-etch, Single Bond Universal gave lower bonding values than Optibond XTR in dentin.

In study, Single Bond Universal showed lower bond performance values compared to Optibond XTR. The cause for this, it may be shown that the adhesive system has polyalkenoic acid copolymer in addition to its ultra-mild acidity. It has been explained that the high molecular weight polyalkenoic acid copolymer competes with the MDP monomer to bond with HAp and prevents monomer convergence.[18, 20]

Yoshihara *et al.*[21] examined the molecular interaction of two different solutions containing GPDM and MDP with the dentin surface using transmission electron microscopy (TEM). They reported that the monomer interaction difference with HAp was clearly visible at the dentin interface. According to the study results, initially, chemical bonding occurs between the Ca of the HAp and the acids (Stage 1). The first bonding stage is accompanied by the dissolution of phosphate and hydroxide ions from HAp to reach electron neutrality. Whether the monomer will remain bonded (stage 2, adhesion route) or de-bonded along with an abundant decalcification (stage 2, decalcification route) is affected by the stability of the monomer-Ca formation. GPDM-Ca salt is less stable than MDP-Ca salt. GPDM basically follows the decalcification route, while MDP-Ca follows the adhesion route.[21] Thus, it was observed that a submicron HAp-rich hybrid layer without obvious collagen exposure formed in the MDP-based adhesive system while GPDM-based adhesive system is formed a thicker and HAp-poor hybrid layer with visible collagen exposure.[22]

The current consensus regarding the studies is that chemical interactions provide more benefits from abrasion in bonding to dentin.[14,23,24] The different bonding performances shown by Single Bond Universal and Optibond XTR can be explained by the chemical composition of the monomers. Although Optibond XTR with GPDM monomer follows the decalcification route, its high bonding values can be attributed to the fact that it has two methacrylate groups and forms a stronger polymer network than the MDP monomer.

The Tokuyama Universal adhesive system demonstrated the lowest bond strength values between all universal adhesive systems. Tokuyama Universal is a chemically polymerized two-component, one-step universal adhesive system. Regarding this newly developed universal adhesive system, Katsumata *et al.*[25] examined the microtensile bond strength of different universal adhesive systems using various restorative materials and concluded that Single Bond Universal showed higher values than Tokuyama Universal, although there was no statistical difference in microtensile bonding values. Similarly, Single Bond Universal showed higher bonding values than Tokuyama Universal in this study. Although Tokuyama Universal has mild acidity, its low bond strength compared to Single Bond Universal, which has ultra-mild acidity, can be attributed to its interactions with HAp depending on polymerization types and monomer differences. The absence of statistical differences between the two adhesive systems maybe the result of using different bond strength tests and restorative materials.

When the fracture types of the groups were examined, a certain relationship was found between bond strength values and fracture type. It was seen that the cohesive fracture type was found more in the adhesive systems with high bonding values, while the adhesive fracture type was more present in the adhesive systems with low bonding values. Available data are compatible with previous studies.[26,27]

Currently, there is no consensus on which type of adhesive system reduces microleakage. The one-step adhesive systems produced today have not achieved the success of conventional multi-step adhesive systems. There are several reasons why these systems failure. One-step self-etch systems are highly hydrophilic even after polymerization and so they act as semi-permeable membranes. These systems have a high solvent concentration. This makes it difficult to obtain a sufficient thickness of resin layers and to remove residual solvent. One-step self-etch adhesives tend to evaporate the solvent so the membranes become permeable after polymerization.[28] During the evaporation of the solvent contained in the one-step systems, the monomer/water ratio can also vary. In later periods, hydrophilic areas and water-filled tunnels (so-called ‘water trees’) are formed that allow the water movement in the substrate.[29] In addition, in this adhesive systems, the hybrid layer thickness is thinner compared to multi-step adhesive systems.[30,31] This layer is inhibited by oxygen and causes poor polymerization, which is one of the important factors of microleakage.[32]

In the study, Single Bond Universal, which is a one-step universal adhesive system, gave higher microleakage values than the Optibond XTR group, which is a two-step system. Single Bond Universal's inability to acidify enamel and dentin/cement due to its ultra-mild acid primer resulting in incomplete hybridization may explain more microleakage. Also, hybrid layer formation that arises from high hydrophilicity and solvent ratio in one-step adhesives can be considered the cause of high microleakage. The polyalkenoic acid copolymer contained in Single Bond Universal competes with the MDP monomer to bond to Ca in HAp. This prevents the convergence of monomers during polymerization due to the high molecular weight, resulting in high microleakage values by affecting the adhesive bond.

In the study, Optibond XTR showed low microleakage values compared to other groups. Rengo *et al.*[9] compared the leakage resistance between different adhesive systems and stated that Optibond XTR used in self-etch mode gave results comparable to Optibond FL, a three-step adhesive system. Sadeghi *et al.*[33] examinated the microleakage values of four different adhesive systems and reported that Optibond XTR applied in self-etch mode gave lower microleakage values than other groups. In parallel with previous studies, the reason for the less microleakage of the Optibond XTR can shown to be a two-step adhesive with a moderate acidic primer that makes a strong chemical bond.

When the microleakage results of adhesive systems were evaluated, the highest microleakage values were observed in the Tokuyama Universal group. Further studies are needed to examine why the formulation of Tokuyama Universal leads to more microleakage. To our knowledge, there is no study comparing the data obtained from self-etch application of Tokuyama Universal published in full text in the relevant literature.

In the evaluation cavity margins of the tested adhesives, it was seen that the amount of leakage at the gingival margins of all three adhesive groups was more than at the occlusal margins. In many studies examining the leakage values of restorative materials, it has been reported that gingival margins have more microleakage than occlusal margins.[34-38]

According to the studies, the microleakage variation between enamel and dentin/ cementum margins is multifactorial and depend on issues such as the hypermineralization and collagen fibrillary network, organic component of the dentin, tubular fluids movement, dentin tubule orientation, the interaction of acidic primers with the smear layer and demineralization and hybrid layer formation.[39,40] Furthermore, the fact that solvents in the adhesive resin react differently with varying dentin moisture can be shown as the cause of microleakage differences between the adhesive resins.[40] In this study, cavity are limited in two separate tooth regions as enamel and dentin/cementum. That the dentin/cementum-composite thermal expansion coefficient is higher than the difference between enamel-composite may be the cause of high leakage in the gingival margin.

The main limitation of this present study was that long-term clinical follow-up was not investigated, because it is difficult to perform in a standardized manner and is time-consuming. *In vitro* tests are frequently used to assess properties and quality of dental materials and technical procedures. Because of the limitation of the methods of investigation using shear strength and dye penetration, further investigations are needed, especially regarding the dentin bonding when universal adhesives are used. Another limitation of this study was the low number of observations. A higher number of observations could show minor changes among the products and highlight further significant differences.

CONCLUSIONS

The results demonstrated that one-step universal adhesive systems did not show bond strength and leakage resistance that was as good as the two-step universal adhesive system. Optibond XTR showed better bonding performance in comparison with other universal adhesives; while Tokuyama Universal showed the worst performance between all adhesive systems. Starting from the study, it can be said that two-step universal adhesive systems are preferable in dentin due to their success in bonding performance and microleakage. *In vivo* research is necessary to evaluate the long-term clinical success of universal adhesive systems.

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CONFLICT OF INTEREST

The authors declare no conflict of interest with respect to the authorship and publication of this article.

Üç Farklı Üniversal Adeziv Sistemin Dentine Makaslama Bağlanma Dayanımlarının ve Mikrosızıntı Değerlerinin Karşılaştırılması

ÖZ

Amaç: *Bu çalışmanın amacı, self-etch modda kullanılan üç farklı üniversal adeziv sistemin dentine olan bağlanma dayanımını ve mikrosızıntısı değerlendirmek ve karşılaştırmaktır.* ***Gereç ve Yöntemler:*** *Bağlanma dayanımını değerlendirmek için, 45 adet çekilmiş insan molar dişlerinin orta koronal dentin yüzeyleri açığa çıkartıldı, hazırlanan dişler adeziv sistemler uygulanmak üzere rastgele 3 gruba ayrıldı: Single Bond Universal (3M ESPE), Optibond XTR (Kerr) ve Tokuyama Universal (Tokuyama Dental) (n=15). Kompozit rezin yerleştirilmesinin ardından örneklere makaslama bağlanma dayanımı testi uygulandı. Kırılan örneklerin* *kopma yüzeyleri taramalı elektron mikroskobunda incelendi. M,ikrosızıntıyı değerlendirmek için, 45 adet çekilmiş insan premolar dişlerinin bukkal yüzeylerinde Sınıf V kaviteler hazırlandı. Hazırlanan dişlere bağlanma dayanımında belirtilen gruplarda olduğu gibi aynı adeziv sistemler uygulandı (n=15). Kaviteler kompozit rezin ile restore edildi ve örnekler 500 devir termal siklusa tabi tutuldu. Ardından bazik fuksinde bekletilen örnekler ikiye ayrıldı ve kesit yüzeyleri stereomikroskop altında incelendi. Veriler tek yönlü ANOVA, Tukey, Ki-kare ve Mann Whitney U testleri kullanılarak analiz edildi.* ***Bulgular:*** *Çalışmada kullanılan adeziv sistemler arasında en yüksek bağlanma dayanımı Optibond XTR'de görülürken, en düşük bağlanma dayanımı ise Tokuyama Üniversal'de gözlendi. (p<0,05). Mikrosızıntı değerleri incelendiğinde ise, okluzal kenarlarda gruplar arasında anlamlı bir farklılık görülmezken; gingival kenarlarda Optibond XTR'nin, Tokuyama Üniversal'den anlamlı derecede daha az sızıntı gösterdiği görüldü. (p<0,05)* ***Sonuçlar:*** *Çalışma bulguları, dentine bağlanmada iki aşamalı universal adeziv systemin tek aşamalı universal adeziv sistemlerden daha başarılı olduğunu göstermiştir. Bağlanmanın restorasyonun uzun ömürlülüğünde major bir rol oynadığı düşünüldüğünde, dentinde iki aşamalı universal adeziv sistemlerinin kullanımının daha başarılı sonuçlar verebileceği söylenebilir.* ***Anahtar kelimeler:*** *Adeziv sistemler, dentine bağlanma dayanımı, mikrosızıntı.*

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Original research

WHICH FINISHING AND POLISHING TECHNIQUE IS MORE EFFECTIVE FOR SURFACE ROUGHNESS AND MICROHARDNESS?

ABSTRACT

Purpose: The aim of this study was to evaluate the effects of finishing and polishing (F/P) techniques on resin restorative materials' surface roughness and microhardness.

Materials and methods: A total of 168 specimens were prepared using compomer, resin composite, and giomer, and subjected to F/P and F/P was performed using Sof-Lex Discs, Sof-Lex Spiral Wheels, and Enamel Plus Shiny. No F/P was performed in the control group. Surface roughness and microhardness were measured. Data were analyzed using one-way ANOVA, two independent samples t-test, and Kruskal-Wallis test. The correlations between parameters was investigated using Pearson's correlation test ($p<0.05$).

Results: Enamel Plus Shiny and the control group were not significantly different in terms of surface roughness. For Sof-Lex Disc, Dyract XP resulted in a significantly higher surface roughness. For Sof-Lex Spiral Wheels, Filtek^{TM} Bulk Fill resulted in a statistically significant lower surface roughness ($p<0.05$). In terms of microhardness, Beautifil II resulted in a significantly higher microhardness in the Sof-Lex Disc group ($p<0.05$). In the control group, Dyract XP resulted in a significantly lower microhardness compared to Filtek^{TM} Bulk Fill and Beautifil II. Sof-Lex Spiral Wheels and Enamel Plus Shiny had statistically different microhardness results. Surface roughness and microhardness values were positively correlated for Filtek™ Bulk Fill and negatively correlated for Dyract XP and Beautifil II.

Conclusions: Proper F/P procedures are essential for aesthetics and longevity of restorations. Within the limits of our study, it has been concluded that the effects of the F/P process depend on both the material and technique used for finishing and polishing, and the restorative material.

Keywords: Dental finishing, dental polishing, dentistry, operative, dental materials.

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INTRODUCTION

The surface characteristics of resin composite restoratives are defined as one of the most prominent factors determining the clinical success.[1-6] The presence of surface irregularities can influence appearance, plaque accumulation, surface discoloration, gingival inflammation, discomfort, and treatment outcomes, including mechanical weakness and aesthetic properties.[2,6-9]

Proper finishing of restorations is desirable not only for aesthetic considerations but also for oral health.[1,4-5,8] Finishing and polishing are required to improve both surface roughness and microhardness for a successful restoration.[4,5,8,10]

Resin restorative materials are affected by the flexibility of finishing and polishing materials, as well as the hardness and size of the abrasive particles.[11-13] Abrasive polishing discs are usually produced by covering a polymer or plastic surface with aluminum oxide particles.[6,8,13,14] Polishing is performed using thick-grained followed by finer-grained discs.[2,8] Abrasive-impregnated polishing brushes are available in different shapes (pointed, wheel-shaped, cup-shaped) and with polymer strings, so that they can effectively reach fissures and interproximal regions.[6] The effectiveness of pastes containing diamond and aluminum oxide for polishing resin materials have been indicated in studies.[8,10] Using pastes can yield results very similar to the natural appearance of the teeth and increases the surface roughness.[15]

Increased microhardness can improve the fracture toughness and wear resistance of the restoration[16,17], and prevents the deformation under various forces.[18] Filler particle size and ratio of the particles within the material affect the microhardness of a restorative material. [12,17-19]

There is no consensus regarding which polishing and finishing system is more effective.[4,9,20] Furthermore, there are only a few studies that evaluate the correlation of surface roughness and microhardness[21-23], and the existing studies have not definitively concluded whether the change in surface properties occur due to the finishing and polishing techniques and/or the characteristics of the material.[12,22,20]

Hence, the aim of this study was to evaluate the effects of various finishing and polishing techniques on the surface roughness and microhardness of the resin restorative materials used in pediatric dentistry.

The null hypothesis was “H_0: Various finishing and polishing techniques do not affect the surface roughness and microhardness of the resin restorative materials used in pediatric dentistry”.

MATERIALS AND METHODS

Before starting the study, power analysis was performed to determine the required sample size for a maximum error of 20%, 5% type 1 error and 95% power for roughness and microhardness assessments, and at least 7 discs were required. All specimens were prepared and finished by the same researcher strictly following the manufacturer's instructions to reduce variability.

A total of 168 samples were prepared according to the manufacturer’s instructions using standard plexiglass molds (5-mm diameter, 2-mm-thick) using three resin restorative materials. A2-shade resin restorative materials were shown in Table 1. Mylar strips (SNA, Universal Strips, Germany) were placed and lightly pressed against the specimens using 1 mm-thick glass slides on both surfaces to prevent air bubble formation and to obtain a leveled surface.

Table 1. The resin restorative materials.

Materials	Contents	Type of Material	Weight/ Volume of Filler Particles	Particle Size	Color	Producing Company
Dyract XP	Urethan dimethacrylate (UDMA), Dimethacrylate modified carboxylic acid (TCB resin), camphorquinone, Ethyl-4-dimethylamino benzoate, butyl hydroxy toluene (BHT), UV stabilizer, Strontium-alumino-sodium-phosphorus Silicate glass, silicon dioxide, strontium ureide, iron oxide and titanium oxide pigments	Compomer	%73 / %47	Average: 0.8 µm	A2	Dentsply/De Trey Konstanz, Germany
Bulk Fill Filtek™	Bis-GMA, UDMA, 1,12-dodecan-DMA, Bis-EMA, Zirconia and Silica fillers	Composite Resin	%64.5 / %42.5	0.01-4.5µm	A2	3 M ESPE GmbH Seefeld, USA
Beautifil II	Bis-GMA (bisphenol A glycidyl ether dimethacrylate), TEGDMA (triethylene glycol dimethyacrylate), Aluminofloro borosilicate glass, camphorquinone	Giomer	%83.3 / %68.6	0.01-5µm	A2	Shofu Inc. Kyoto,

The light density of the LED light-curing unit (3M ESPE Elipar S10 1790 mW/cm^2) was measured using a radiometer (HILUX Curing Light Meter, Benlioglu; Ankara, Turkey) before each polymerization to confirm that the device had the required light intensity. After polymerization, all samples were stored in distilled water at 37 ^{0}C for 24 hours.

7 specimens from each group were allocated as controls and received no finishing and polishing technique. The finishing and polishing techniques used in the study are presented in Table 2.

Table 2. The finishing and polishing techniques.

Finishing and Polishing Techniques	Composition	Producing Company
Tungsten Carbide Burs	12-bladed tungsten carbide bur	Carbide Burs, Kerr
Sof-Lex® Disc	Aluminum oxide-coated abrasive discs	3M ESPE, St. Paul, MN, USA
Sof-Lex Spiral Wheels	Abrasive wheels that are impregnated with aluminum oxide	3M ESPE, St. Paul, MN, USA
Enamel Plus Shiny		
Shiny A	Abrasives containing 3-micron diamond paste + goat hairbrush	
Shiny B	Abrasives containing 1-micron diamond paste + goat hairbrush	Micerium S., Avegno, Italy
Shiny C	Aluminum oxide paste + the felt brush	

For the experimental groups, the specimens were finished using a high-speed handpiece under water-cooling and tungsten carbide burs, all in the same direction parallel to the surface. Subsequently, the samples were randomly divided into groups of 7, treated with three different polishing techniques according to the manufacturer's instructions.

Low-speed handpiece at 20000 rpm was used for finishing and polishing procedure and each finishing and polishing material was replaced after one use.

Discs (Sof-Lex® Disc, 3M ESPE, St. Paul, MN, USA), spiral wheels (Sof-Lex Spiral Wheels) or brushes (Enamel Plus Shiny, Micerium S., Avegno, Italy) used for polishing were applied with the same pressure according to the manufacturer's instructions. Moreover, for standardization, all finishing and polishing agents were applied for 15 seconds, after which each sample was washed with air-water spray for 10 seconds and dried for 5 seconds.

Surface roughness was measured with a profilometer (Perthometer M2 Profilometer, Mahr, Germany). Three measurements from different sites were made for each specimen, and the average value (Ra) was used for statistical analysis.

Vickers microhardness number (VHN) was evaluated using a microhardness tester (Zwick/Roell ZHV 10, Germany). During Vickers hardness measurement, a 200 g load was applied for 17 seconds. Three measurements from different sites were made for each specimen, and microhardness was calculated accordingly.

The Kolmogorov-Smirnov goodness-of-fit test was used to decide which hypothesis testing would be used for each obtained data set. Surface roughness values of the resin composite restorative materials were normally distributed; thus, the independent samples t-test was used. The one-way ANOVA (Analysis of Variance) test was used for intergroup comparison. The Kruskal-Wallis Test was used for to compare the groups in terms of microhardness ($p<0.05$). The data conformed to normal distribution was normally distributed, therefore, Pearson's correlation test was used to investigate any correlations between the different finishing and polishing techniques and the surface roughness and microhardness values of the applied resin restoratives materials ($p<0.05$).

RESULTS

The means and standard deviations of surface roughness (Ra: µm) are listed in Table 3.

Table 3. The means and standard deviations Surface Roughness Values of Resin Composite Restorative Materials According to Finishing and Polishing Techniques (Ra: µm) (mean ± SD)

Finishing and Polishing Techniques	n	Dyract XP	Filtek™ Bulk Fill	Beautifil II
Control Group	7	0.062 (±0.015) ^{Aa}	0.067 (±0.012) ^{aA}	0.056 (±0.012) ^{aA}
Sof-Lex Disc	7	0.279 (±0.167) ^{Ba}	0.123 (±0.025) ^{bB}	0.244 (±0.085) ^{bAB}
Sof-Lex Spiral Wheels	7	0.210 (±0.072) ^{Ba}	0.135 (±0.031) ^{bB}	0.236 (±0.048) ^{bA}
Enamel Plus Shiny	7	0.161 (±0.66) ^{Ba}	0.131 (±0.032) ^{bA}	0.193 (±0.045) ^{bA}

$p < 0.05$

Different lower-case letters in the same column indicate a significant difference.

Different upper-case letters in the same row indicate a significant difference.

The surface roughness obtained after using Sof-Lex Disc was significantly higher for Dyract XP compared to Filtek™ Bulk Fill ($p<0.05$). In the Sof-Lex Disc group, surface roughness result of Beautifil II was not significantly different than the remaining two materials. The surface roughness obtained after using Sof-Lex Spiral Wheels was significantly lower for Filtek™ Bulk Fill than the remaining two materials ($p<0.05$). It was determined that the control and Enamel Plus Shiny group displayed the lowest surface roughness values on the restorative materials used in this study and there was no statistically difference between the two.

Microhardness values of the resin restorative materials according to the used finishing and polishing techniques are presented in Table 4.

Table 4. The Microhardness Values of the Resin Restorative Materials According to the Finishing and Polishing Methods (VHN) (Mean ± SD).

Finishing and Polishing Techniques	n	Dyract XP	Filtek™ Bulk Fill	Beautifil II
Control Group	7	84.2^{aA} (±2.041)	92.1^{aB} (±0.187)	97.4^{aB} (±5.521)
Sof-Lex Disc	7	126.7^{bA} (±4.036)	137.4^{bA} (±11.024)	188.1^{bB} (±16.448)
Sof-Lex Spiral Wheels	7	147.5^{cA} (±3.155)	138.7^{bB} (±4.091)	173.2^{cC} (±14.790)
Enamel Plus Shiny	7	143.5^{cA} (±7.939)	104.8^{cB} (±7.904)	203.3^{bC} (±3.987)

$p < 0.05$

Different lower-case letters in the same column indicate a significant difference.
Different upper-case letters in the same row indicate a significant difference.
In the control group, the microhardness value of Dyract XP was significantly lower compared to Filtek™ Bulk Fill and Beautifil II (p<0.05). In the Sof-Lex Disc group, the microhardness value of Beautifil II was significantly higher compared to the remaining two materials (p<0.05). In the Sof-Lex Spiral and Enamel Plus Shiny groups, the resulting microhardness values of the different resin restorative materials were significantly different (p<0.05) and were in the following order: Beautifil II> Dyract XP> Filtek™ Bulk Fill.

Correlation analysis results of surface roughness and microhardness values are presented in Figure 1.

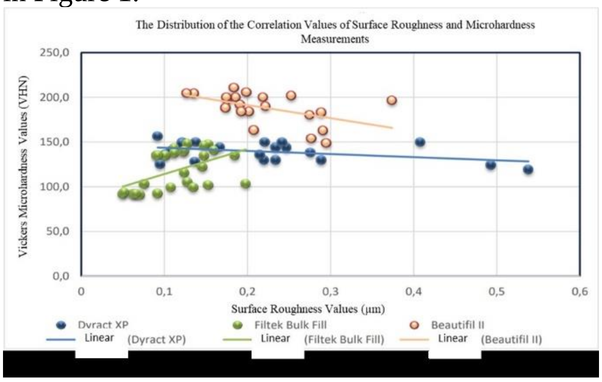

Figure 1. The distribution of correlation values between the surface roughness and microhardness values of the resin restorative materials according to the finishing and polishing techniques.

Surface roughness and microhardness values were positively correlated for Filtek™ Bulk Fill and negatively correlated for Dyract XP and Beautifil II.

DISCUSSION

In clinical practice, the finishing of resin restorative materials under a Mylar strip results in the lowest surface roughness.[2,4,8,12-14,22,24] The initial surface obtained by using a Mylar strip is an unstable and resin free surface, rich in organic matrix and monomers.[2,9] Therefore, this layer should be removed through finishing and polishing procedure.[14,20,22,25,26]

In our study, the control group had the smoothest surface and significantly lower surface roughness compared to the Sof-Lex Disc and Sof-Lex Spiral Wheels groups (p<0.05). However, the control and Enamel Plus Shiny groups were not statistically significantly different. For dental materials, surface roughness below 0,2 µm significantly reduced the possibility of bacterial adhesion.[27] Thus, it is recommended that the Ra values should be lower than 0.2 µm to prevent bacteria accumulation in the mouth.[2,27,28] It should be noted that surface roughness in the Enamel Plus Shiny group was below the indicated threshold.

In the Sof-Lex Disc and Sof-Lex Spiral Wheels groups, the surface roughness of Dyract XP was significantly higher (Ra: 0.279 µm, 0.210 µm) compared to Filtek™ Bulk Fill (Ra: 0.123 µm, 0.135 µm). Ryba *et al.*[29] indicated that resins with larger particles result in rougher surfaces after finishing and polishing. When the ratio of the organic matrix is smaller than filler particles, it is easier for the particles to come loose. Hence, resins with smaller particles are easier to polish.[30] Considering the particle sizes of Dyract XP (0.8 µm) and Filtek™ Bulk Fill (0.01- 4.5 µm), our results are consistent with the notion that surface roughness is associated with the size of filler particles.

In the Sof-Lex Disc group, surface roughness was statistically different between Filtek™ Bulk Fill and Dyract XP. However, surface roughness was not statistically different between Beautifil II and the other two materials. This finding could be ascribed to the shape and abrasive properties of the finishing and polishing techniques and the size of the filler particles of the restorative materials.

Sof-Lex Spiral Wheels used with Filtek™ Bulk Fill had a statistically significantly smoother ($p<0.05$) surface compared to the other techniques. The content and size of the filler particles of the resin restorative materials play an important role in the success of the finishing/polishing and longevity of the restoration.[31]

The evaluation of the effectiveness of the finishing/polishing techniques require the definition of the surface roughness, and determining the microhardness values using surface hardness tests, which is one of the most important factors that determine the clinical application and success of the material[2,5,18-19,21] It is also reported that when resin composite materials are polymerized using a transparent band under pressure, the ratio of particles decreases and the ratio of the resin increases on the surface, thus reducing microhardness.[21] Therefore, finishing and polishing techniques are critical and should be applied to improve the chemical stability of the material, the mechanical surface properties, and to remove the resin-rich surface layer.[20,21,24]

Every restorative material has a different microhardness value as the chemical composition and filler content affect physical properties.[2,13,17,18] The materials with higher filler content have higher microhardness values.[17-19] The filler weight ratios of the used restorative materials were as follows: 83.3% for Beautifil II, 73% for Dyract XP, and 64,5% for Filtek™ Bulk Fill.[32,33]

In the control group, the microhardness of Dyract XP (84.2 VHN) was significantly lower ($p<0.05$) than Filtek™ Bulk Fill (92.1 VHN) and Beautifil II (97.4 VHN). We ascribe this result to the differences in the polymer matrix, rather than particle content and amount.

In the Sof-Lex Disc group, the microhardness of Beautifil II (188.1 VHN) was significantly higher than the other two materials ($p<0.05$). We ascribe this difference to the relatively higher filler content of the Beautifil II. Indeed, the literature indicates that microhardness is positively correlated with the filler content of the material.[17,34]

In the Sof-Lex Spiral group, the microhardness of the three resin restorative materials were significantly different and in the following order: Beautifil II> Dyract XP> Filtek™ Bulk Fill. This result could be explained by the filler content of the materials. The literature indicates that resin composite materials with a higher filler content have higher hardness values compared to the resin materials without fillers.[4]

In the Enamel Plus Shiny group, the microhardness of the three resin restorative materials were significantly different and in the following order: Beautifil II> Dyract XP> Filtek™. Enamel Plus Shiny contains aluminum oxide particles together with diamond particles as abrasives. The filler content of the Filtek™ Bulk Fill is lower than the other two materials, and the diamond particles are more abrasive than aluminum oxide particles. Consequently, more filler particles were removed from the surface of the Filtek™ Bulk Fill, and thus surface microhardness was lower.

There are heterogeneous components that influence the surface roughness and microhardness values of resin composite materials.[17,19] However, it is accepted that finishing/polishing techniques are effective in improving surface hardness.[5,21]

The in vitro studies have concluded that surface roughness and microhardness properties of restorative materials were correlated.[21-23] Tjan and Chan.[23] indicated that there was a direct correlation between surface roughness and microhardness and that the highest surface roughness values were found together with the highest microhardness values. Erdemir *et al.*[22] reported that the high surface roughness values were associated with high microhardness values in tooth-colored restorative materials.

The microhardness evaluation should be done on a smooth surface.[21] Even though we found that the surfaces that were finished with the Mylar Strip (i.e. the control group) had the smoothest surfaces, this layer must be removed since due to poor surface properties and higher organic content.

According to the results of the present study, there was a positive correlation between the surface roughness and the microhardness values of Filtek™ Bulk Fill after finishing and polishing. In contrast, this correlation was negative for Dyract XP and Beautifil II. Our results are consistent with the literature.[20-21]

The positive correlation determined for Filtek™ Bulk Fill indicates that the final obtained surface is smoother due to the smaller size of the filler particles within the material and that the microhardness values are lower because the filling content is lower.

The purpose of finishing and polishing is to obtain a more resistant and stable surface from the resin materials. However, this is not always possible due to the resin composite materials' different filler particles, particle sizes, and different hardness values associated with filler particles and the matrix, as was observed in the present study.

CONCLUSIONS

Our null hypothesis "H_0" was rejected as all resin restorative materials yielded different results for different finishing and polishing techniques due to their specific physical and mechanical properties. In this context, it is not possible to say that a finishing and polishing technique that yields the best surface properties for a specific material may do so when applied to a different material. It seems that the ideal finishing and polishing techniques should be chosen according to the properties of resin restorative materials. Bulk fill composite resins eliminate incremental technique and reduce chair time in children, and when used with Enamel Plus Shiny, the resulting smooth surface properties will be useful in terms of pediatric dentistry in the clinical setting.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

Hangi Bitirme Ve Parlatma Tekniği Yüzey Pürüzlülüğü Ve Mikrosertlik İçin Daha Efektiftir?

ÖZ

Amaç: *Bitirme ve parlatma (F/P) tekniklerinin kompozit rezin restorasyon materyallerinin yüzey pürüzlülüğü ve mikro sertliği üzerindeki etkilerini değerlendirilerek materyal için en ideal yüzey özelliği oluşturan bitirme ve parlatma tekniğinin araştırılmasıdır.* ***Gereç ve Yöntemler:*** *Pleksiglas kalıplar kullanılarak 168 örnek hazırlamak için kompomer, kompozit rezin ve giomer kullanıldı ve örnekler F/P tekniklerine tabi tutuldu. Kontrol Grubunda F/P yapılmadı. F/P için; Sof-Lex Disk; Sof-LexTM Spiral Lastikler ve Enamel Plus Shiny kullanıldı. Yüzey pürüzlülüğü ve mikro sertlik değerleri ölçüldü. Veriler tek yönlü ANOVA, iki bağımsız örnek t-testi, Kruskal Wallis kullanılarak analiz edildi ve iki parametre arasındaki korelasyon için Pearson korelasyon testi kullanıldı (p<0,05).* ***Bulgular:*** *Elde edilen veriler doğrultusunda yüzey pürüzlülük değerler karşılaştırıldığında; Enamel Plus Shiny ile kontrol grubu arasında istatistiksel olarak anlamlı fark bulgulanmadı. Sof-Lex Disk kullanıldığında Dyract XP grubunda, yüzey pürüzlülüğünün anlamlı derecede daha yüksek olduğu tespit edildi (p<0,05). Sof-Lex Spiral Lastikler kullanıldığında, FiltekTM Bulk Fill'in istatistiksel olarak anlamlı derecede daha düşük yüzey pürüzlülüğü değeri gösterdiği bulgulandı (p <0,05). Mikrosertlik değerlerinde ise Sof-Lex Disk kullanıldığında; Beautifil II ye ait mikrosertlik değerlerinin anlamlı olarak daha yüksek olduğu tespit edildi (p <0,05), kontrol grubu için ise Dyract XP'nin, FiltekTM Bulk Fill ve Beautifil II ile karşılaştırıldığında mikrosertlik değerinin en düşük değer gösterdiği bulgulandı. Sof-Lex Spiral Lastikler ve Enamel Plus Shiny için, restoratif materyallerin mikrosertlik değerleri arasında istatistiksel olarak anlamlı farklılıklar gözlenmiştir. Yüzey pürüzlülüğü ve mikro sertlik arasındaki korelasyon ise; FiltekTM Bulk Fill materyalinde pozitif korelasyona sahipken; Dyract XP ve Beautifil II materyallerinde negatif korelasyona sahiptir.* ***Sonuçlar:*** *Uygun F/P prosedürleri, restoratif materyaller için estetik ve uzun ömürlülüğü arttıran gerekli adımlardır. Çalışmamızın sınırları dahilinde, en ideal bitirme ve parlatma tekniğinin kullanılan rezin içerikli restoratif materyalin özelliklerine bağlı olarak değişkenlik gösterdiği, F/P tekniklerinin etkilerinin hem bitirme ve parlatma tekniğine hem de restoratif materyale bağlı olduğu sonucuna varılmıştır.* ***Anahtar Kelimeler:*** *Diş parlatma, dental materyaller, bitirme ve parlatma materyalleri.*

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Original research

CORRELATION BETWEEN THE MORPHOMETRIC PARAMETERS OF MAXILLARY SINUSES AND NASAL APERTURES AS A FORENSIC IDENTIFICATION AID USING CONE BEAM CT: A PILOT STUDY

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ABSTRACT

Objectives: Bone remodelling of the cranium determines the enlargement of the maxillary sinuses. The process involves the resorption of the internal walls of the maxillary sinus that slightly exceed the growth of the maxilla. During this process, bone deposition occurs at the medial border of the nasal cavity as does simultaneous resorption of the lateral wall of the nasal cavity. Very few studies have investigated the correlation between the growth of the maxillary sinuses with changes in the dimensions of the nasal aperture. Therefore, the present study aimed to determine, compare and correlate the three-dimensional morphometric parameters of the maxillary sinus and nasal apertures in a study population from the states of Karnataka and Kerala in India, to utilize the data for the purpose of individual identification, sexual dimorphism or any other application in the field of forensic facial reconstruction and/or human identification.

Materials and Methods: This pilot study analysed the measurements of the morphometric landmarks of the maxillary sinus and the nasal aperture of 20 subjects, ranging in age from 18 to 30.

Results: The Morphometric parameters of the maxillary sinus and the nasal aperture were seen to be statistically significant in a few of the groups, and these findings can be applied to evaluate sexual dimorphism.

Conclusions: The maxillary sinuses remain intact even though the skull and other bones of the cranium may be severely disfigured in victims that are incinerated or that have experienced external trauma. Morphometric measurements, such as width, depth and height which were used to investigate the accuracy and reliability of the maxillary sinuses, can also be used for sex estimation. These dimensions can be correlated with the measurements of the nasal aperture, which will also provide an insight into the development of the cranium. Moreover, these measurements are important anthropometric parameters for classifying the race and sex of an individual whose identity is unknown.

Key words: maxillary sinus, nasal cavity, forensic, facial, reconstruction, morphometric measurements.

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INTRODUCTION

Maxillary sinuses play an important role in victims whose bodies have been incinerated but reported to stay intact even in severely disfigured and incinerated skulls.[1] The morphometric measurements that are used to estimate the indices of the maxillary sinus parameters are the width, depth and height of the maxillary sinuses; these can also be used for sex estimation and other forensic applications.[2] The shapes and sizes of the human nose vary with ethnicity, and these have a direct impact on facial appearance. Nasal parameters are important for anthropometry, and they can be applied for classifying the race and sex of an individual whose identity is unknown. Hence, we conducted this study to determine and correlate the morphometric measurements of the nasal cavity and the maxillary sinus using Cone Beam Computed Tomography (CBCT) in subjects from the states of Karnataka and Kerala in India. The results can be applied to estimate the sex of individuals whose identity is unknown in the population under study.

MATERIALS AND METHODS

CBCT data of 20 subjects from the states of Karnataka and Kerala in India were collected from the Department of Oral Medicine and Radiology. CBCT data acquisition was done using ProMax 3D Mid (Planmeca, Helsinki, Finland). The standard protocol was used: Full field of view 200 x 170 cm; voxel size 400 mm; exposure time 4.7 seconds. Hard tissue and soft tissue landmarks of the nose were marked, and morphometric measurements were obtained using NEMOCEPH 3D-the exclusive Cephalometric and Orthodontic Analysis software of Nemostudio: The Digital Medical Company. The parameters were analysed as per the stated objectives of the study. The subjects included in the study ranged in age between 18 and 30; they had no congenital anomalies/syndromes, oro-facial pathologies, orthodontic correction, history of trauma, surgical intervention or exposure to radiotherapy.

Ethical clearance was obtained from the Institutional Review Board, dated 20.11.2018. Informed consent and subject information sheets were obtained from all the subjects that who participated in the study.

STATISTICAL ANALYSIS METHOD

The mean, standard deviation and standard error, along with the confidence interval of the craniometric (skull) and capulometric (soft tissue) measurements of the nasal aperture and maxillary sinus, were documented. The comparison of various measurements of the nose the maxillary sinuses between the sexes (Table 1) and the two states (Table 2) was done by using the student t-test.

Table 1. Comparison between gender

		Sex	N	Mean	SD	Mean Difference	95% Confidence Interval of the Difference		t	df	p-value
							Lower	Upper			
Height - MS	Right	1	8	37.41	5.49	3.25	-0.68	7.18	1.74	18	0.10(NS)
		2	12	34.16	2.89						
	Left	1	8	38.43	3.15	2.87	0.09	5.66	2.17	18	0.04*
		2	12	35.56	2.74						
Width - MS	Right	1	8	28.59	4.52	0.33	-3.46	4.12	0.18	18	0.86(NS)
		2	12	28.26	3.54						
	Left	1	8	30.20	4.85	0.87	-3.11	4.84	0.46	18	0.65(NS)
		2	12	29.33	3.63						
Depth - MS	Right	1	8	39.57	3.40	2.16	-0.95	5.28	1.46	18	0.16(NS)
		2	12	37.40	3.14						
	Left	1	8	40.53	2.41	2.06	-0.23	4.35	1.89	18	0.08(NS)
		2	12	38.47	2.38						
NA	Height	1	8	40.81	3.97	4.81	2.24	7.37	3.93	18	0.001*
		2	12	36.00	1.30						
	Width	1	8	24.81	2.30	1.45	-0.57	3.48	1.51	18	0.15(NS)
		2	12	23.36	1.99						

Independent sample t test *p<0.05 Statistically Significant p>0.05 Non Significant, NS

Table 2. Comparison between states

		State	N	Mean	SD	Mean Difference	95% Confidence Interval of the Difference		t	df	p-value
							Lower	Upper			
Height - MS	Right	1	10	34.96	2.18	-0.99	-5.13	3.14	-0.50	18	0.62(NS)
		2	10	35.95	5.83						
	Left	1	10	36.22	2.47	-0.98	-4.01	2.04	-0.68	18	0.50(NS)
		2	10	37.20	3.83						
Width - MS	Right	1	10	27.89	4.03	-1.01	-4.69	2.67	-0.58	18	0.57(NS)
		2	10	28.89	3.80						
	Left	1	10	28.73	4.17	-1.90	-5.71	1.90	-1.05	18	0.31(NS)
		2	10	30.63	3.92						
Depth - MS	Right	1	10	37.24	2.91	-2.06	-5.12	1.00	-1.41	18	0.17(NS)
		2	10	39.30	3.57						
	Left	1	10	38.70	2.40	-1.19	-3.58	1.19	-1.05	18	0.31(NS)
		2	10	39.89	2.67						
NA	Height	1	10	36.57	1.71	-2.71	-5.86	0.45	-1.80	18	0.09(NS)
		2	10	39.27	4.43						
	Width	1	10	23.05	1.60	-1.78	-3.69	0.14	-1.95	18	0.07(NS)
		2	10	24.83	2.40						

Independent sample t test *$p<0.05$ Statistically Significant $p>0.05$ Non Significant, NS

The association between the categorical variables was determined using the Chi-square test. A p value <0.05 was considered to be statistically significant. Data were analysed using statistical SPSS software.

RESULTS

This paper presents the morphometric parameters of the maxillary sinuses and the nasal apertures of patients that were obtained from the analysis of the CBCT images derived from the subjects from the states of Karnataka and Kerala.

Descriptive statistics

For this pilot study, the data submitted for statistical analysis consisted of the morphometric parameter results for 8 male and 12 female subjects (2 males from Karnataka and 6 from Kerala; and 8 females from Karnataka and 4 from Kerala,, respectively) (Table 3 and Table 4).

Table 3. Comparison between states in each gender

Sex			State	N	Mean	SD	Mean Difference	95% Confidence Interval of the Difference		t	df	p-value
								Lower	Upper			
1	Height - MS	Right	1	2	35.91	1.33	-2.00	-13.67	9.67	-0.42	6	0.69(NS)
			2	6	37.91	6.37						
		Left	1	2	36.89	1.33	-2.06	-8.53	4.42	-0.78	6	0.47(NS)
			2	6	38.95	3.50						
	Width - MS	Right	1	2	29.13	5.67	0.72	-9.01	10.45	0.18	6	0.86(NS)
			2	6	28.41	4.69						
		Left	1	2	31.23	7.24	1.38	-9.00	11.75	0.32	6	0.76(NS)
			2	6	29.86	4.67						
	Depth - MS	Right	1	2	37.76	2.55	-2.41	-9.33	4.51	-0.85	6	0.43(NS)
			2	6	40.17	3.62						
		Left	1	2	38.74	2.21	-2.39	-7.01	2.24	-1.26	6	0.25(NS)
			2	6	41.13	2.34						
	NA	Height	1	2	38.49	2.69	-3.09	-11.09	4.91	-0.94	6	0.38(NS)
			2	6	41.58	4.22						
		Width	1	2	22.82	2.21	-2.66	-6.85	1.54	-1.55	6	0.17(NS)
			2	6	25.48	2.08						
2	Height - MS	Right	1	8	34.73	2.35	1.70	-2.26	5.66	0.96	10	0.36(NS)
			2	4	33.02	3.90						
		Left	1	8	36.05	2.73	1.47	-2.32	5.25	0.86	10	0.41(NS)
			2	4	34.58	2.88						
	Width - MS	Right	1	8	27.57	3.97	-2.05	-6.90	2.80	-0.94	10	0.37(NS)
			2	4	29.62	2.31						

		Left	1	8	28.10	3.56	-3.69	-8.18	0.80	-1.83	10	0.10(NS)
			2	4	31.79	2.57						
	Depth - MS	**Right**	1	8	37.11	3.14	-0.88	-5.34	3.58	-0.44	10	0.67(NS)
			2	4	37.99	3.55						
		Left	1	8	38.69	2.60	0.65	-2.73	4.02	0.43	10	0.68(NS)
			2	4	38.04	2.15						
	NA	**Height**	1	8	36.09	1.20	0.27	-1.58	2.11	0.33	10	0.75(NS)
			2	4	35.82	1.66						
		Width	1	8	23.11	1.60	-0.75	-3.54	2.04	-0.60	10	0.56(NS)
			2	4	23.86	2.83						

Independent sample t test *p<0.05 Statistically Significant p>0.05 Non Significant, NS

Table 4. Comparison between gender in each state

State			**Sex**	**N**	**Mean**	**SD**	**Mean Difference**	**95% Confidence Interval of the Difference**		**t**	**df**	**p-value**
								Lower	**Upper**			
1	**Height - MS**	**Right**	1	2	35.91	1.33	1.18	-2.91	5.28	0.67	8	0.52(NS)
			2	8	34.73	2.35						
		Left	1	2	36.89	1.33	0.84	-3.89	5.58	0.41	8	0.69(NS)
			2	8	36.05	2.73						
	Width - MS	**Right**	1	2	29.13	5.67	1.56	-6.14	9.25	0.47	8	0.65(NS)
			2	8	27.57	3.97						
		Left	1	2	31.23	7.24	3.13	-4.52	10.79	0.94	8	0.37(NS)
			2	8	28.10	3.56						
	Depth - MS	**Right**	1	2	37.76	2.55	0.65	-4.95	6.25	0.27	8	0.80(NS)
			2	8	37.11	3.14						
		Left	1	2	38.74	2.21	0.05	-4.60	4.70	0.03	8	0.98(NS)
			2	8	38.69	2.60						
	NA	**Height**	1	2	38.49	2.69	2.40	-0.27	5.08	2.07	8	0.07(NS)
			2	8	36.09	1.20						
		Width	1	2	22.82	2.21	-0.29	-3.36	2.79	-0.22	8	0.83(NS)
			2	8	23.11	1.60						
2	**Height - MS**	**Right**	1	6	37.91	6.37	4.89	-3.41	13.18	1.36	8	0.21(NS)
			2	4	33.02	3.90						
		Left	1	6	38.95	3.50	4.37	-0.52	9.25	2.06	8	0.07(NS)
			2	4	34.58	2.88						
	Width - MS	**Right**	1	6	28.41	4.69	-1.22	-7.13	4.70	-0.47	8	0.65(NS)
			2	4	29.62	2.31						
		Left	1	6	29.86	4.67	-1.94	-7.91	4.04	-0.75	8	0.48(NS)
			2	4	31.79	2.57						
	Depth - MS	**Right**	1	6	40.17	3.62	2.18	-3.16	7.53	0.94	8	0.37(NS)
			2	4	37.99	3.55						
		Left	1	6	41.13	2.34	3.09	-0.29	6.46	2.11	8	0.07(NS)
			2	4	38.04	2.15						
	NA	**Height**	1	6	41.58	4.22	5.76	0.57	10.95	2.56	8	0.03*
			2	4	35.82	1.66						
		Width	1	6	25.48	2.08	1.62	-1.94	5.17	1.05	8	0.32(NS)
			2	4	23.86	2.83						

Independent sample t test *p<0.05 Statistically Significant p>0.05 Non Significant, NS

Comparison between of the two states

Of the two states, the subjects from Karnataka had the have highest mean morphometric measurements for most of the parameters, except for Width – maxillary sinus (MS): Right, Width – MS: Left among the males. The mean Height – MS: Right, Height – MS: Left, Depth – MS: left and nasal aperture (NA): Height was observed to be higher among the females than the males for the subjects from Kerala (Table 3).

Sexual dimorphism of the parameters in both of the states

The male subjects from Karnataka had higher mean values than the females for all the parameters except NA: Width, which was higher among the females. The male subjects from

Kerala also had higher mean values than the females for all the parameters except Width – MS: Right and Width – MS: Left (Table 3).

The correlation between gender in each state showed a significant p value for NA: Height between the sexes of the subjects from Kerala (Table 4). The correlation between the NA and MS variables according to gender and state showed a significant p value between the parameters Width – NA of the females subjects from Karnataka and Height – MS of Left side (Table 5).

Table 5. Correlation between nasal aperture and maxillary sinus variables according to gender and state.

State	Sex			Height - MS		Width - MS		Depth - MS	
				Right	Left	Right	Left	Right	Left
1	1	Height - NA	r	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
			p-value	.	.	.	.	.	.
		Width - NA	r	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
			p-value	.	.	.	.	.	.
	2	Height - NA	r	0.30	-0.04	0.24	0.25	-0.22	0.15
			p-value	0.47(NS)	0.93(NS)	0.57(NS)	0.56(NS)	0.60(NS)	0.72(NS)
		Width - NA	r	-0.32	-0.75	0.37	0.28	0.05	0.39
			p-value	0.45(NS)	0.03*	0.37(NS)	0.50(NS)	0.91(NS)	0.34(NS)
2	1	Height - NA	r	-0.57	-0.59	-0.59	-0.37	-0.74	-0.72
			p-value	0.24(NS)	0.22(NS)	0.22(NS)	0.47(NS)	0.09(NS)	0.11(NS)
		Width - NA	r	0.42	0.45	0.35	0.27	0.24	0.34
			p-value	0.41(NS)	0.37(NS)	0.50(NS)	0.60(NS)	0.65(NS)	0.52(NS)
	2	Height - NA	r	-0.08	-0.55	-0.48	-0.58	0.14	-0.75
			p-value	0.92(NS)	0.45(NS)	0.52(NS)	0.42(NS)	0.86(NS)	0.25(NS)
		Width - NA	r	-0.44	0.28	-0.58	0.93	-0.31	-0.06
			p-value	0.56(NS)	0.72(NS)	0.42(NS)	0.07(NS)	0.69(NS)	0.94(NS)

Pearsons correlation test *p<0.05 Statistically Significant p>0.05 Non Significant, NS

The correlation between the NA and MS variables in each state showed a statistically significant p value with respect to Width - NA and Height – MS of the Left side in the subjects from Karnataka (Table 6).

Table 6. Correlation between nasal aperture and maxillary sinus variables in each state.

State			Height - MS		Width - MS		Depth - MS	
			Right	Left	Right	Left	Right	Left
1	Height - NA	r	0.21	-0.03	-0.02	-0.002	-0.23	-0.06
		p-value	0.57(NS)	0.93(NS)	0.95(NS)	0.99(NS)	0.53(NS)	0.86(NS)
	Width - NA	r	-0.38	-0.74	0.05	-0.10	-0.10	0.19
		p-value	0.28(NS)	.02*	0.88(NS)	0.78(NS)	0.78(NS)	0.61(NS)
2	Height - NA	r	-0.04	0.06	-0.53	-0.45	-0.17	-0.006
		p-value	0.91(NS)	0.88(NS)	0.11(NS)	0.19(NS)	0.64(NS)	0.99(NS)
	Width - NA	r	0.26	0.49	0.01	0.31	0.10	0.33
		p-value	0.48(NS)	0.15(NS)	0.98(NS)	0.39(NS)	0.78(NS)	0.35(NS)

Pearsons correlation test *p<0.05 Statistically Significant p>0.05 Non Significant, NS

The cCorrelation between the NA and MS variables in both genders showed no statistically significant results between the groups (Table 7).

Table 7. Correlation between nasal aperture and maxillary sinus variables in each gender.

Sex			Height - MS		Width - MS		Depth - MS	
			Right	Left	Right	Left	Right	Left
1	Height - NA	r	-0.46	-0.43	-0.61	-0.46	-0.55	-0.45
		p-value	0.25(NS)	0.29(NS)	0.11(NS)	0.25(NS)	0.16(NS)	0.26(NS)
	Width - NA	r	0.37	0.43	0.02	-0.10	0.24	0.33
		p-value	0.37(NS)	0.29(NS)	0.96(NS)	0.81(NS)	0.57(NS)	0.43(NS)
2	Height - NA	r	0.13	-0.19	0.02	-0.05	-0.09	-0.12
		p-value	0.68(NS)	0.55(NS)	0.96(NS)	0.87(NS)	0.78(NS)	0.70(NS)
	Width - NA	r	-0.42	-0.31	0.12	0.49	-0.09	0.17
		p-value	0.18(NS)	0.32(NS)	0.72(NS)	0.11(NS)	0.79(NS)	0.59(NS)

Pearsons correlation test *p<0.05 Statistically Significant p>0.05 Non Significant, NS

DISCUSSION

As an individual grows, adaptive changes in human nasal aperture morphology directly affect the maxillary sinus morphology. Various populations present with different ethnicities, racial changes and exposures to different climates, which directly affect the osteometric morphology of the human skeleton.[3] To date, very few studies have investigated the correlation between the nasal/piriform aperture morphology and the maxillary sinus morphology. These variations in morphology can be used for sexual dimorphism and forensic identification.

In the present study, statistical analysis was done by calculating the mean and standard deviation measurements of both the nasal apertures and maxillary sinuses, which were calculated and correlated. In this paper, we discuss the parameters that showed statistically significant results when correlated between the groups.

Different populations exhibit various osteometric morphological patterns of sexual dimorphism, as documented in several studies.[4-6] In our study, mean morphometric measurements were higher in the subjects from the state of Karnataka in reference to all of the parameters in both states, except for Width – MS: Right and Width – MS: Left among the males. The Height – MS: Right, Height – MS: Left, Depth – MS: left and NA: Height was observed to be higher in the female subjects from Kerala in comparison to the male subjects from that state.

The male subjects from Karnataka had higher mean values than the female subjects for all the parameters except NA: Width, which was higher among the females. The male subjects from Kerala also had higher mean values than the females from that state for all the parameters, except the MS Width: Right and MS Width: Left. Similar findings were reported by Banik, who found that the mean values of craniometric characteristics were higher in male skulls than in female skulls among a West Bengal population.[7] Tambawala *et al*. showed statistically significantly lower values for both the left and right MS among females in relation to the MS dimensions.[8] Sexual dimorphism has been studied with piriform apertures in various populations.[9,10]

Facial features based on the parameters of the skull aid in forensic facial reconstruction. Strapasson evaluated the relationships between alar cartilage, piriform aperture, nose morphology and facial typology.[11] That study's findings showed that nasal width was associated with decreased width of the piriform aperture, the skeletal vertical pattern of the face, sex and age. The results of our study are in partial agreement with those results (Tables 4-7). The study by Strapasson suggested that forensic facial guidelines can be improved by establishing a correlation between the alar cartilages and the biological profile characteristics of a given population. Very few studies in the literature have investigated this topic in this context. Hence, we conducted this pilot study to establish a correlation that could be used for sexual dimorphism, individual identification and as a guide for forensic facial reconstruction.

CONCLUSIONS

This study has shown that the dimensions of MS and NA in the population from the states of Karnataka and Kerala in India may be used to estimate sex. The measurements may also be used for ethnic differentiation during human identification and provide data for forensic facial reconstruction. Consequently, it is recommended that a future study be conducted with a larger sample size to derive an equation so the data may be used to determine an individual's sex and aid in forensic identification and facial reconstruction.

CONFLICT OF INTEREST STATEMENT

None

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Original research

INFLUENCE OF DIFFERENT REPAIR PROTOCOLS AND ARTIFICIAL AGING ON BOND STRENGTH OF COMPOSITE TO POLYMER-INFILTRATED CERAMIC NETWORK MATERIAL

ABSTRACT

Objectives: The aim of this in vitro study was to evaluate the effects of different repair protocols and artificial aging on the shear bond strength (SBS) of a composite to polymer-infiltrated ceramic network (PICN).

Materials and methods: A total of 120 PICN (Vita Enamic, Vita Zahnfabrik) specimens were prepared, artificially aged (5000 thermal cycles between 5°C-55°C), and assigned to 5 repair protocols: (1)TS: tribochemical silica coating (Rocatec Soft; 3M ESPE)+Single Bond Universal (SBU; 3M ESPE) (2)ES: etching with hydrofluoric acid (HF; Bisco)+SBU (3)EU:HF+Ultradent Porcelain Repair (UPRS; Ultradent Products Inc.) (4)GU: grinding with diamond bur (G)+UPRS (5)GI:G+Ivoclar Vivadent Ceramic Repair (Ivoclar Vivadent). All specimens received a composite resin cylinder (Clearfil Majesty Esthetic,Kuraray) formed with a silicone mold (4mm diameter, 2mm height) to simulate repair. Then, 2 subgroups were composed according to the artificial aging procedures as baseline and aging (5000 thermal cycles between 5°C-55°C) (n=12). The SBS tests were performed by using a universal testing machine. Failure types were classified as cohesive failure in PICN, cohesive failure in composite, adhesive,and mixed. The SBS data were analyzed with 1-way ANOVA, factorial ANOVA, LSD, and Duncan tests (α=0.05). Failure modes were calculated as a percentage for each group.

Results: The baseline results showed that the mean SBS values for ES and GU were higher than TS (p<0.05). Considering artificially aged groups, ES showed higher SBS than EU and GU (p<0.05). SBS values for ES, EU, and GU groups decreased significantly after the artificial aging procedure compared to baseline (p<0.05). At baseline, the dominant failure mode was cohesive in PICN for all groups and no adhesive failures were observed for ES and GU groups. However, after aging, the only group that did not show adhesive failure was ES.

Conclusions: Considering the time-efficiency and effectiveness, etching with HF followed by Single Bond Universal application can be recommended as the intraoral repair protocol for PICN.

Keywords: CAD/CAM, dental restoration repair, shear strength, composite resins.

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INTRODUCTION

The use of computer-aided design and computer-aided manufacturing (CAD/CAM) has become a popular treatment option with a wide range of materials available for this technology.[1] Among these materials, glass-matrix ceramics are highly preferred due to their improved esthetic appearance, biocompatibility, and color stability.[2,3] However, disadvantages include abrasive effect on opposing dentition, brittleness, and susceptibility to cracks or fractures.[3-5] The CAD/CAM hybrid ceramic blocks are developed with the idea of combining favorable characteristics of ceramics and composites.[6,7] Hybrid ceramic restorations have flexural properties similar to dentine and they are more flexible and less brittle than ceramic materials.[4,8-11] A recent material, Vita Enamic, is a hybrid ceramic composed of an organic polymer of 14% which penetrates into the inorganic feldspathic ceramic matrix of 86%.[3,11] Thus, Vita Enamic is called as polymer-infiltrated ceramic network (PICN) hybrid material.[6,12]

Despite the advantages of shock absorption and decreased crack propagation as a result of the combination of crystalline matrix and polymeric material, PICN materials still present a low elastic modulus and biaxial strength.[3,9,11-13] Therefore, fracture of a PICN restoration can be encountered in clinical practice due to parafunctional habits, aging, and trauma.[14] Considering the replacement cost and the possibility of sound tooth structure loss or pulpal trauma, intraoral repair of these restorations may be preferred over replacement.[7,15,16] Moreover, intraoral repair can be advantageous considering reduced chair time for both patient and dentist.[14]

Various intraoral repair systems have been developed to enhance the functionality of the restoration.[7] The choice of the most appropriate system that would provide a certain outcome can be complicated for the clinician.[7,17] Those systems differ in terms of the surface treatments and adhesive agent used which improve the bond strength between the restorative material and composite resin for repair.[2,9] Surface treatments include grinding with a diamond bur[7], etching with hydrofluoric or phosphoric acid in different concentrations[18,19], and air-abrasion with alumina particles or tribochemical silica coating.[9,12] The success and maintenance of the repaired restoration may vary according to the repair system or protocol used.[2,9,14,20] Surface grinding followed by the application of a universal adhesive was advised by Silva *et al*.[9] for the repair of Vita Enamic restorations. On the other hand, a recent study suggested hydrofluoric acid (HF) etching and silanization.[20] Furthermore, the bond strength of the repair composite to PICN restoration may be influenced after a period of intraoral service.[7,20]

Restorations may fail after aging in a humid oral environment.[7] Also, the repair potential of the material may alter with aging conditions which may cause some alterations on the surfaces of restorative materials.[2,14] Clinical service is simulated artificially in in vitro studies with storage in water, acids or artificial saliva[7,20], and thermal cycling alone[7,14] or in combination with loading.[14] After a certain artificial aging period, the bond strength of repair composite to restorations can be evaluated by using macro or micro techniques of shear and tensile tests.[2,7,9,12,14] The previous studies have commonly used the shear bond strength (SBS) test because it is an easy and reliable method.[2] Also, due to its widespread use, comparing the results with a wide range of in vitro studies is more feasible.

The best repair protocol to treat a fractured or chipped PICN restoration is still controversial. The aim of this study, therefore, was to investigate the effects of five different repair protocols and artificial aging on the shear bond strength (SBS) of composite implemented on the PICN material. The null hypothesis was that different repair protocols and artificial aging would not influence the SBS values.

MATERIALS AND METHODS

The design of this research was approved by the Clinical Research Ethics Committee of Ankara University Faculty of Dentistry, Turkey (2020-11/03).

Specimen Preparation

Materials used in this study are presented in Table 1.

Table 1. Materials used in this study

Brand	Chemical Composition	Manufacturer
Vita Enamic (Polymer infiltrated ceramic)	**Ceramic Network (86 wt%):** SiO2 (58–63%), Al2O3 (20–23%), Na2O (9-11%), K2O (4-6%), B2O3 (0,5-2%), ZrO2 (< 1%), CaO (< 1%) **Polymer Network (14 wt%):** UDMA, TEGDMA	VITA Zahnfabrik, Bad Säckingen, Germany
Single Bond Universal	10-methacryloyloxydecyl dihydrogen phosphate (MDP) monomer, Dimethacrylate resins, HEMA, Vitrebond copolymer, Filler, Ethanol, Water, Initiators, Silane	3M ESPE, St. Paul, MN, USA
Rocatec Soft	High-purity aluminium oxide 30 µm, modified with silica (SiO_2)	3M ESPE, St. Paul, MN, USA
Porcelain Etchant	4% Hydrofluoric acid	Bisco Inc., Schaumburg, IL, USA
Ultradent Porcelain Repair System	**Ultradent porcelain etch:** 9% Hydrofluoric acid, **Ultradent silane:** 8% Methacryloxypropyl-trimethoxysilane, Isopropyl alcohol, Acetic acid **Peak Universal Bond:** 7.5% Ethyl alcohol, 0.2% Chlorhexidine, Methacrylic acid, 2-HEMA	Ultradent Products, South Jordan, UT, USA
Ceramic Repair N System Kit	**Monobond Plus:** Adhesive monomers (4%), Ethanol (96%) **Heliobond:** Bis-GMA and tri-ethylene glycol dimethacrylate (99 wt.%), initiators and stabilizers (<1%).	Ivoclar Vivadent AG, Schaan, Liechtenstien
Clearfil Majesty Esthetic Composite	Silanated barium glass filler (average: 0.7 µm), Pre-polymerized organic filler including nano filler, Bis-phenol A diglycidylmethacrylate (Bis-GMA), Hydrophobic aromatic dimethacrylate, dl-Camphorquinone, Initiators, Accelerators, Pigments, Others	Kuraray, Tokyo, Japan

PICN CAD/CAM blocks (Vita Enamic, Vita Zahnfabrik, Bad Sackingen, Germany) were sectioned under continuous water cooling by using a low-speed diamond saw (Micracut 201, Metkon, Turkey) and 120 specimens with 1,5 mm thickness were obtained. All specimens were embedded in self-curing acrylic (Integra, Birlesik Group Dental, Ankara, Turkey). Then, the surfaces of the specimens were grounded with 600, 800, and 1000 grit silicon carbide papers for 30 seconds to standardize the surfaces. Afterward, the specimens were ultrasonically cleaned in distilled water for 5 min. Artificial aging was applied on all specimens by using a thermocycler (THE-1100, SD Mechatronik, Feldkirchen-Westerham, Germany) with the following parameters: thermal application between 5ºC and 55ºC, 30 seconds dwelling time, and 5000 cycles. Aged specimens were randomly allocated into 5 groups (n=24) according to the repair protocol performed on the PICN surface: 1) TS: tribochemical silica coating-Single Bond Universal 2) ES: etching with HF-Single Bond Universal 3) EU: etching with HF-Ultradent Porcelain Repair System 4) GU: grinding with diamond bur-Ultradent Porcelain Repair System 5) GI: grinding with diamond bur-Ivoclar Vivadent Ceramic Repair System. Test groups and repair protocols are described in Table 2.

Table 2. Test groups, abbreviations, and application protocols used in the present study.

Test group	Group abbreviations	Application protocol
Tribochemical silica coating & Single Bond Universal	**TS**	- Air abrasion with Rocatec soft for 10 sec at a distance of 10 mm with 2 bar pressure - Ultrasonic cleaning for 5 minutes in alcohol - Single Bond Universal application for 1 min
Etch & Single Bond Universal	**ES**	- Bisco Porcelain Etchant application for 5 min - Rinsing with a water spray for 10 sec/ air-drying for 5 sec - Single Bond Universal application for 1 min
Etch & Ultradent Porcelain Repair System	**EU**	- Porcelain Etch application for 90 sec - Rinsing with a water spray for 10 sec/ air-drying for 5 sec - Application of %37 phosphoric acid for 5 sec - Rinsing with a water spray for 10 sec/ air-drying for 5 sec - Ultradent silane application, allowed to evaporate for 1 min and dried - Peak Universal Bond applied for 10 sec
Grinding & Ultradent Porcelain Repair System	**GU**	-Surface grinding with a coarse diamond bur (181 µm grit) -Application of the EU protocol
Grinding & Ivoclar Vivadent Ceramic Repair System	**GI**	- Surface grinding with a coarse diamond bur (181 µm grit) - Monobond plus application and allowing to react for 60 sec then drying with air - Heliobond application and thinned with air

Surface treatments and porcelain repair systems were applied in line with the manufacturers' recommendations.

Polymerization of the bonding agents in all groups was performed with a light-emitting diode (LED) curing unit (Bluephase 20i, Ivoclar Vivadent, Schaan, Liechtenstein) at 1200 mW/cm^2 for 10 seconds. The specimens treated with different surface conditioning protocols were repaired by using a composite resin (Clearfil Majesty Esthetic, Kuraray, Tokyo, Japan) applied in cylindrical silicone molds (diameter: 4 mm; height: 2 mm). LED curing was implemented on composite cylinders for 20 seconds. Afterward, the specimens were immersed in distilled water at 37^{o}C for 24 hours.

Half of the specimens from each group were subjected to SBS test immediately (Baseline groups), while the other half were aged for 5000 thermal cycles between 5^{o}C and 55^{o}C with a dwelling time of 30 seconds before SBS testing (Aging groups) to simulate a period of intraoral service after the repair (n = 12).

SBS Test

A computer-controlled universal testing machine (Lloyd Instruments, Fareham Hants, England) with 1 mm/min crosshead speed was used to perform the SBS tests. The maximum load at failure was recorded in Newtons (N). The SBS value in megapascals (MPa) for each specimen was calculated by dividing the SBS in N by the adhesive surface area (mm²).

Failure Mode Analysis

A stereomicroscope (M3Z, Leica Microsystems, Wetzlar, Germany) was used to determine the failure mode for each debonded specimen. Failure modes classified under 25x magnification were as follows: 1) cohesive failure in the PICN, 2) cohesive failure in the composite, 3) adhesive failure at the PICN-composite interface, 4) mixed failure (a combination of adhesive and cohesive failures). Recorded failure modes were calculated as a percentage for each group.

Statistical Analysis

One-way ANOVA and Duncan's multiple comparison tests were used to compare the SBS data for different surface treatment protocols. Factorial analysis of variance (ANOVA) and post-hoc least significant difference (LSD) tests were used to determine significant differences between the SBS values of each surface treatment protocol before and after artificial aging (baseline vs aging) (α = 0.05). All the statistical analyzes were performed by using R v.3.5.3 (Microsoft Corporation, Redmond, WA, USA).

RESULTS

The ANOVA results are shown in Tables 3 and 4.

Table 3. One-way ANOVA results for SBS tests

Aging procedure	Effect	Sum of squares	df	Mean squares	F	P Value
Baseline	Between Groups	266.560	4	66.640	3.258	.018
	Within Groups	1125.072	55	20.456		
	Total	1391.632	59			
Aging	Between Groups	164.442	4	41.111	3.053	.024
	Within Groups	740.554	55	13.465		
	Total	904.996	59			

Table 4. Factorial ANOVA results for SBS tests.

Effect	Sum of squares	df	Mean squares	F	P Value
Intercept	22108.08	1	22108.08	1303.524	0.000
Repair protocol	255.454	4	63.86	3.765	0.007
Aging procedure	165.85	1	165.85	9.779	0.002
Repair protocol * Aging procedure	175.54	4	43.89	2.588	0.041
Error	1865.63	110	16.96		

One-way ANOVA demonstrated that different surface treatment protocols influenced the SBS results for both baseline (p=0.018) and aging (p=0.024) groups (Table 3). Considering baseline results, the mean SBSs for ES and GU groups were not significantly different from each other (p>0.05) but were higher than that for the TS group (p<0.05). EU and GI showed comparable mean SBS results with all groups and with each other (p>0.05). After aging, SBS for the ES group was found out to be higher than the EU and GU groups (p<0.05) which demonstrated comparable results (p>0.05). TS and GI demonstrated similar SBS values with all groups (p>0.05) (Table 5).

Table 5. Means ($\bar{x}$, in MPa) and standard deviations (SD) of shear bond strength tests for each group

Surface treatment protocol	Baseline $\bar{x}$ ±SD	Aging $\bar{x}$ ±SD
TS	11.2 ± 3.2 Ba	12.82 ± 4.05 ABa
ES	17.15 ± 4.43 Aa	15.02 ± 2.8 Ab
EU	14.1 ± 5.42 ABa	10.36 ± 3.3 Bb
GU	16.6 ± 5 Aa	10.9 ± 4.95 Bb
GI	14.69± 4.2 ABa	12.89 ± 2.87 ABa

*Means followed by different uppercase in the same column and lowercase in the same line indicate a statistically significant difference (p<0.05).
**TS, tribochemical silica coating & Single Bond Universal; ES, etch & Single Bond Universal; EU, etch & Ultradent Porcelain Repair System; GU, grinding & Ultradent Porcelain Repair System; GI, grinding & Ivoclar Vivadent Ceramic Repair System.

Factorial ANOVA showed that the interaction between the repair protocol and aging procedure was significant (p=0.041), indicating that the SBS result of a particular repair protocol differed significantly with regard to artificial aging (Table 4). Mean SBS values for ES, EU, and GU decreased significantly after aging (p<0.05). However, TS and GI groups showed comparable SBS results before and after aging (p>0.05) (Table 5).

Figure 1 shows the failure type distrubition for the test groups.

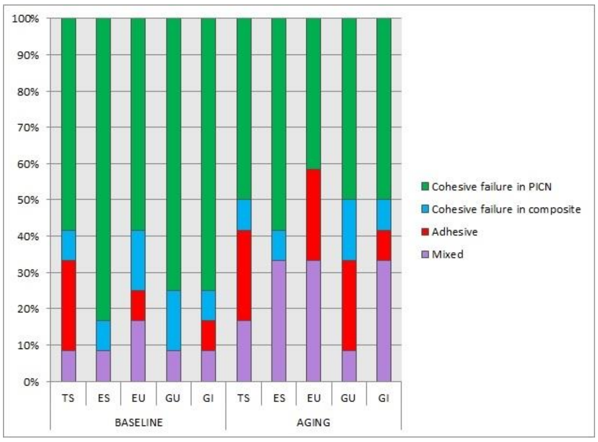

Figure 1. Distribution of the failure modes for each repair protocol before and after artificial aging.
*PICN: Polymer-infiltrated ceramic network; TS, tribochemical silica coating & Single Bond Universal; ES, etch & Single Bond Universal; EU, etch & Ultradent Porcelain Repair System; GU, grinding & Ultradent Porcelain Repair System; GI, grinding & Ivoclar Vivadent Ceramic Repair System.

Cohesive failure in PICN was dominant for all surface treatment protocols at baseline. ES showed the highest cohesive failure in PICN among groups (83%). After the aging procedure, ES demonstrated mostly cohesive failure in PICN (58%) while half of the specimens of TS, GU, and GI groups showed cohesive failure in PICN. No adhesive failures were observed for ES neither at the baseline nor after the aging process. Also, GU did not show any adhesive failures at baseline. However, the TS, EU, and GU groups failed up to 25% adhesively after aging.

DISCUSSION

Small fractures or chippings of hybrid CAD/CAM restorations that occur during the intraoral service can be repaired chairside to allow for extended clinical use.[21] Thus, a strong bond should be ensured between the restoration and repair composite. The bond strength of the composite to the restoration surface may vary according to repair protocols and intraoral aging.[7,20,22] This study applied 5 different repair protocols on the surface of an aged PICN material and SBS of the repair composite was evaluated before and after artificial aging. Based on the present results, SBS differed significantly with regard to the repair protocol used and aging procedure. Therefore, the null hypothesis should be rejected.

The success and longevity of the repaired restoration may be influenced by various factors including the CAD/CAM restorative material,[2] composite material used for repair,[21] and surface conditioning procedures.[7,17] In this study, CAD/CAM material (PICN) and composite resin used for the repair were standardized to evaluate the effect of different repair protocols on SBS and their durability after the aging procedure. The PICN material was aged (5000 thermal cycles) before the application of surface treatments as the thermocycling aging has a significant influence on the repair strength due to the degradation of the microstructure.[23,24]

In the present study, regarding baseline results before the artificial aging, HF etching followed by Single Bond Universal application showed higher SBS than tribochemical air abrasion. This finding is consistent with the results of some studies;[7,9] however, contradicts others suggesting similar bond strengths for HF etching and tribochemical silica coating.[12,19] Etching with HF causes dissolution of silica in the glassy phase of the PICN material, producing a porous micro-retentive surface with high energy.[25,26] Tribochemical air abrasion with 30-μm silica-coated alumina roughens the surface and enhances silica content on the surface, producing silicatization.[27,28] Campos *et al*.[27] demonstrated better micromechanical interaction and higher surface roughness of PICN material for HF etching compared to tribochemical air abrasion. On the other hand, tribochemical air abrasion was found to be more effective than HF on the materials with higher resin content[27-29] Since PICN is composed of 86% ceramic and 14% resin, HF treatment can be expected to present better repair bond strength for this type of material.[29]

After artificial aging, tribochemical air abrasion represented a stable bond; however, the SBS of the composite applied on the surfaces treated with Ultradent Porcelain Repair System and with HF etching followed by Single Bond Universal application decreased significantly. In line with our findings, Silva *et al*.[9] reported a durable bond for tribochemical air abrasion but indicated a decrease in SBS when the PICN surfaces were treated with grinding, HF etching, and Single Bond Universal application. The authors attributed the decrease in bond strength to the tendency for hydrolysis in the MDP content of the adhesive materials during the aging protocol. Water can penetrate small spaces between polymers or functional groups owing to its small molecular size and high molar concentration, leading to a degradation in adhesive properties.[27] Considering tribochemical air abrasion, it can be assumed that additional silicatization provided by silica-coated alumina particles may have promoted the chemical interaction between the repair composite and PICN material.[27]

The ceramic repair systems used in the present study (Ultradent and Ivoclar Vivadent) represented similar SBS results for both aged and nonaged groups consistent with the findings reported by Ustun *et al*.[2] This was not surprising considering that both systems require similar multi-steps including grinding with a diamond bur or acid etching, silanization, and adhesive application. The manufacturer recommended grinding with a diamond bur prior to HF etching for the Ultradent Porcelain Repair System. However, grinding did not significantly improve the SBS neither for non-aged nor for aged specimens. The time-efficiency is of importance in clinical practice and each additional step prolongs the treatment.[30] Therefore, when using the Ultradent system for PICN repair, grinding with a diamond bur may be considered as a redundant step.

The bond strength of HF etched and Single Bond Universal applicated group (ES) was comparable with both ceramic repair systems before aging and was better than the Ultradent Porcelain Repair System after the aging procedure. Universal adhesives are simplified systems that contain some or all of the bonding components in a single bottle.[31] Single Bond Universal unifies both silane and bonding agent in an individual unit. The use of universal adhesives in clinical practice not only reduces the complexity of application procedures but also provides ease of practice for the clinicians[29,32] Furthermore, ES repair protocol provided an adequate repair bond strength within the range of 15 to 25 MPa for both before and after the aging procedure (17.15 ± 4.43 MPa and 15.02 ± 2.8 MPa, respectively).[7] Single Bond Universal diverges from the other adhesives used in this study by the MDP monomer in its content. The MDP is a bifunctional monomer capable of bonding to both oxides and methacrylate monomers on the surface of the PICN.[19] The increased bond strength values for Single Bond Universal was reported in the previous studies and was attributed to the combined effects of MDP monomer, silane, and Vitrebond copolymer.[19,28,31] The first step of the ES protocol is the HF etching which reacts with silicon dioxide, dissolves the glassy phase of the PICN surface, and results in an increased surface energy of the ceramic.[33] The phosphoric acid groups of MDP monomer in the Single bond Universal infiltrates into the micro-irregularities composed by the HF application in the ceramic network.[9] It can be assumed that the enhanced bond strength obtained with ES repair protocol was stemmed from the MDP content. Therefore, when intraoral repair of the PICN material is required, clinicians may choose to etch with HF followed by a silane-containing universal adhesive application as the surface treatment instead of multi-step repair systems considering the time-efficiency and effectiveness of this protocol.

Cohesive and mixed failures indicate high bond strength; however, adhesive failure can be associated with poor bond strength.[34] The groups showed lower SBS results (TS before and after aging, and EU-GU after aging) demonstrated an adhesive failure rate of 25% while the ES group which showed high SBS results for both aging protocols failed cohesively in PICN dominantly.

Therefore, it can be suggested that in the present study, the findings of the stereomicroscobic analysis supported the SBS testing.

One limitation of this study was the lacking of a control group. A group considered as control with no surface treatment was performed but most of the specimens failed pre-test, therefore implementing the SBS test was not feasible. Another limitation of this study was that the macro-SBS test was used to evaluate the bond strength. The macro-bond strength tests were reported to result in the overestimation of the bond strengths.[35] Therefore, the present results should be interpreted with caution. Also, a single aging procedure (5000 thermal cycles) without any cyclic loading was applied. Repair protocols tested in this study may be varied with different combinations of adhesive systems and composites. Future studies should investigate the effects of the diversified repair and the aging protocols combined with cyclic loading conditions on the repair bond strength of composite to PICN material.

CONCLUSIONS

Within the limitations of this study, the following conclusions can be drawn:

1. At the baseline, ES and GU enhanced the bond strength of repair composite to PICN compared to TS repair protocol.
2. After aging, the ES repair protocol provided better repair bond strength than either repair protocols involved Ultradent Porcelain Repair System.
3. TS and GI repair protocols showed more stable bond strengths compared to other protocols after the aging procedure. Although affected negatively by the aging procedure, SBS of ES was higher than both groups, yet not significant.
4. Repair of the PICN with ES protocol demonstrated SBS values within the acceptable clinical range both before and after the aging procedure.

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CONFLICT OF INTEREST

The authors of this study declare no conflict of interest.

Farklı Onarım Protokollerinin ve Yapay Yaşlandırmanın Kompozitin Polimer-İnfiltre Seramik Ağ Materyaline Bağlanma Kuvvetine Etkisi

Öz

Amaç: *Bu çalışmanın amacı, farklı onarım protokollerinin ve yapay yaşlandırmanın PICN malzemesinin onarımında kullanılan kompozitin kayma bağlantı dayanımı (SBS) üzerindeki etkisini değerlendirmektir.* ***Gereç ve Yöntemler:*** *Toplam 120 PICN (Vita Enamic, Vita Zahnfabrik) numunesi hazırlandı, yapay olarak yaşlandırıldı (5°C ile 55°C arasında 5000 termal döngü) ve 5 onarım protokolüne göre gruplandı: (1) TS: tribokimyasal silika kaplama (Rocatec Soft; 3M ESPE)+Single Bond Universal (SBU; 3M ESPE) (2) ES: hidroflorik asit ile pürüzlendirme (HF; Bisco)+SBU (3) EU: HF +Ultradent Porselen Onarım Sistemi (UPRS; Ultradent Products Inc.) (4) GU: elmas frezle aşındırma (G)+UPRS (5) GI: G +Ivoclar Vivadent Seramik Onarım Sistemi (Ivoclar Vivadent AG). Onarımı simüle etmek amacıyla tüm örneklere silikon bir kalıpla (4 mm çap, 2 mm yükseklik) oluşturulmuş kompozit silindirler (Clearfil Majesty Esthetic, Kuraray) uygulandı. Daha sonra yapay yaşlandırma prosedürüne göre başlangıç ve yaşlandırma (5 ° C ile 55 ° C arasında 5000 termal döngü) olarak 2 alt grup oluşturuldu (n = 12). SBS testleri universal test cihazı kullanılarak gerçekleştirildi. Başarısızlık tipleri PICN içinde koheziv, kompozit içinde koheziv, adeziv ve karışık olarak sınıflandırıldı. SBS verileri istatistiksel olarak tek yönlü ANOVA, faktöryel ANOVA, LSD ve Duncan testleri ile analiz edildi. (α=0.05) Başarısızlık tipleri her grup için yüzde olarak hesaplandı.* ***Bulgular:*** *Başlangıç sonuçları, ES ve GU için ortalama SBS değerlerinin TS'den daha yüksek olduğunu gösterdi ($p<0.05$). Yapay olarak yaşlandırılmış gruplara bakıldığında ES grubu EU ve GU'dan daha yüksek SBS gösterdi ($p<0.05$). ES, EU ve GU grupları için SBS değerleri, suni yaşlandırmadan sonra başlangıca göre önemli ölçüde azaldı ($p<0.05$). Başlangıçta, dominant başarısızlık modu tüm gruplar için PICN içinde kohezifti ve ES ve GU grupları için* *adezif başarısızlık gözlenmedi. Bununla birlikte, yaşlandırmadan sonra adezif başarısızlık göstermeyen tek grup ES idi.* ***Sonuçlar:*** *Zaman verimliliği ve etkinlik göz önüne alındığında, HF ile aşındırmanın ardından Single Bond Universal uygulaması PICN için ağız içi onarım protokolü olarak önerilebilir.* ***Anahtar Kelimeler:*** *CAD/CAM, dental restorasyon onarımı, kayma mukavemeti, bileşik rezinler.*

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Original research

A COMPARISON OF THE EFFECTS OF EXTRACTION AND NONEXTRACTION ORTHODONTIC TREATMENTS ON CEPHALOMETRIC PARAMETERS AND ARCH WIDTHS

ABSTRACT

Objectives: To compare the effects of two different treatment approaches on cephalometric measurements and arch widths.

Materials and Methods: The retrospective study evaluated pre- and post-treatment cephalometric radiograms and dental models of 45 patients with Class I malocclusions and moderate-severe dental tooth size arch length discrepancies that underwent extraction or nonextraction treatment between 2015 and 2020. Group I (n=22 [9 female, 13 male]; mean age, 18.0 ± 1.68 years) was treated with the Damon Q bracket system and Group II (n=23 [11 female, 12 male]; mean age, 17.9 ± 1.34 years) was treated with the conventional MBT bracket system. Pre- and post-treatment lateral cephalometric radiograms were obtained and arch widths were measured for each subject. Paired samples t-test was used to evaluate the treatment changes within each group. To compare the changes between groups, independent samples t-test was performed.

Results: No significant change was detected in the sagittal and vertical skeletal parameters in both groups ($p>0.05$). The upper and lower incisors proclined significantly in Group I ($p<0.01$) and the mandibular incisors retroclined significantly in Group II ($p<0.05$). The lips protruded significantly and the upper lip thickness decreased significantly in Group I ($p<0.01$), whereas no significant difference was observed in Group II ($p>0.05$). All the transversal dimensions increased significantly in Group I ($p<0.01$), while only the intermolar distances decreased significantly in Group II ($p<0.01$).

Conclusions: Both treatment methods provided significantly different outcomes with regard to soft tissue parameters and arch widths.

Key words: Extraction, nonextraction, orthodontics.

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INTRODUCTION

The tooth size arch length discrepancies are commonly encountered malocclusion in dental practice.[1,2] This problem can be treated by two approaches during permanent dentition: extraction and nonextraction treatment. Over the last century, however, the decision to extract permanent teeth in cases with tooth size arch length discrepancies have remained a controversial issue due to aesthetic concerns.[3]

Extraction of premolar teeth for orthodontic reasons is widely performed to achieve ideal levelling of incisor teeth and to ensure a high-standard orthodontic finishing and long-term stability.[4] However, nonextraction treatment has become highly popular particularly in the presence of condylar displacement, dark buccal corridors, concave profile, and suboptimal mandibular growth concerns.[5,6]

Nonextraction treatment eliminates the irregularities via transversal expansion of arches and proclination of incisors.[7,8] The Damon self-ligating bracket system (Ormco, Glendora, California, USA) is a nonextraction treatment that has been shown to be superior to conventional bracket systems due to its production of low force and low friction. Additionally, this system has also been shown to provide several advantages including increased patient comfort during treatment, fewer visits to the orthodontist, shorter treatment times, less need for extraction, and better results in terms of both occlusal and facial aesthetics.[9-11]

Studies comparing the effects of extraction and nonextraction treatments on the arch widths, contrary to popular belief, have revealed that premolar extraction methods lead to no significant decrease in the intercanine distance compared to nonextraction methods.[6] Moreover, it has also been shown that the Damon bracket system can achieve a significant expansion in buccal segments in nonextraction treatments.[8,12,13] On the other hand, while some of the studies comparing the Damon bracket system and conventional bracket systems in patients undergoing nonextraction treatment found significant differences in intermolar distances[8,14,15], some others found no significant differences between the bracket systems with regard to intermolar distance.[13-16]

To our knowledge, there has been no study comparing the cephalometric and arch width parameters in patients treated with a nonextraction approach using the Damon bracket system and with an extraction approach using the MBT system, particularly in borderline cases. The retrospective study was designed to compare cephalometric measurements in borderline patients with Class I malocclusions and moderate-severe tooth size arch length discrepancies who were treated with these two treatment approaches and to analyze the effects of these measurements on dental arches. The null hypothesis is that there are significant differences between two approaches with regard to their cephalometric and dental arc measurements.

MATERIALS AND METHODS

The retrospective study evaluated pre- and post-treatment cephalometric radiograms and dental models of patients that underwent extraction or nonextraction treatment in Adiyaman University School of Dentistry Orthodontics Department between 2015 and 2020. An approval was obtained from Adiyaman University Noninterventional Clinical Research Ethics Committee (Approval No: 2019/8-6).

Power analysis was performed using GPOWER statistical software (Ver. 3.1 Franz Faul, Universität Kiel, Kiel, Germany), in which the minimum number of samples was determined as 34 based on an alpha level of 0.05, a power of 0.80, and an effect size of 0.87 considering the mean PAR score after treatment was 3.5 ± 3.19 in four first premolar extraction group and 1.4 ± 1.14 in the nonextraction group derived from İleri *et al.*[17] To increase the power of the study, a total of 45 patients were included in the analysis.

To create a comparable dataset, the treatment records of each patient were re-examined to identify treatment procedures and only those treated with the same procedure were analyzed. The pretreatment inclusion and selection criteria for the nonextraction group were as follows; skeletal Class I malocclusion (ANB [A point, nasion, B point], 0-5°), angle Class I malocclusion, age in the permanent dentition period, a minimum of 5-mm maxillary and mandibular tooth size arch length discrepancies according to Hayes-Nance analysis, absence of systemic diseases, absence of missing permanent teeth or congenitally absent teeth, absence of prior orthodontic treatment, and not using any additional appliance (miniscrew, Herbst appliance, lip bumper appliance, headgear, or distalization device), during the treatment, using the Damon Q bracket system (Ormco, California, USA) (0.022-inch bracket slot size) and bonding brackets in the upper and lower arches to the level of seventh teeth (Figure 1), finishing the treatment by performing dental levelling and alignment with 0.19"x0.25" stainless steel archwires.

Figure 1. Nonextraction treatment with the Damon bracket system.

The nonextraction group consisted of 22 patients (9 female, 13 male; mean age, 18.0 ± 1.68 years).

The patients who fulfilled the following pretreatment inclusion and selection criteria were included in the extraction group; skeletal Class I malocclusion, angle Class I malocclusion, age in the permanent dentition period, a minimum of 5-mm maxillary and mandibular tooth size arch length discrepancies according to Hayes-Nance analysis, absence of systemic diseases, absence of missing permanent teeth or congenitally absent teeth, absence of prior orthodontic treatment, and not using any additional appliance, during the treatment, extraction of the four first premolars and applying the MBT bracket system (Mini Master Series; American Orthodontics, Sheboygan, WI, USA) and bonding brackets in the upper and lower arches to the level of seventh teeth (Figure 2), achieving the dental levelling and alignment with 0.014", 0.016", 0.016"x0.022" and 0.017"x0.022" Nickel titanium archwires, performing the canine distalization with moderate anchorage using 0.17"x0.22" stainless steel archwires, and finalizing the treatment by applying the finishing procedures after performing incisor consolidation. The extraction group consisted of 23 patients (11 female, 12 male; mean age, 17.9 ± 1.34 years).

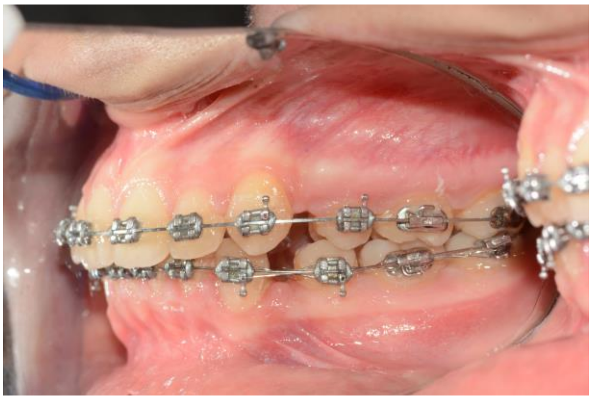

Figure 2. Four premolar extraction with the MBT bracket system.

Cephalometric radiograms along with extra- and intra-oral images and plaster models were obtained both before (T1) and after the treatment (T2) by the same operator using the same cephalostat. Digital lateral cephalometric radiograms were obtained by the same operator using a Planmeca EC Proline PM 2002 Panoramic Dental X-ray Unit. The exposure values were set at 68-74 kV, 5 mA, and with an exposure time of 0.5 s. The receptor-source distance was fixed at 150 cm. The rate of radiographic magnification was adjusted to 1.1 and all the digital cephalometric radiograms were obtained in a standing position with the teeth in centric occlusion and the subject's head positioned with Frankfurt's horizontal plane parallel to the ground, with the cephalostat ear-rods adjusted to hold the head in natural head position.

All the scanned images were processed by the same operator using Dolphin Imaging Version 10.5 (Dolphin Imaging, Chatsworth, California, USA) (Figure 3).

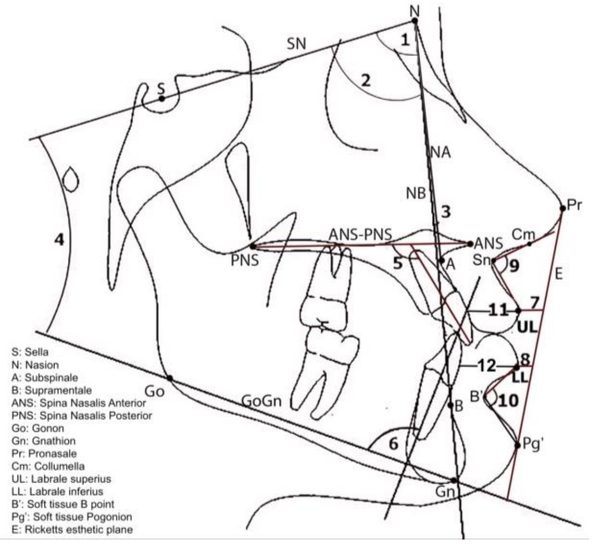

Figure 3. Cephalometric angular and linear measurements used in the study. 1. SNA°, angle formed by S-N and N-A planes; 2. SNB°, angle formed by S-N and N-B planes; 3. ANB°, angle formed by N-A and N-B planes; 4. SN/GoGn°, angle formed by S-N and Go-Gn planes; 5. U1/PP (º), angle formed by U1 plane and ANS-PNS plane; 6. IMPA (º), angle formed by L1 plane and Go-Gn plane; UL-E (mm), the distance between UL point and Pr-Pg' (E) plane; LL-E (mm), the distance between LL point and Pr-Pg' (E) plane; 9. Nasolabial angle, angle formed by Cm-Sn and Sn-UL planes; 10. Mentolabial angle, angle formed by LL-B' and B'-Pg' planes; 11. UL thickness, the distance between the most facial point of the maxillary incisor and UL point and 12. LL thickness, the distance between the most facial point of the mandibular incisor and LL point.

Maxillary and mandibular tooth size arch length discrepancies were assessed on pretreatment dental casts using Hayes-Nance analysis. Crowding was categorized according to the Little's[18] irregularity index [ideal alignment (0-0.9 mm), minimal (1-3.9 mm), moderate (4-6.9 mm), severe (7-9.9 mm), extreme (more than 10 mm)]. Measurements of pre- and post-treatment dental models were performed by the same operator using a digital caliper (Mitutoyo, Tokyo, Japan). Additionally, intercanine and intermolar width were also measured to assess the transversal changes induced by the treatment (Figure 4).

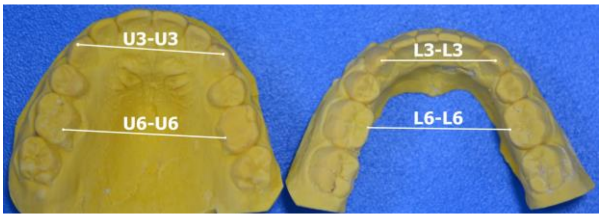

Figure 4. Measurement of maxillary and mandibular intercanine and intermolar distances on dental casts. U3-U3: the distance between the tips of the left and right upper canines; U6-U6: the distance between the most supero-palatal points of distolingual grooves of the left and right upper first molars; L3-L3: the distance between the tips of the left and right lower canines; L6-L6: the distance between the most supero-lingual points of lingual grooves of the left and right lower first molars.

Three weeks after the first measurements, 20 randomly selected cephalometric radiograms were redrawn and the model measurements were repeated to assess interrater reliability. In these measurements, the reliability coefficient was close to 1.00 (range, 0.92-0.99).

Statistical analysis

Data were analyzed using SPSS 22.0 (IBM Corp. released 2013. IBM SPSS Statistics for Windows, Version 22.0, Armonk, NY: IBM Corp.). Descriptives were expressed as mean ± standard deviation (SD). Normal distribution of data was determined using Kolmogorov-Smirnov test. Two independent variables with normal distribution were compared using Paired-Samples *t*-test and variables nonnormal distribution were compared using Mann-Whiney U test. Interrater reliability was assessed using Intraclass Correlation Coefficient (ICC). A p value of <0.05 was considered significant.

RESULTS

Mean pretreatment maxillary tooth size arch length discrepancies were 7.70 ± 0.61 mm in the extraction group and 6.80 ± 0.34 mm in the nonextraction group. In contrast, mean pretreatment mandibular tooth size arch length discrepancies were 7.30 ± 1.1 mm in the extraction group and 5.70 ± 0.36 mm in the nonextraction group. No significant difference was found between the two groups with regard to pretreatment tooth size arch length discrepancy values (p>0.05).

Table 1 presents the comparison of baseline cephalometric measurements in both groups.

Table 1. Baseline descriptives and comparison of differences between the groups.

	Extraction		Nonextraction		Overall P value
	Mean	SD	Mean	SD	
Age (years)	17.90	1.34	18.00	1.68	0.187
Skeletal cephalometric parameters					
SNA (º)	79.80	0.72	82.85	0.65	0.019*
SNB (º)	75.80	0.71	80.05	0.61	0.001***
ANB (º)	4.40	0.46	2.65	0.44	0.040*
SN/GoGn (º)	38.00	1.21	32.80	1.19	0.002**
Dental cephalometric parameters					
U1/PP (º)	109.30	4.98	111.40	1.43	0.674
IMPA (º)	89.5	1.43	83.55	1.48	0.153
Soft tissue cephalometric parameters					
UL-E (mm)	-1.40	0.48	-3.30	0.40	0.035*
LL-E (mm)	-1.10	0.51	-1.40	0.36	0.006**
Nasolabial angle	111.40	1.23	104.80	3.74	0.004**
Mentolabial angle	138.00	2.13	127.50	2.03	0.006**
UL thickness	10.60	0.41	12.50	0.45	0.004**
LL thickness	10.30	0.34	12.05	0.32	0.001***
Dental cast parameters					
Overjet (mm)	3.50	0.38	3.50	0.43	0.699
Overbite (mm)	2.50	0.32	3.10	0.42	0.202
U3-U3 (mm)	33.50	0.57	34.7	0.64	0.420
U6-U6 (mm)	43.00	0.50	46.2	0.64	0.001***
L3-L3(mm)	25.50	0.37	25.8	0.51	0.892
L6-L6 (mm)	38.4	0.47	41.05	0.60	0.005**
Maxillary TSALD	-7.70	0.61	-6.80	0.34	0.187
Mandibular TSALD	-7.30	1.01	-5.70	0.36	0.382

P: test result, SD: Standard deviation, mm: millimeter, TSASD: tooth size arch length discrepancies, *: P<0.05, **: P<0.01, ***: P<0.01.

A significant difference was found between the two groups with regard to skeletal and soft tissue measurements ($p<0.05$ for both), while no significant difference was observed with regard to dental measurements ($p>0.05$). Moreover, a significant difference was found between the two groups with regard to maxillary and mandibular intercanine measurements ($p<0.05$ for both), whereas no significant difference was observed in terms of interdental measurements ($p>0.05$).

Table 2 presents pre- and post-treatment cephalometric measurements and their changes in both groups.

Table 2. Descriptive values and comparison of variables at pretreatment and posttreatment periods.

	Extraction			Nonextraction		
	Pretreatment	Posttreatment	P	Pretreatment	Posttreatment	P
	Mean±SD			Mean±SD		
Skeletal cephalometric parameters						
SNA°	79.80±072	79.30±0.92	0.420	82.85±0.65	83.05±0.65	0.783
SNB°	75.8±0.71	76.00±0.77	0.438	80.05±0.61	80.15±0.71	0.845
ANB°	4.40±0.46	3.90±0.37	0.721	2.65±0.44	2.55±0.38	0.341
SN/GoGn°	38.00±1.21	37.50±1.25	0.073	32.80±1.19	32.10±1.18	0.357
Dental cephalometric parameters						
U1/PP°	109.30±4.98	107.6±4.37	0.064	111.40±1.43	118.65±1.42	0.01**
IMPA°	89.5±1.43	86.7±1.64	0.016*	83.55±1.48	93.85±1.69	0.01**
Soft tissue cephalometric parameters						
UL-E (mm)	-1.40±0.48	-3.00±0.49	0.001***	-3.30±0.40	-2.70±0.38	0.01**
LL-E (mm)	-0.10±0.51	-0.90±0.48	0.011*	-1.40±0.36	0.10±0.36	0.004**
Nasolabial angle	111.40±1.23	111.40±1.83	0.513	104.80±3.74	98.80±2.50	0.300
Mentolabial angle	138.00±2.13	134.00±2.52	0.833	127.50±2.03	127.30±1.99	0.385
UL thickness	10.60±0.41	11.70±0.45	0.135	12.50±0.45	10.85±0.46	0.01**
LL thickness	10.30±0.34	10.10±0.31	0.738	12.05±0.32	11.30±0.41	0.229
Dental cast parameters						
Overjet (mm)	3.50±0.38	2.40±0.14	0.088	3.50±0.43	2.45±0.11	0.070
Overbite (mm)	2.50±0.32	2.40±0.15	0.273	3.10±0.42	2.10±0.12	0.093
U3-U3 (mm)	33.50±0.57	35.00±0.44	0.012*	34.7±0.64	37.3±0.51	0.01**

U6-U6 (mm)	43.00±0.50	41.9±0.33	0.001***	46.2±0.64	48.0±0.59	0.01**
L3-L3 (mm)	25.50±0.37	26.90±0.27	0.095	25.8±0.51	28.2. ±0.41	0.01**
L6-L6 (mm)	38.4±0.47	37.3±0.54	0.009**	41.05±0.60	42.10±0.43	0.01**

P: test result, SD: Standard deviation, mm: millimeter, *: P<0.05, **: P<0.01; ***: P<0.001.

In the group treated with Damon Q system, no significant change was observed between pre- and post-treatment skeletal measurements (*p*>0.05). The proclination of upper and lower incisors was statistically significant (*p*<0.05 for both), while the reduction in the overjet and overbite was statistically insignificant (*p*>0.05). On the other hand, the lower and upper lips significantly moved anteriorly (*p*<0.01), no significant change occurred in nasolabial and mentolabial angles (*p*>0.05), the upper lip thickness decreased significantly (*p*<0.01), and no significant change occurred in the lower lip thickness (*p*>0.05). Moreover, a significant increase was observed in interdental distances in both maxillary and mandibular molars (*p*<0.01 for both).

In the group treated with the MBT bracket system with four premolar extraction, no significant change was observed between pre- and post-treatment skeletal measurements (*p*>0.05). Although the retroclination of the lower incisors was statistically significant (*p*<0.05), no significant change was observed in the upper incisor angles (*p*>0.05). Similarly, no significant change was observed in overjet and overbite (*p*>0.05 for both). Both the lower and upper lips significantly moved posteriorly (*p*<0.05 for both), while no significant change was detected in the nasolabial and mentolabial angles and in the lower and upper lip thickness (*p*>0.05 for all). In model measurements, the maxillary intercanine distance increased significantly (*p*<0.05), the maxillary and mandibular intermolar distances decreased significantly (*p*<0.05), and no significant change was observed in the mandibular intercanine distance (*p*>0.05).

Table 3 presents the changes detected in both groups.

Table 3. Treatment changes descriptive statistics of parameters and significance values between groups.

	Extraction		Nonextraction		P value
	Mean	SD	Mean	SD	
Skeletal cephalometric parameters					
SNA°	0.60	0.64	0.50	0.54	0.685
SNB°	2.00	0.75	2.00	0.75	0.460
ANB°	-0.30	0.44	0.15	0.29	0.733
SN/GoGn°	-2.50	0.65	-0.60	0.45	0.666
Dental cephalometric parameters					
U1/PP°	-0.10	6.63	6.80	0.37	0.001***
IMPA°	-1.90	1.15	5.75	1.30	0.001***
Soft tissue cephalometric parameters					
UL-E (mm)	-1.80	0.44	1.00	0.21	0.001***
LL-E (mm)	-1.80	0.56	1.10	0.25	0.001***
Nasolabial angle	-1.00	2.66	-6.45	-4.16	0.001***
Mentolabial angle	2.00	2.09	-2.50	2.00	0.725
UL thickness	0.40	0.87	-1.40	0.19	0.001***
LL thickness	0.20	0.34	-0.55	0.45	0.224
Dental cast parameters					
Overjet (mm)	-1.10	0.44	-0.80	0.40	0.856
Overbite (mm)	-0.30	0.46	-0.55	0.38	0.053
U3-U3 (mm)	1.8	0.62	2.25	0.41	0.666
U6-U6 (mm)	-0.80	0.60	1.60	0.69	0.001***
L3-L3 (mm)	1.60	0.69	2.20	0.32	0.012*
L6-L6 (mm)	0.00	0.55	1.05	0.35	0.001***

P: test result, SD: Standard deviation, mm: millimeter, *: P<0.05, **: P<0.01, ***: P<0.01.

No significant difference was found between the two groups with regard to the changes in skeletal measurements (*p*>0.05). A significant difference was found with regard to the changes in the lower and upper incisor angles (*p*<0.001) while no significant change was found with regard to the changes in overjet and overbite (*p*>0.05). A significant difference was found between the two groups with regard to the changes in upper and lower lip position, nasolabial angle, and upper lip thickness ($p<0.05$ for all), whereas no significant difference was observed with regard to the changes in mentolabial angle and lower lip thickness ($p>0.05$ for both). In model measurements, no significant difference was found between the two groups with regard to the maxillary intercanine distance ($p>0.05$), while significant difference was found in terms of the changes in other maxillary and mandibular interdental distances ($p<0.05$).

DISCUSSION

Tweed[19] claimed that the leveling and alignment of the teeth should be above the basal bone and leaded a new trend involving orthodontic treatment with tooth extraction against the previous idea[20] of enlarging dental arches. Similar to the previous idea, in the 1990s, Dwight Damon developed the Damon system, which includes a passive self-ligating bracket design and broader super elastic archwires, based on the thesis that low friction and light forces produce more biologically stable results.[10] The Damon philosophy states that biologically friendly light forces expands posterior parts of dental arches and reduce the need for tooth extraction to dissolve crowding.[11] When tooth extraction is inevitable, it is important to minimize the torque loss after incisor retraction. McLaughlin, Bennett, and Trevisi introduced the MBT prescription in 1997 and became very popular system among orthodontists. This prescription contained the following differences compared to others; greater palatal root inclination values at maxillary central incisor brackets (17 degrees), greater palatal root inclination values at maxillary lateral incisor brackets. (10 degrees), greater lingual crown inclination values at mandibular incisor brackets (−6 degrees) and reduced tip values in the maxillary canine brackets (8 degrees). Researchers reported that the greater palatal root inclination values in the maxillary incisors improve the appearance of teeth with reduced torque values especially in cases with tooth extraction.[21] In the literature, the effects of these two very popular prescriptions in treatments with and without extraction have not yet been compared. Therefore, the present study retrospectively evaluated pre- and post-treatment changes in cephalometric and dental model measurements between patients that were treated with an extraction approach using the conventional MBT bracket system and patients that were treated with a nonextraction approach using a self-ligating Damon bracket system.

An analysis of pretreatment measurements of both groups indicated that there are a number of factors taken into consideration when deciding whether to extract or retain premolar teeth, including soft tissue profile of the subject, the SNA (Sella-Nasion-point A angle) and SNB (Sella-Nasion-point B angle) angles that show the sagittal position of the maxilla and mandible with respect to the cranial base, and he SN-GoGn angle that is used to assess the vertical skeletal pattern. In the group that underwent four premolar extraction, the lips of the subjects were more protrusive and both the maxilla and mandible were located in more anterior positions when compared to the cranial base and also had a higher vertical angle while no significant differences were found between pretreatment inclinations of upper and lower incisors. Similarly, previous studies also indicated that the extraction of premolars and the retraction of the anterior segment in subjects with protrusive lips contribute to the improvement of lip profile through the retraction of lips.[22,23] In contrast, Erdinc *et al.*[24] showed significantly more protrusive and proclined incisors between extraction and nonextraction groups at the beginning of the study, while Basciftci *et al.*[25] reported no significant differences in the positions of incisors were observed between the extraction and nonextraction Class I groups before treatment in agreement with our findings. The discrepancies in these outcomes may be related to the differences in inclusion criteria between studies.

In our study, no significant change was observed in cephalometric skeletal measurements in both groups, which could be attributed to the fact that the treatment remained at the dental level and the patients included in the study had not completed their growth and development. This finding was consistent with the findings reported by Başçiftçi and Üşümez[25] and Başçiftçi *et al.*[26]

On the other hand, a significant increase was detected in the upper and lower incisor angles in the dental cephalometric measurements of the nonextraction group. This finding was consistent with the findings presented by previous studies reporting on the Damon bracket system.[16,26-28] In the extraction group, however, the mandibular incisors retroclined significantly (*p*<0.05) while no significant difference was observed in maxillary incisors (*p*>0.05), which implicates that the anterior tooth size arch length discrepancies were eliminated by moderate anchorage and no effective upper incisor consolidation was performed to reduce dental angles. These findings were consistent with those reported by Finnoy *et al.*[29] and Erdinç *et al.*[24], while they contradicted those reported by Zierhut *et al.*[30] and Başçiftçi *et al.*[26] This contradiction could be attributed to the use of different space closure techniques at the beginning of the treatment in the extraction group and to the different levels of tooth size arch length discrepancies in the studies. On the other hand, both overjet and overbite did not change significantly in both groups. This finding could be ascribed to the treatment mechanics administered in both groups (implementation of moderate anchorage in the extraction group and the expansion of arches with the Damon Q bracket system). Although this finding was consistent with the findings presented by Atik and Ciğer[27] who performed a nonextraction treatment with the Damon bracket system, it was inconsistent with the findings presented by Başçiftçi and Üşümez[25] who found a significant reduction in overjet in Class I patients. This contradiction could be associated with the differences in subjects' pretreatment overjet values and the implementation of different treatment mechanics in the studies.

The treatment approaches performed in our study expectedly had different effects on the lip profiles of the subjects. In the nonextraction group, the lips moved significantly anteriorly due to the marked proclination of both the upper and lower teeth, which specifically led to a significant reduction in the upper lip thickness. In contrast, Başçiftçi *et al.*[26] reported that only the lower lip significantly moved anteriorly in their patients. This difference could be related to the level of maxillary tooth size arch length discrepancies at the beginning of the treatment. Nevertheless, in our extraction group, both the lower and upper lips significantly moved posteriorly while no significant change was observed in lip thickness and angles.

In our study, the maxillary intercanine distance increased significantly in the group treated with an extraction approach using the conventional MBT bracket system. Meaningfully, an increase in the distance between the canines that are moved posteriorly following distalization with wide arches and arch forms is an expected outcome and this outcome was consistent with the findings presented by Aksu and Kocadereli[1] and Kim and Gianelly.[20] In contrast, the maxillary and mandibular intermolar distances decreased significantly, which could be associated with the movement of these molars towards the mesial segment as a result of moderate anchorage. This finding was consistent with the findings presented by Kim and Gianelly[20], while it was inconsistent with those presented by Aksu and Kocadereli.[1] On the other hand, no significant change occurred in the mandibular intercanine distance despite the use of wide arches, which is highly important for the avoidance of post-treatment relapse. This finding contradicted the findings presented by Kim and Gianelly[20] and Aksu and Kocadereli[1], which could be attributed to the difference in the widths of arches used in the studies.

In the group treated with a nonextraction approach using the Damon bracket system, the interdental distance between all the maxillary and mandibular molars increased significantly. This finding confirmed the commonly known hypothesis that the Damon bracket system is useful for expanding the arches during the treatment and was consistent with the findings presented by Atik and Ciğer[27], Vajaria *et al.*[28], and Başçiftçi *et al.*[26] Nevertheless, the increase in mandibular intercanine distance can be alarming particularly for treatment stability.[26]

Although no significant difference was found between the two groups with regard to maxillary intercanine distance, both treatment approaches were found to provide similar outcomes with regard to maxillary intercanine distance through the use of wide arches.

Our study was limited since baseline skeletal and soft tissue measurements of both groups were significantly different from each other and only short-term effect of these treatments were evaluated in the study. Additionally, no evaluation was performed for the total duration of treatment for the patients. Further longitudinal studies are needed to provide a more robust comparison of changes induced by these treatment approaches by standardizing the cephalometric parameters and to investigate post-treatment relapse in the subjects. Moreover, further studies may involve different age groups and larger sample sizes and may compare these approaches with other techniques such as miniscrew-assisted treatment.

CONCLUSIONS

Both treatment methods provided significantly different outcomes with regard to cephalometric parameters except skeletal values, mentolabial angle and lower lip thickness and dental model parameters except overjet, overbite and maxillary intercanine distances. These two different treatment approaches showed opposite effects on the lips, mandibular incisor inclinations and intermolar widths. Accordingly, when selecting the treatment, these differences as well as the position of incisors, transversal dimensions of the dental arches and the lip profiles of the subjects should be taken into consideration.

CONFLICTS OF INTEREST STATEMENT

The authors declare that there is no competing interest.

Çekimli ve Çekimsiz Ortodontik Tedavilerin Sefalometrik Yapılar ve Ark Genişlikleri Üzerine Etkilerinin Karşılaştırılması

ÖZ

Amaç: *İki farklı tedavi yaklaşımının sefalometrik ölçümler ve ark genişlikleri üzerindeki etkilerini karşılaştırmaktır.* ***Gereç ve Yöntemler:*** *Sınıf I maloklüzyona sahip ve orta-şiddetli çapraşıklığı bulunan 45 bireyin sefalometrik radyografileri ve dental modelleri elde edilmiştir. Bireyler çekim yapılmayan (birinci) ve dört premolar çekimli (ikinci) olmak üzere iki gruba ayrılmıştır. Birinci grup, Damon Q sistemi ile tedavi gören 22 hastadan (9 kız, 13 erkek ortalama yaş 18.0 ± 1.68) oluşmakta iken ikinci grup konvansiyonel MBT braket sistemi ile tedavi edilen 23 hastadan (11 kız, 12 erkek yaş ortalaması: 17.9 ± 1.34) oluşmaktadır. Hastaların tedavi öncesi ve sonrası lateral sefalometrik radyografileri ve ark genişlikleri ölçülüp karşılaştırılmıştır. Her gruptaki tedavi değişikliklerini değerlendirmek için eşleştirilmiş örnekler t-testi kullanıldı. Gruplar arasındaki değişiklikleri karşılaştırmak için bağımsız örnekler t-testi yapıldı.* ***Bulgular:*** *Her iki grupta da tedavi ile sagital ve vertikal iskeletsel değerlerde istatistiksel olarak anlamlı bir değişiklik görülmemiştir (p>0,05). Üst ve alt kesici dişlerde birinci grupta anlamlı proklinasyon gözlenirken (p<0,01); ikinci grupta mandibular dişlerde anlamlı (p<0,05) retroklinasyon bulunmuştur. Dudakların birinci grupta belirgin olarak protrüze olduğu ve üst dudağın inceldiği gözlenmiş (p<0,01), ancak ikinci grupta istatistiksel olarak anlamlı bir değişiklik gözlenmemiştir (p>0,05). Birinci grupta tüm transvers dental model ölçümlerinde anlamlı (p<0,01) artış tespit edilmiş, ancak ikinci grupta sadece intermolar genişliklerde anlamlı bir azalma gözlenmiştir (p<0,01).* ***Sonuç:*** *İki tedavi yöntemi dental ve yumuşak dokular ile ark genişlikleri üzerine birbirine zıt ve anlamlı etkiler göstermiştir.* ***Anahtar Kelimeler:*** *Çekimli, çekimsiz, ortodonti.*

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Original research

THE SMEAR LAYER REMOVAL EFFICIENCY OF DIFFERENT CONCENTRATIONS OF EDTA IN PRIMARY TEETH: A SEM STUDY

ABSTRACT

Objectives: The present study aims to evaluate the effects of different concentrations of ethylenediamine tetraacetic acid (EDTA) on smear layer removal in primary teeth by using scanning electron microscopy (SEM).

Materials and Methods: The present study was performed with 28 extracted upper primary incisors assigned into four main groups (n=7) as 5%, 10% and 17% EDTA, and 1% sodium hypochlorite (NaOCl). The root canal surfaces (coronal, middle and apical) were scanned by SEM and scores of smear layer removal were recorded and compared after the root canal irrigation procedures. The results were analyzed using Kruskal–Wallis, Friedman and Dunn tests.

Results: In all the root portions, although EDTA groups removed the smear layer more effectively than NaOCl, a statistically significant difference was observed between 17% EDTA and 1% NaOCl only in middle third ($p < 0.05$). Also, smear layer was removed more effectively in coronal than apical in most of the groups (10% EDTA, 17% EDTA and 1% NaOCl) ($p < 0.05$). Erosive defects were seen in 10% EDTA and 17% EDTA groups, mostly in 17% EDTA group. These findings were not detected in 5% EDTA and 1% NaOCl group.

Conclusions: It is possible to recommend the use of 5% EDTA irrigation solution in root canal treatment of primary teeth due to its similar smear layer removal efficacy with NaOCl and high concentration EDTA groups, low erosive potential and low concentration for periapical safety.

Keywords: EDTA, root canal irrigants, smear layer.

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INTRODUCTION

The root canal treatment process of primary teeth with necrotic or irreversibly inflamed pulp are quite important to avoid the consequences of the dental infection. The success of root canal treatment involving the instrumentation, irrigation and obturation of the root canal system, depends on the chemo-mechanical debridement and effective removal of infective microorganisms in root canals.[1-6]

Smear layer formed during root canal instrumentation is a composite tissue containing dentin, necrotic and viable tissue residues, odontoblastic remnants and bacteria.[5,7,8] The smear layer reduces the permeability of dentin by penetrating into the dentinal tubules,[5,9] inhibits the effects of antibacterial agents, the seal of the root canal filling and complete removal of microorganisms in root canal.[8,10,11] Therefore, an important factor that increases the success of root canal treatment is the removal of the smear layer.[2,5,6,10]

Especially in primary teeth, the smear layer removal is as important as mechanical instrumentation.[5,12] The presence of inaccessible areas such as ramifications, lateral and accessory canals or morphological variations in the root canals especially in primary molar teeth increases the need for chemical debridement.[6,8,12-15] Moreover, the inability to provide an effective obturation and lateral condensation in root canals due to increase the diameter of apical foramen with the physiological root resorption especially in the apical portion of the roots, highlight effective smear layer removal for long-term success.[6,12]

Numerous different irrigation solutions/ protocols are used in primary tooth pulpectomies for smear layer removal.[6-8,13,16] Sodium hypochlorite (NaOCl) is frequently used due to its potent antibacterial, antiviral and antifungal effects and necrotic/organic tissue dissolving ability. However, although NaOCl dissolves the organic part of the smear layer, it is reported that it has a limited effect in removing the inorganic part.[7] Ethylenediamine tetraacetic acid (EDTA), which is a chelator agent, removes the especially inorganic part of the smear layer in root canal irrigation, however, it has been known that its antibacterial effect is limited. Also, the prolonged exposure of EDTA with the root canal walls results in excessive removal of peritubular and intratubular dentin, therefore, the combined use of NaOCl and EDTA agents is recommended for both antibacterial effect and effective smear layer removal.[2,6,8]

In permanent teeth, EDTA is mostly used in 17% concentration in irrigation protocols. However, differences in water and organic content and hardness of the structure of primary tooth dentin require the use of different EDTA concentrations.[2,5,6,14] Even lower concentrations than those used in permanent teeth cause erosive defects and excessive removal of dentine in primary tooth root dentin.[2,5,6] Although the researches investigating the use of 10% to 17% EDTA, there is no certain protocol that has been proven for the use of EDTA in primary teeth and evidence-based long-term clinical results. Morever, sufficient detected information is not available for the concentrations of <10% EDTA. Therefore, in the present study, it is aimed to evaluate the effects of different concentrations of EDTA as final irrigation solution on smear layer removal in primary root canals under in-vitro conditions.

MATERIALS AND METHODS

Ethical Approval and Statements

Ethical approval for the presented study was provided by the Clinical Research Ethics Committee of Ankara University, Faculty of Dentistry (approval decision number: 11/04, decision date: 14.10.2020). Wherefore the extracted human primary teeth were used in this study, written and verbal consents was obtained from child patients and their parents. The principles of the Declaration of Helsinki were followed in the study. Also, the presented study has followed the Checklist for Reporting In-vitro Studies (CRIS) guidelines for in-vitro studies as discussed in the 2014 concept note by Krithikadatta *et al.*[17]

Sample Size Calculation and Including/ Excluding Criteria

The statistical power analysis was carried out to determine the sample size for this in-vitro study. For the determination the differences between the study groups (effect size: 0.70) indicated that a minimum of 28 deciduous incisor teeth were required to detect a significant difference (80% power and 5% type I error). In this study, 28 upper primary incisor teeth extracted due to extent dental caries and periapical lesion, dento-alveolar abscess, non-restorable crown structure or dento-alveolar trauma were used. Considering the including criteria for the presented study, teeth were selected to be as single rooted, without root anomalies, root resorption level not more than one third of the total root length (on the basis of Kramer and Ireland[18]) and apical foramen size not larger than the #50 K file diameter. In addition, root fractures, cracks, macro calcifications, internal root resorption or root canal obliteration were examined with a stereomicroscope and the teeth containing mentioned conditions were excluded from the study procedures.

Tooth Storing Procedures

The organic debris, PDL residues and remnants on the outer root surfaces of the teeth included in the study were removed using 2.5% NaOCl solution and periodontal curette and washed under tap water. Then, teeth were kept in 0.9% Physiological Saline (PS) solution until the procedures of the study.

Study Procedures

The teeth prepared as mentioned above were embedded in wax blocks as the roots to be remain inside to carry out the study procedures. Afterwards, the endodontic access cavity was prepared using high speed fissure burs. The coronal pulp tissue and residues were removed using a sharp excavator and slow speed round burs and the pulp chamber was irrigated with saline solution. The pulp tissue in root canal was removed using an appropriate size barbed broach and the root canals were irrigated with PS to remove tissue residues. The working length for each tooth was determined on periapical radiography as to be 2 mm shorter than the root apex using a #15 K-file (G-star Medical Co., Ltd., Guangdong, China). The root canal instrumentation was performed using #15 to 45 K-files. Between each file and at the end of all instrumentation (final irrigation), the root canals were irrigated with different irrigation protocols. The root canal irrigation procedures were performed with 27 gauged needle tip attached to 2 ml dental syringe (Ayset Medical Products, Adana, Turkey). The needle was placed into root canal to be 2 mm shorter than the working length and the canals were irrigated with appropriate finger pressure.

Determination of the Study Groups

28 teeth prepared for the study were randomly assigned to 4 different groups (n=7) and irrigation procedures for each group are given below.

Group 1- 5% EDTA Group: Between each file, the canals were irrigated with 10 ml of 1% NaOCl. 5% concentration of EDTA was used as the final irrigation solution and the canals were irrigated with 10 ml of 5% EDTA for 1 min. after all instrumentation procedures. Finally, the canals were dried with paper points between NaOCl and EDTA solutions.

Group 2- 10% EDTA Group: Between each file, the canals were irrigated with 10 ml of 1% NaOCl. 10% concentration of EDTA was used as the final irrigation solution and the canals were irrigated with 10 ml of 10% EDTA for 1 min. after all instrumentation procedures. Finally, the canals were dried with paper points between NaOCl and EDTA solutions.

Group 3- 17% EDTA Group: Between each file, the canals were irrigated with 10 ml of 1% NaOCl. 17% concentration of EDTA was used as the final irrigation solution and the canals were irrigated with 10 ml of 17% EDTA for 1 min. after all instrumentation procedures. Finally, the canals were dried with paper points between NaOCl and EDTA solutions.

Group 4- 1% NaOCl Group (Control Group): Between each file, the canals were irrigated with 10 ml of 1% NaOCl. 1% concentration of NaOCl was used as the final irrigation solution and the canals were irrigated with 10 ml of 1% NaOCl for 1 min. after all instrumentation procedures. Finally, the canals were dried with paper points.

SEM Analysis and Scoring the Samples

The amount of removal of the smear layer was evaluated and scored using the SEM (Carl Zeiss, Gemini SEM 500-71-08, Germany) in the present study. Prior to SEM analysis, the roots were removed from wax blocks and divided into two halves mesiodistally along the longitudinal axis using a chisel and mallet. For SEM analysis, each specimen was dehydrated in 25%, 50%, 75%, and 90% ethanol series for 25 min, and finally 100% ethanol for 60 min. The samples were point-dried and mounted on aluminum stubs. Subsequently, the specimens were sputter-coated with 135 A0 thickness gold-palladium particles. Each specimen was evaluated in 3 sections along the inner coronal, middle third and apical root surfaces. In the evaluation, it was important that the images were at the same magnification (x3.5K). The photos of the SEM images were scored blindly at 1-week intervals by the same researcher who was not aware of which sample belonged to which study groups. The assessment of what amount the smear layer was removed was made on the basis of the following criteria:[3,6]

Score 0: absence of the smear layer (majority of dentinal tubules open)

Score 1: Moderate presence of the smear layer and outline of tubules partially visible (majority of the dentinal tubules partially obliterated)

Score 2: presence of abundant smear layer (majority of the dentinal tubules complete obliterated)

Statistical Analysis

Intra-examiner validity (for 1-week interval) was assessed by Kappa statistics. Kappa value was 0.9, demonstrating good reliability. The differences between groups were analyzed with Kruskal-Wallis test, and the differences between coronal-middle-apical third of the roots were analyzed with Friedman test. Binary comparisons were performed with Dunn's test. The statistical significance level was considered as %5.

RESULTS

According to statistical comparisons, in coronal and apical region of the roots, there was no statistically significant difference between all the groups, while 17% EDTA group was statistically significantly superior compared to 1% NaOCl group in the middle third (p=0,016) (Table 1, Figure 2 to 4).

Table 1: SEM evaluation scores and the median values of all the groups in coronal, middle and apical third of the roots.

Irrigation Groups	Coronal Third	Middle Third	Apical Third	p	
5% EDTA Group	0 [0 – 1]	1 [0 – 1]	1 [0 – 2]	0.104	-
10% EDTA Group	0 [0 – 1]	0 [0 – 1]	1 [0 – 2]	0.006	Coronal-Apical: p<0.05
17% EDTA Group	0 [0 – 0]	0 [0 – 1]	1 [0 – 2]	0.039	Coronal-Apical: p<0.05
1% NaOCl Group	1 [0 – 1]	1 [0 – 2]	2 [1 – 2]	0.035	Coronal-Apical: p<0.05
p	0.061	0.016	0.068		
	-	Group 3-Group 4: p<0.05	-		

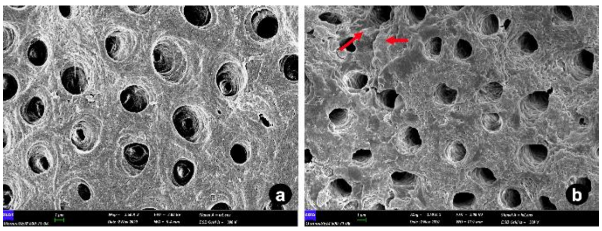

Figure 2: SEM images of the coronal third for Group 1 (a) (Score 0) and middle third for Group 2 (b) (Score 0). Note the erosive defects and peritubular dentin removal around the tubules in the second image (arrows).

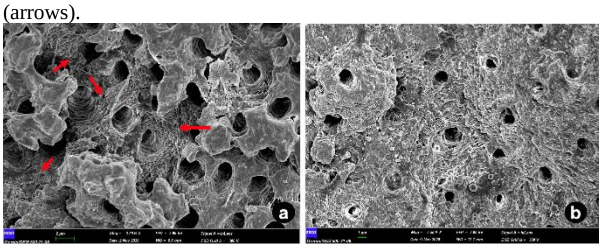

Figure 3: SEM images of the coronal third for Group 3 (a) (Score 0) and middle third for Group 2 (b) (Score 1). Note the severe erosive defects and excessive intra/peritubular dentin in the first image (arrows).

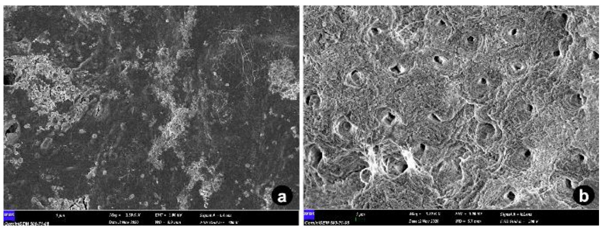

Figure 4: SEM images of the apical third for Group 4 (a) (Score 2) and middle third for Group 4 (b) (Score 1). Note the unsufficiently removed smear layer in the first image.

According to the scoring values obtained with the evaluation of the SEM images, the scores of the EDTA irrigation groups (Groups 1, 2 and 3) were found to be lower than the NaOCl group, indicating that EDTA groups removed the smear layer more effectively (Table 1, Figure 1) in all root thirds.

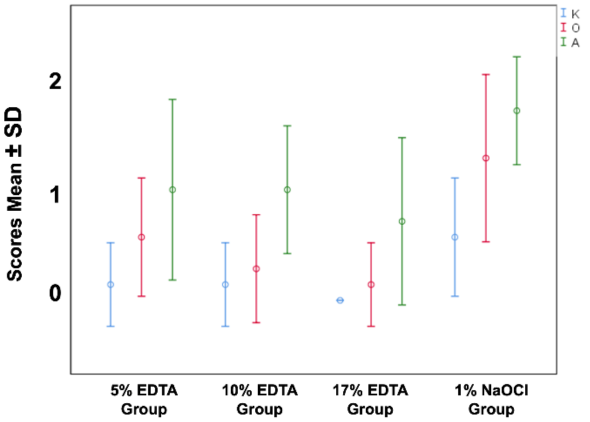

Figure 1: The distribution of SEM evaluation scores of all the groups in coronal, middle and apical third of the roots.

In the evaluation of the root surfaces, the smear layer was more effectively removed in coronal third compared to apical third with the statistically significant difference in 10% EDTA group, 17% EDTA group and 1% NaOCl group (p=0.006, p=0.039, p=0.035, respectively) (Table 1, Figure 2 to 4).

Additionally, erosiv defects, excessive intertubular and peritubular dentin removal was mostly seen in 10% and 17% EDTA group (Figure 2b and 3a) (more in 17%). However, mentioned defects were not observed in 5% EDTA and 1% NaOCl group. Also, erosive defects were mostly found in the coronal and middle thirds, and not detected in apical third.

DISCUSSION

The removal of the smear layer in root canals of the primary teeth is an important factor that increases the final success of the treatment.[2,5,7,14,19] Because the smear layer obliterates the dentinal tubules and creates a barrier between canal system and dentin surfaces, it negatively affects the adaptation of canal sealers and the effectiveness of irrigants and medicaments.[14-16] The success of pulpectomies applied with smear layer removal has also been confirmed in clinical studies. It was reported that pulpectomy of primary teeth with smear layer removal showed higher success rates at the end of the follow-up period in clinical trials.[7,19] In addition to the disadvantages of the smear layer, accessory canals in primary roots and the physiological root resorption process cause the unsuccess conditions in endodontic treatment.[14,20-22] Moreover, the difficulties of accessing these areas such as mentioned anatomical variations, ramifications, lateral branches and incomplete seal of the antibacterial filling material increase the need for removal of this layer, especially in primary molar teeth which have more narrow and divergent root canals.[5,6,8,14] Therefore, it was aimed to evaluate the effects of different irrigation materials on smear layer removal in primary teeth in this study.

NaOCl is the most commonly used irrigation solution in pediatric endodontic treatments.[8,23,24] NaOCl, which acts by disrupting many vital functions in microbial cells, is a potent antimicrobial agent even when used at 0.5% concentration. Although the use of NaOCl appears to be in the range of 1-5% concentration[25], it is toxic in case of its extruding into periapical tissues. Especially due to the risk of damaging the permanent tooth follicle, peripheral tissues and oral mucosa[24] it is mostly recommended to use 1% concentration in primary teeth.[25] However, due to its limited effects in smear layer removal, it has been suggested that NaOCl should be combined with EDTA.[3,8,23,24] EDTA, which effectively removes the inorganic part of the smear layer, may cause the excessive removal of the peritubular and intratubular dentin and erosive defects as a result of prolonged exposure with the dentinal surfaces.[2,6,8,26] Although 17% concentrations of EDTA are also used in some primary teeth studies,[3,12,23] it was also observed the use of 10% and 14% forms.[2,5,6] Also, the erosive potential of even 10% EDTA in addition to 17% concentrations has been determined in primary teeth.[2,6] Indeed, Demirel *et al.*[6] reported that the safer acids/irrigation protocols should be used due to erosive effects of EDTA even with 10% use. Therefore, in this study, it was aimed to investigate the uses of EDTA at concentrations less than 17% and 10%.

In the literature, there is limited information about the use of EDTA <10% dilutions in primary teeth. Therefore, in this study, in addition to 17% and 10% EDTA, 5% EDTA was also included to the study procedures, with the prediction that the use of <10% EDTA will reduce the erosive defects and offer the clinician safety use.

It is known that the root canal morphology are quite variable especially in primary molars, and exist numerous ramifications, accessory and lateral canals and branches.[14,20-22,27] In order to ensure that the mentioned variations do not affect the results and to provide the standardization, the use of single rooted upper primary incisors was preferred in the present study. In addition, the increasing opening/widening of apical foramen with physiological root resorption[28] and the inaccessibility problems to apical region are observed in primary teeth.[2,5,6] These conditions of the apical region create differences in smear layer removal efficiency in apical third. Therefore, as in the other studies[2,6,10,16,23] the internal root surfaces were evaluated in 3 separate sections as coronal, middle third and apical in the present study.

As a result of the present study, in coronal third of the roots, the statistically significant differences were not found between all the irrigation groups. However, EDTA groups was found to be more effective than NaOCl in smear layer removal according to smear removal scores. Hariharan *et al.*[2] reported that 10% EDTA+5.25% NaOCl removed the smear layer more effectively than 5.25% NaOCl. Similarly, Demirel *et al.*[6] reported that 10% EDTA + 1% NaOCl group was superior than 1% NaOCl in smear layer removal. However, the authors reported that the statistical difference was observed in coronal third, in contrast to the present study. Also, Ximenes *et al.* [23], stated that there was no statistical difference between 17% EDTA+1% NaOCl irrigation and 1% NaOCl in coronal third similar to present study. However, authors emphasized that 17% EDTA+1% NaOCl solution could not remove the smear layer effectively and the dentinal tubules were not always visible. On the other hand, EDTA solutions causes erosive defects in inner dentinal surfaces of the roots.[2,6] Hariharan *et al.*[2] reported that in 10% EDTA+5.25% NaOCl irrigation, erosion of peritubular dentin, and break down in intertubular dentin and conjugation of dentinal tubules were detected in coronal thirds. Similarly, Demirel *et al.*[6] reported that erosive defects were observed in coronal third in 10% EDTA+1% NaOCl protocol. In the present study, erosive defects were observed in 10% and 17% EDTA groups, more in 17% in coronal third. However, erosive defects or excessive removal of intra/peritubular dentin were not observed in 5% EDTA and 1% NaOCl groups. Therefore, based on obtained results, It is possible to recommend the use of 5% EDTA, which is as effective as NaOCl and other EDTA groups in terms of smear removal efficiency and which might considered to be safer due to its less erosive defects potential on the root surfaces.

In the middle third of the roots, 17% EDTA group was superior than 1% NaOCl with statistical significance in smear layer removal ($p<0.05$). On the other hand, EDTA groups was found to be more effective than NaOCl according to smear layer removal scores. Hariharan *et al.*[2] and Demirel *et al.*[6] reported that the use of 10% EDTA+5.25% NaOCl and 10% EDTA+1% NaOCl, respectively, removed the smear layer more effectively than single use of NaOCl in the middle third. Also, Toyota *et al.*[5] reported that 14% EDTA removed the smear layer more effectively than 5% NaOCl in middle third. Similar to the coronal third, erosive defects and excessive removal of inter/peritubular dentin were most observed in 17% EDTA and 10% EDTA groups (more in 17%), respectively, but not observed in 5% EDTA and %1 NaOCl groups in the present study. Toyota *et al.*[5] reported that severe erosion of the intertubular and peritubular dentin was detected in the use of 14% EDTA in middle third. The authors also reported that erosive defects were increased by the ultrasonic equipments which the irrigation solution was activated for to be more effective to the dentin surfaces. However, Pitoni *et al.*[3] reported that 17% EDTA+1% NaOCl removed the smear layer more effectively than 1% NaOCl, but not emphasized that any signs of erosion on the root surfaces. Hariharan *et al.*[2] and Demirel *et al.*[6] reported that the findings of the erosive defects were observed in the middle third as in the coronal, in 10% EDTA+5.25% NaOCl and 10% EDTA+1% NaOCl irrigations, respectively. As with the coronal third, it is possible to recommend the use of 5% EDTA, which is as effective as NaOCl and other EDTA groups in terms of smear removal efficiency and is safer due to its less erosive defects potential.

In apical thirds, although EDTA groups removed the smear layer more effectively than NaOCl, no statistically significant difference was observed between the groups. In other studies mentioned above[2,6], it has been stated that EDTA solutions have more effective scores than NaOCl in smear layer removal. Similar to the findings of this study, Toyota *et al.*[5] reported that although the findings related more effective smear removal scores in the use of 14% EDTA, significant difference was not observed between 14% EDTA and 5% NaOCl at apical third. In this study, it was observed that the smear layer removal scores were higher (lower smear layer removal efficiency) in apical thirds in all irrigation groups. This finding was attributed to irrigation agent did not reach the apical, since the needle tip was positioned 2 mm more coronally than the apex and the solution was applied with the limited pressure due to avoiding the extrusion into periapical area. Moreover, no erosive defect or excessive dentin removal was found in apical, which was attributed to the inaccessibility of the irrigation solution to the apical dentinal walls for above-mentioned reasons, regardless of the irrigation material. In apical third, it may be beneficial to recommend the use of 5% EDTA due to avoiding the extrusion of the material into periapical tissues and providing periapical safety.

The another finding of this study is that the removal efficiency of the smear layer in apical third was significantly lower compared to coronal third in use of 1% NaOCl, 10% and 17% EDTA groups. Lower smear layer removal efficiency has been attributed to reaching problems of the irrigants to apical region, therefore, the use of special needles (with lateral opening) or ultrasonic irrigation systems that provide better access to the apical can be recommended.[5] In this regard, it has been reported that ultrasonic generators are more effective than conventional needle irrigations.[29] Toyota *et al.*[5] reported that the use of ultrasonic equipment in 14% EDTA irrigation resulted in statistical difference in smear layer removal efficacy in the apical portion of the primary teeth. However, the authors also reported that the erosive defects were increased by using an ultrasonic generator.

Additionally, there are more organic materials and water in dentin structure of primary teeth than in permanent teeth, resulting in decreasing of hardness.[5] Therefore, dentin structure of primary teeth is more reactive to chemical irrigants and medicaments than permanent teeth dentin.[5,30] These mentioned differences cause the smear layer to be removed more easily in primary teeth than permanent teeth. However, this increases the possibility of erosive potential risk in the root dentin of primary teeth.[5] In this regard, it has been reported that dentinal loss caused by erosion weakens the root structure even in permanent teeth, therefore, all the care should be taken in the use of EDTA in primary teeth.[5,26,31] Moreover, it will be safer to use lower concentrations of irrigants, due to their toxic effects in case of extrusion to the periapical area and erosive potentials on dentinal surfaces as the concentrations of irrigants increase. On the other hand, considering the toxicity of the irrigation materials, the use of EDTA is more appropriate option than preferring NaOCl. Indeed, Botton *et al.*[32] reported that in primary teeth pulpectomies, even a high EDTA concentration such as 17% EDTA+1% NaOCl provides more cell viability and lower toxicity than 1% NaOCl. Therefore, based on both the results of this study and the conditions discussed above, it may be more appropriate to recommend the use of EDTA in primary teeth dentin due to the fact less toxicity compared to NaOCl and its superior efficacy in smear removal. However, due to the destructive erosive effect of the increasing concentrations of EDTA on root canal dentin and the potential risk of toxicity, especially due to increasing apical opening due to physiological root resorption process in primary teeth, the use of 5% EDTA -which removes the smear layer with the same efficacy compared to other higher EDTA concentrations and has less erosive potential- may be recommended.

CONCLUSIONS

Within the limitations of the present in-vitro study, it is possible to recommend "5% EDTA+1% NaOCl" protocol in primary teeth pulpectomies due to smear layer removal performance as effectively as other EDTA solution groups. Moreever, this irrigation protocol should be preferred due to less erosive defect in root dentin surface compared to high concentrations of EDTA groups and due to its safety use because of its low concentration in case of extrusion to the periapical area. In addition, further clinical studies are required to verify the results obtained in the present study and investigate the effectiveness of special needles and ultrasonic systems to increase the reaching of irrigants to apical region.

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CONFLICTS OF INTEREST STATEMENT

No potential conflict of interest was reported by the author.

Süt Dişlerinde Farklı EDTA Konsantrasyonlarının Smear Tabakasını Uzaklaştırma Etkinliği: Bir SEM Çalışması

ÖZ

Amaç: *Bu çalışma farklı konsantrasyonlardaki etilendiamin tetraasetik asitin (EDTA), süt dişlerinde smear tabakasının uzaklaştırılmasına olan etkilerini tarama elektron mikroskopu (TEM) ile değerlendirmeyi amaçlamaktadır.* ***Gereç ve Yöntemler:*** *Bu çalışma 28 adet çekilmiş üst süt kesici diş ile gerçekleştirilmiş ve bu dişler %5, %10, %17 EDTA ve %1 sodyum hipoklorit (NaOCl) olacak şekilde dört ana gruba (n=7) atanmıştır. Kök kanal irrigasyon prosedürlerinin ardından, kök kanal yüzeyleri (koronal, orta ve apikal) SEM ile taranmış ve smear tabakası uzaklaştırma skorları kaydedilmiş ve karşılaştırılmıştır. Sonuçlar Kruskal–Wallis, Friedman ve Dunn testleri kullanılarak analiz edilmiştir.* ***Bulgular:*** *Tüm kök bölümlerinde, EDTA gruplarının smear tabakasını NaOCl'den daha efektif uzaklaştırmasına rağmen, sadece orta üçlüde %17 EDTA ile %1 NaOCl arasında istatistiksel anlamlı fark gözlenmiştir (p<0,05). Smear tabakası, birçok grupta (%10 EDTA, %17 EDTA ve %1 NaOCl) koronalde apikale göre daha efektif uzaklaştırılmıştır (p<0,05). Eroziv defektler en çok %17 EDTA, daha az olarak da %10 EDTA grubunda görülmüş ve bu bulgulara %5 EDTA ve %1 NaOCl gruplarında saptanmamıştır.* ***Sonuç:*** *Smear tabakası uzaklaştırılmasında, NaOCl ve yüksek konsantrasyondaki EDTA grupları ile benzer etkinlik sunması, düşük eroziv potansiyeli ve periapikal güvenlik için düşük konsantrasyonu nedeniyle süt dişi kanal tedavilerinde irrigasyon solüsyonu olarak %5 EDTA kullanımını önermek mümkündür.* ***Anahtar Kelimeler:*** *EDTA, kök kanalı sulayıcıları, smear tabakası.*

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Original research

ONE-YEAR CLINICAL EVALUATION OF CLASS II INDIRECT PORCELAIN, HYBRID AND COMPOSITE BLOCKS RESTORATIONS

ABSTRACT

Objectives: This clinical study aims to evaluate the clinical performance of indirect class II restorations made using three different CAD/CAM blocks.

Materials and Methods: A total of 60 indirect class II restorations were performed in 41 patients using Cerasmart (GC Dental Products Europe, Leuven, Belgium) composite, IPS e.max CAD (Ivoclar Vivadent, Schaan, Liechtenstein) ceramic and Vita Enamic (Vita Zahnfabrik, Bad Sackingen, Germany) hybrid blocks. The restorations were evaluated for 13 different criteria using modified FDI criteria at the end of one week, six months, and one year. Data were analyzed using the Chi-square, Fischer and Mc Nemar tests.

Results: Vita Enamic indirect restorations showed a statistically significant difference in terms of color matching criteria from Cerasmart and IPS e.max CAD using groups in all follow-up periods ($p<0.05$). There was no significant difference between the groups in terms of other criteria ($p>0.05$).

Conclusion: Cerasmart and IPS e.max CAD restorations showed better color matching than Vita Enamic restorations.

Keywords: CAD/CAM, ceramic block, hybrid block, indirect restoration.

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INTRODUCTION

The demand for posterior aesthetic restorations as an alternative to amalgam has been increasing for the last 25 years.[1] Today, numerous different techniques are used in the construction of posterior restorations[2], and the most commonly used techniques are direct composite restorations. However, when direct composite restorations are used in the posterior region; abrasion, fracture, polymerization shrinkage due to the deterioration of the edge compatibility, followed by microleakage, secondary caries and postoperative sensitivity are disadvantages.[3] In order to prevent these problems, inlay/onlay techniques have been developed by using metal, composite or ceramic materials.[2]

If a cavity is large enough to be contraindicated in direct restorative techniques and an aesthetic restoration is considered; composite, ceramic, and hybrid indirect restorations are indicated. Since these restorations are prepared outside the mouth, the polymerization shrinkage is no longer a problem. Occlusal anatomy and proximal contact can be established more successfully. Besides, they have better physical properties than direct composite restorations because they are prepared under more ideal conditions.[1]

The restoration of modern materials with traditional production techniques has not shown sufficient clinical success, leading to the development of new production techniques. The most modern system used today is the CAD/CAM system (computer-aided design/computer-aided manufacturing).[4] The CAD/CAM system used in the clinic provide clinicans with a choice of different restorative materials to suit their cases.[5] Industrially manufactured standard-manufactured scrapable CAD/CAM blocks can be composite, ceramic, or a hybrid structure that includes some properties of both materials.[6]

Different methods such as the FDI evaluation system, the CDA evaluation system, and the USPHS evaluation system can be used for clinical evaluation of indirect restorations.[7] The USPHS criteria have three rating scores, while the FDI has five scores, which makes FDI assessments more sensitive.[8] FDI criteria were approved by the scientific committee of the FDI World Dental Federation in 2007 as criteria and classification, and in 2008 they were accepted as the standard criteria for the evaluation of restorative materials or operative techniques as clinical research. The use of FDI criteria in clinical cases can be modified in terms of criteria and scoring, thus FDI criteria offer different options to researchers.[9]

In the literature, there are in-vitro studies investigating the physical and mechanical properties of CAD/CAM blocks of different structures, while studies evaluating the clinical performance of these materials are not sufficient. Therefore, in the present study, we aim to evaluate the one-year clinical performance of indirect class II restorations made of Cerasmart composite block, IPS e.max CAD ceramic block and Vita Enamic hybrid blocks and by using modified FDI criteria. The null hypothesis of this study is that there would be no significant differences in the clinical performance among the indirect restorations made with these three different blocks.

MATERIALS AND METHODS

Study Design

The study was approved by the Erciyes University Clinical Research Ethics Committee, Turkey (Decision No: 2017/452). The study design was a controlled randomized clinical trial and was registered at www.clinicaltrials.in.th (TCTR identification No. TCTR20191212002), and this study follows CONSORT guidelines. The registration of the records of all patients (n=41) who had received indirect restorations (n=60) from a total of 800 patients were made during the period in February 2018 to August 2018. Patients selected from ordinary patients who were referred to the dental clinic of the Department of Restorative Dentistry, Erciyes University, and were treated by a dentist with experience of restorative dentistry. The randomization of restorative materials was done using a table of random numbers.[10] The indication for treatment was the replacement of failed restorations or primary caries class II preparations on premolar and molar teeth. A list of the inclusion and exclusion criteria adopted in the study is provided in (Table 1).

Table 1. List of inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Vital teeth	Non-vital teeth
Absence of clinical signs and symptoms of periapical pathology	Patients with parafunctional habits
The presence of teeth in the proximal contact of the restoration	Teeth with cusp loss
Teeth being in occlusion to antagonistic teeth	Teeth subjected to direct pulp-capping
Patients who agreed to attend regular checks	Severe periodontal problems

All patients were males and females at least 18 years of age with regular oral hygiene. The flowchart for patient selection and treatment protocol is given in Figure 1.

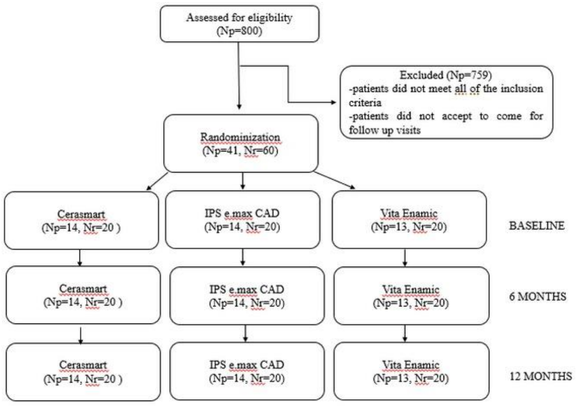

Figure 1. Study Flowchart, Np: number of patients, Nr: number of restorations

Patients were informed about the need for good gingival health and were educated in effective plaque control. Both preoperative and post-operative photographs were taken for each patient in order to evaluate changes in appearance (Fig. 2-4). Gingival bleeding indexes of all patients were evaluated.[11]

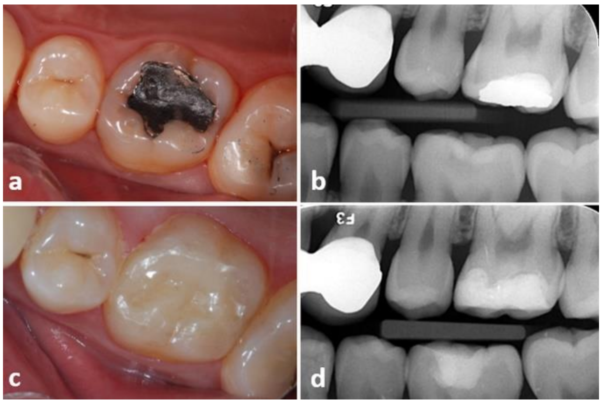

Fig. 2 (a) A maxillary left first molar, with caries recurrence on an occlusal amalgam restoration **(b)** Bite-wing radiograph of the maxillary left first molar **(c)** 1 year follow-up of cerasmart indirect restoration **(d)** Bite-wing radiography of cerasmart indirect restoration

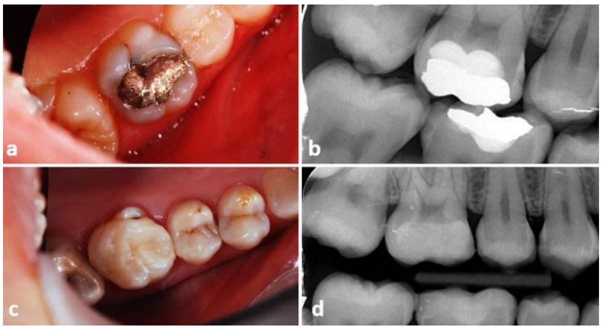

Fig. 3 (a) A maxillary right first molar, with caries recurrence on an occlusal amalgam restoration **(b)** Bite-wing radiograph of the maxillary right first molar **(c)** 1 year follow-up of IPS e.max indirect restoration **(d)** Bite-wing radiography of IPS e.max indirect restoration

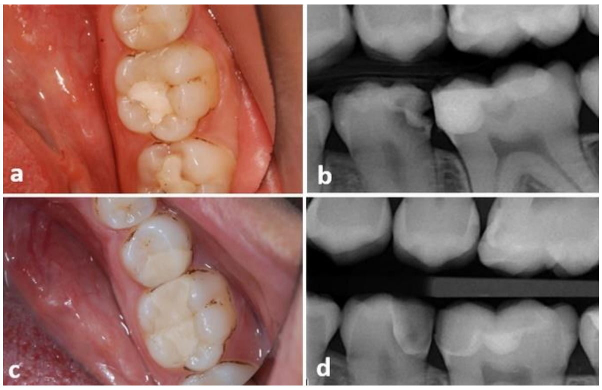

Fig. 4 (a) A mandibular left second premolar and first molar, with caries recurrence on an occlusal composite restoration **(b)** Bite-wing radiograph of the mandibular left second premolar and first molar **(c)** 1 year follow-up of Vita Enamic indirect restoration **(d)** Bite-wing radiography of Vita Enamic indirect restoration

Tooth Preparation

Materials, manufacturers, chemical compositions, and batch numbers of main materials used in this study are listed in Table 2. Since the restoration of vital teeth was planned, treatment was started with the removal of the old restorative material and/or the caries under local anesthesia.

Table 2. Restorative materials used in study

Material	Manufacturer	Compositions	Batch number
IPS e.max CAD	Ivoclar Vivadent (Schaan, Liechtenstein)	SiO_2 (57-80%), Li_2O (11-19%), K_2O (0- 13%), P_2O_5 (0.5-11%), ZrO_2 (0-8%), ZnO (0- 8%), Al_2O_3 (0-5%), MgO (0-5%), oxide pigments (0-6%)	W36995
Cerasmart	GC (Leuven, Belgium)	Bis-MEPP, UDMA, DMA, weight %71 silika (20 nm), baryum cam (300 nm) nano partikülleri	1411041
Vita Enamic	Vita-Zahnfabrik (Bad Sackingen, Germany)	Ceramic: SiO_2 (58-63%), Al_2O_3 (20-23%), Na_2O (6-11%), K_2O (4-6%), B_2O_3 (0.5-2%), CaO (<1%), ZrO2 (<1%), Polymer: UDMA, TEGDMA	61280
Silan	Ultradent (Cologne, Germany)	Etanol, 3-trimetoksipropil metakrilat,10-MDP (MDP), sülfid metakrilat	BG3TD
RelyX U200	3M ESPE (St. Paul, MN, USA)	Base paste: fiberglass, phosphoric acid methacrylate esters, TEGDMA, silano treated sílica and sodium persulfate.	3324998
Telio CS Onlay	Ivoclar Vivadent (Schaan, Liechtenstein)	The monomer matrix consists of methacrylates (by weight) 36.3%). Dispersed silicon dioxide and copolymers (62% by weight. Fluoride (1500) ppm), catalysts, stabilizers and pigments (0.6% by weight)	W98823

All walls of the cavity were prepared using onlay bur (Frank Dental GmbH, Gmund, Germany) at an angle of 6-10º with the long axis of the tooth. Internal angles were smoothed to reduce the stress concentration, and contacts at the marginal ridge were avoided. The preparation of margins were not bevelled but prepared as butt joint form. A light-curing composite filling material (i-FLOW; i-dental, Siauliai, Lithuania) was then used to block out defectrelated undercuts and to maintain a standardized preparation protocol.

After the preparation of the retraction cord (AtriaPak, Seoul, South Korea) was placed in the gingival sulcus to remove the gum from the cavity. Impressions were made using a silicone impression material (Heavy and Light Body Zetaplus, Zhermack, Bovazeccihino, Italy) using an individually designed impression tray. Temporary restorations were then made chairside using a photopolymerized resin composite material (Telio CS Onlay, IvoclarVivadent, Schaan, Liechtenstein).

Laboratory Operations

After the measurements were sent to the laboratory, the Dentalwings (DWOS, Montreal, Canada) the device was scanned. The scanned measurements were transferred to a computer, and restorations were designed in exoCAD program. Designed restorations were transferred to Dentaswiss DS1300 (Biodenta Swiss, Berneck, Switzerland) and milled from the blocks placed in the device. One dental technician fabricated all indirect restorations.

Indirect ceramic restorations were obtained by milling only IPS e.max CAD blocks in the CAD/CAM device are present in the blue/purple precrystallized phase at this stage while being crystallized for 10 minutes at 850 ° C in the Programat EP 5010 (Ivoclar Vivadent, Schaan, Liechtenstein), the furnace in the laboratory. Finally, a glaze layer was applied.

Placements of the Indirect Restorations

Before permanent restorations were placed in teeth, the temporary filling material was removed from the tooth and the cavity was cleaned with alcohol. Each type of material was treated in accordance with the manufacturers' instructions before the cementation. The internal surfaces IPS e.max CAD and Vita Enamic restorations were etched with 9.5% hydrofluoric acid (Porcelain Etch, Ultradent, South Jordan, UT, USA) and Cerasmart restorations were abraded with 50 μm aluminium oxide (KaVo, Biberach, Germany), using an intraoral sandblasting device (KaVo RONDOflex plus 360, Biberach, Germany). The tip of the micro etcher was kept 5 cm away from the surfaces and applied for 10 s at 2.0 bar pressure.[12] Restorations were subsequently rinsed under running water to remove the debris (20 s), cleaned in an ultrasonic device (2 mins), and air-dried.

All restorations were treated with a silane coupling agent (Ultradent, South Jordan, UT, USA) for 60 seconds and air-dried. Each tooth was isolated with a cotton roll and saliva suction device, there was no need to use a rubber dam. Also, the cavity was isolated with the help of the sectional matrix (Standard matrix, Palodent, Dentsply, York, PA, USA) and wedge. Then, phosphoric acid was applied to enamel surfaces for 30 seconds washed, and dried.

All indirect restorations were cemented by a self-adhesive resin cement (RelyX U200, 3M ESPE, St. Paul, MN, USA). The light-curing operation was made (VALO, Ultradent, South Jordan, UT, USA) for 40 seconds from each aspect of the restoration.

Centric and eccentric occlusal contacts were adjusted with diamond finishing burs before Soflex spiral disks (3M ESPE; St Paul, MN, USA). Overhangs were removed and polished in the same way, proximally with interdental polishing strips (GC Epitex strips, Leuven, Belgium).

Evaluation of Restorations

Indirect restorations were evaluated by an experienced dentist after one week, six months and one year. Bite-wing radiographs and photographs were taken from restored teeth in each control session. Modified FDI criteria were used to evaluate restorations.[9] There were three evaluation categories (aesthetics, function and biological). A blinded and calibrated experienced dentist performed follow-up evaluation.

Statistical Analysis

The distribution of variables was measured by the Kolmogorov Smirnov test. The Chi-Square test was used for the analysis of independent qualitative data and the Fischer test was used when the Chi-Square test conditions were not met. The McNemar test was used to evaluate the secondary qualitative data. The SPSS 22.0 program was used in the analyses.

RESULTS

A total of 41 patients (27 females, 14 males) aged 18-47 years (mean 29,27 ± 9,14) participated in the study. In 41 patients, 21 premolars (mandible 9, maksilla 12), 39 molar (mandible 22, maksilla 17) indirect restorations were applied to a total of 60 teeth. When the gingival index was evaluated, eight patients had bleeding and 33 patients had no bleeding. All patients were evaluated at one week, six months and one year.

At the end of one year, clinical failure was seen in one restoration due to the periodontal response in the Vita Enamic group. The success rate of Cerasmart and IPS e.max CAD indirect restorations after 12 months was 100%, while that of Vita Enamic restorations was 95%. The results for baseline and follow-up evaluation are summarized in Table 3.

Table 3. Results of the clinical evaluation at baseline and after 6 and 1 year

		Cerasmart			IPS e.max CAD			Vita Enamic		
		Baseline 1/2/3/4/5	6 months 1/2/3/4/5	1 year 1/2/3/4/5	Baseline 1/2/3/4/5	6 months 1/2/3/4/5	1 year 1/2/3/4/5	Baseline 1/2/3/4/5	6 months 1/2/3/4/5	1 year 1/2/3/4/5
Esthetic	Surface gloss	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0
	Surface/marginal staining	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0
	Color match	20/0/0/0/0a	20/0/0/0/0x	20/0/0/0/0α	20/0/0/0/0a	20/0/0/0/0x	19/1/0/0/0α	6/14/0/0/0[b]	6/14/0/0/0[y]	8/12/0/0/0[β]
	Anatomic form	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0
Functional	Fractures and retention loss	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	19/1/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0
	Marginal adaption	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	17/1/2/0/0	20/0/0/0/0	20/0/0/0/0	19/1/0/0/0
	Wear	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0
	Contact point	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0
Biological	Patient satisfaction	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0
	Postoperative hypersensitivity	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	19/1/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0
	Caries/erosion/ abfraction	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0
	Tooth integrity	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0	20/0/0/0/0
	Periodontal response	20/0/0/0/0	19/0/1/0/0	18/0/1/1/0	20/0/0/0/0	20/0/0/0/0	18/0/2/0/0	20/0/0/0/0	20/0/0/0/0	17/1/2/0/0

a, b : Evaluation of baseline comparisons of Cerasmart, IPS e.max CAD and Vita Enamic restorations
x, y : Evaluation of 6 months comparisons of Cerasmart, IPS e.max CAD and Vita Enamic restorations
α, β : Evaluation of 12 months comparisons of Cerasmart, IPS e.max CAD and Vita Enamic restorations

Esthetic Characteristics

There were no changes for the surface gloss, surface/marginal staining, and anatomic form criteria at the follow-up evaluation, compared to the baseline evaluation ($p>0.05$). In the IPS e.max CAD group, one restoration had reduction for criteria color match from clinically excellent (category 1) to clinically good (category 2) at 12-month evaluation. In the Vita Enamic group, 14 indirect restorations after one week and six months and 12 indirect restorations after one year were evaluated as clinically good (category 2). The Vita Enamic group was significantly different from other groups in all follow-up periods ($p<0.05$).

Functional Characteristics

There was no change for marginal adaptation, wear and contact point criteria at the follow-up evaluation, compared to the baseline evaluation ($p>0.05$). In the IPS e.max CAD group, one restoration showed fracture and retention loss and evaluated as clinically good (category 2) in the follow-up evaluation.

Biological Characteristics

At the follow-up evaluation, 100% of the patients were satisfied with their restorations (category 1). At twelve months follow-up evaluation revealed a small amount of post-op hypersensitivity for a short time (category 2) in one restoration in the IPS e.max CAD group. There was no recurrence of initial pathologies, like caries, erosion, or abrasion at the follow-up evaluation (category 1). There was no change for tooth integrity criteria at follow-up evaluation, compared to the baseline evaluation. At one year evaluation, one restoration in the Cerasmart group was scored as '4', one restoration as '3', two restorations in the IPS e.max CAD group were '3' and two restorations in the Vita Enamic group were '3'. Since the score '4' required treatment, the patient was referred to the periodontology clinic ($p>0.05$).

DISCUSSION

In this study, one-year clinical performances of indirect restorations to posterior vital teeth using three different CAD/CAM blocks (Cerasmart, IPS e.max CAD, Vita Enamic) with different contents were evaluated, and no statistically significant difference was found except for color matching. Therefore, our initial hypothesis was partially accepted.

Nowadays, increasing demands for aesthetic restorations, many discussions on possible side effects of dental amalgam, and problems (polymerization shrinkage, microleakage and secondary caries) with the use of composite resins for extensive restorations in posterior teeth have led to an increased interest in indirect posterior teeth restoration.[13] Özakar-İlday *et al.*[14] performed three year follow-up study of 60 direct and indirect composite restorations and found that indirect restorations showed better clinical results than direct restorations. As seen in clinical studies, indirect restorations in the posterior region showed higher success than direct restorations. Therefore, in our study, we preferred to perform indirect restorations to posterior teeth with class II cavities that require restoration.

Indirect restorations can be produced in different ways. Conventional indirect restorations include many procedures such as measuring, occlusal recording, preparing a working model from plaster, shaping wax or restorative materials, waxing, and firing. Besides, dental CAD/CAM systems for indirect restorations have shown rapid progress and now are used worldwide.[15] CAD/CAM systems are advantageous in that restorations, for instance they can be performed in a single session.[16] Hickel and Manhart[17] reviewed annual failure rates of posterior restorations in the dental literature and reported this rate as 0-11.8% for conventional composite indirect restorations, 0-4.4% for CAD/CAM indirect restorations.

The increase in the aesthetic expectations of patients have led to the development of full ceramic restorations as well as the development of other metal-free dental materials with different mechanical and optical properties used with CAD/CAM. Ceramic and hybrid blocks are used in CAD/CAM systems. In recent years, manufacturers have introduced the CAD/CAM material group called “hybrid ceramics” with the claim that they reflect the positive properties of ceramic and composite materials. In various studies, it is emphasized that these materials having ceramic and polymer double web structures can be processed more efficiently, are less brittle, and provide better edge compatibility.[18] Nowadays, hybrid nano ceramic and resin infiltrated ceramic materials are available on the market.[19] Della Bona *et al.*[20] reported that Vita Enamic's(a polymer infiltrated ceramic structure material) mechanical properties, which has been used in the study, were average of ceramic and composite materials. Awada *et al.*[21] compared Vita Enamic, Lava Ultimate, Cerasmart, IPS Empress CAD, Vita Block Mark II, and Paradigm MZ100 CAD/CAM blocks' mechanical properties (bending modulus, bending strength, and flexibility modulus) and the edge compatibility. In general, they stated that polymer-based materials outperform ceramic materials in bending tests. In the study, it was stated that the difference observed between the materials in terms of elastic properties was the resin component and the resin component was found to help reduce the brittleness of the material. For these reasons mentioned above, we preferred to use ceramic and hybrid blocks to compare the clinical behavior of different CAD/CAM blocks in our study.

In the present study, self-adhesive resin cement RelyX U200 was used in cementation of 60 indirect restorations and no cement-induced failure was observed. Similar to our study, Azevedo *et al.*[22] 42 adhered indirect restorations with self-adhesive cement for one year and reported that there was no failure at the end of one year. In contrast in a study by Kim *et al.*[23], two self-adhesive cement compared with traditional resin cement and traditional resin cement has shown higher bond strength than self-adhesive resin cements. The reason for this difference may appear due to the application of acid to enamel before applying self-adhesive resin cement.[24]

In clinical follow-up studies, as well as how the restorations are performed, the criteria according to which the restorations are evaluated are critical. In a study evaluating restorations of primary teeth, FDI criteria and 'United States Public Health Service' (USPHS) criteria (known as RYGE criteria), found that the FDI criteria give more accurate results in determining the differences for evaluation of composite resin restorations made in primary teeth.[9] In another study, 36-month evaluations of Scotchbond Universal adhesive were made according to FDI and modified USPHS criteria, and it was found that FDI criteria were more sensitive in detecting small changes.[8]

There was no statistically significant difference between the groups (surface gloss, surface/marginal coloring, anatomical form) except the color matching of the esthetic criteria in our study. Stawarczyk *et al.*[25] compared translucency values in experimental groups with Vita Enamic and Cerasmart materials and found lower translucency values of the Vita Enamic group. This is because Vita Enamic has a large particle size and a large number. In another study using different blocks (CELTRA Duo, Vita Enamic, IPS Empress, Lava Ultimate, IPS e.max CAD, Vita Mark II), Vita Enamic (VITA Zahnfabrik) showed the lowest translucency values. This is due to fact that Vita Enamic contained higher amounts of Al_2O_3 (about 20-23% by weight) than other blocks.[21] In our study, we associated the reason for low color matching in the Vita Enamic group with the above results.

In short-term clinical follow-up studies, the most common cause of failure was reported as restoration fracture and retention loss.[26] In our study, there was no loss of retention, and one fracture occurred in the restoration. Tagtekin *et al.*[27] reported that there was a loss of retention in one restoration after 35 inlay/onlay ceramic restorations on canal-treated teeth that took 6 months of work. They cemented the same restoration again and there was no restoration loss occurred at the end of two years. In the one of the IPS e.max CAD restorations performed in our follow-up study, only fracture requiring correction was observed, which was attributed to the fine finishing of the restoration in that area, and groups were found to be 100% successful.

Indirect restorations to provide an ideal marginal adaptation leads to a less gingival irritation and also less cements dissolution.[28] Therefore, the possibility of microleakage and plaque accumulation decreases, the likelihood of encountering unwanted conditions such as secondary caries, periodontal disease, postoperative sensitivity and marginal discoloration also decreases.[28,29] Hayashi *et al.*[30], as a result of clinical follow-up of 45 inlay restorations using traditional bakable ceramics, observed marginal adaptation of five restorations at the end of two years and six restorations at the end of four years. They reported that marginal adaptation was impaired in a total of 11 restorations (24%) at the end of eight years of control. On the contrary when the restorations performed within the scope of our study which were evaluated in terms of marginal adaptation criteria, after 12 months controls, the Cerasmart group showed 100% success, and acceptable disturbances were seen in three restorations in the E.max group and one restoration in the Vita Enamic group.

Patient satisfaction results were excellent at 12 months of clinical follow-up of all restoration groups. These results show that CAD/CAM restorations are more satisfactory for the patient. Despite the problem of color matching in Vita Enamic restorations, high patient satisfaction suggests that patients do not have high esthetic expectations in posterior restorations.

It is not uncommon for patients who undergo adhesive restorative procedures to experience postoperative sensitivity. Sjögren *et al.*[31] used Vita Mark I and Vita Mark II in their study using CAD/CAM ceramics reported post-operative sensitivity in 10 of 72 patients. Fasbinder *et al.*[32] reported that they had mild postoperative sensitivity in 92% of Vita Mark II onlays in 13% of them at the end of one week and in 4% of them at the end of the second week, but that no patient had postoperative sensitivity at the end of one month. Our study showed similarity with the literature in terms of post-operative sensitivity and when the teeth we restored were evaluated in terms of post-operative sensitivity. One restoration in the IPS e.max CAD group showed slight sensitivity in one week controls, while no restoration sensitivity was observed in the Cerasmart and Vita Enamic groups. No restoration sensitivity was observed in the six month and 12-month controls and all groups were considered 100% successful. The high success rate may be related to our attention to study protocols while preparing the cavity and to the low sensitivity potential of self-adhesive resin systems.

Secondary caries is one of the most important reasons for the failure of dental restorations and has a role in about half of all operative dental procedures performed in adults.[33] In some indirect restoration studies using a CAD/CAM system and followed in different periods, they reported that none of the restorations had secondary caries.[34] As seen in the studies, the risk of secondary caries formation is very low in CAD/CAM restorations. This can be attributed to the fact that the restorations can be made fully compatible with the cavity and the restorations do not have the risk of polymerization shrinkage. Secondary caries formation was not observed in any of the restored teeth in our study.

Tooth integrity weakening as a result of a fracture in healthy teeth under functional forces is rarely seen, but the loss of material created in the cavity preparation weakens the tooth and causes the tendency to break.[35] St-Georges *et al.*[36] reported that 59% of the teeth were weakened when extensive MOD restorations were performed in premolar teeth, and studies have reported an increase in the brittleness of endodontic treated teeth.[37] In the scope of our study, tooth integrity was not observed in any of the restored teeth. In this case, we think that preparing cavities with a tooth wall thickness of at least 2 mm and choosing vital teeth may have an effect.

The periodontal response, in which the compatibility of the restorations with the surrounding tissues is evaluated, plays a vital role in the continuation of the clinical success of the restoration for a long time. Zimmerman's one-year CAD / CAM indirect clinical study showed no signs of gingivitis in forty-eight restorations: '1' had a minimum plaque '2' in 10 restorations, and two restorations scored '3' according to FDI evaluation.[38] In our study, at 12 months, one restoration had '4' in the Cerasmart group, one restoration '3', two restorations '3' in the IPS e.max CAD group, and two restorations '3' in the Vita Enamic group. Since the score '4' indicated the necessity of treatment, the patient was referred to the periodontology clinic. It has been learned that this patient was pregnant, and we think that hormonal changes during pregnancy and less sensitivity to oral hygiene may create such a condition.

CONCLUSIONS

This study shows that CAD/CAM onlay restorations made of porcelain, composite and hybrid blocks have a high clinical success rate after 12 months. Vita Enamic restorations showed significantly lower color matching than Cerasmart and IPS e.max CAD restorations. A more extended clinical evaluation period is required to produce more results.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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Original research

DENTISTS' KNOWLEDGE ABOUT MANAGEMENT OF TRAUMATIC DENTAL INJURIES IN A PART OF TURKEY: A CROSS-SECTIONAL STUDY

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ABSTRACT

Objectives: The aim of the present study was to evaluate the level of knowledge of general dental practitioners (GDPs) and dental specialists (DSs) about the management of Traumatic Dental Injuries (TDIs).

Materials and methods: A total of 199 participants from three cities in Turkey completed the online questionnaires. The first section of the questionnaire consisted of personal information about the dentists, while the second section consisted of multiple-choice questions regarding their knowledge of managing different types of TDIs in children. The data were statistically analyzed using the Chi-square test or Fisher's test and Mann-Whitney U test or Kruskal Wallis test. The level significance was taken as 0.05 in all tests.

Results: The questionnaires were completed by 145 GDPs and 54 DSs. In total, 29.1% of the participants (58) had less than 3 years of experience, 20.6% (41) had between 3 and 6 years of experience, 16.1% (32) had between 7 and 10 years of experience, 14.1% (28) had between 11 and 15 years of experience, 8% (16) had between 16 and 20 years of experience, and 12.1% (24) had more than 20 years of experience in clinical practice. Dentists with fewer years of experience (<10 years) were more knowledgeable than those with more years of experience (p=0.001). Moreover, DSs were more knowledgeable than GDPs (p=0.002).

Conclusions: Our findings revealed a moderate level of knowledge about TDI management among dental practitioners. These findings highlight the need to improve dentists' knowledge about TDI treatment protocols.

Keywords: Attitudes, dental trauma, dentists, emergency, knowledge.

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INTRODUCTION

Traumatic dental injuries (TDIs) are recognized as a serious and significant public health problem. In particular, their frequency and associated economic burden could affect the patients' quality of life.[1,2] Dental injuries could range from simple crown fractures to avulsion. A few important interventions after dental injuries (especially in patients with complicated crown fractures and avulsion) can significantly affect the prognosis.[3] In patients with TDIs, the prognosis could vary depending on the period elapsed, type of trauma, degree of mobility or luxation of the tooth, fracture location, the state of root development and the age of the patient.[4]

Inadequate treatment planning following TDIs may result in psychological problems, pain and loss of function. In particular, accurate diagnosis and treatment planning are crucial in patients with avulsion injuries.[5-7] To minimize complications and enhance treatment outcomes, immediate and appropriate treatment management is often required. Therefore, for the management of TDIs, it is important that the level of knowledge of dental clinicians is sufficient and updated.[8,9]

The International Association of Dental Traumatology (IADT) is a professional organization whose mission is to promote optimal prevention, diagnosis, treatment, and follow-up services in the field of TDIs through interaction with dental and medical colleagues, the general public, and interested parties in education, sports, industry, public service, and governmental agencies across the globe. The IADT guidelines also offer recommendations for the diagnosis and treatment of specific TDIs and should assist dentists and patients in decision making and in providing the best care effectively and efficiently.[10]

Dental literature regarding TDIs reveals a low level of knowledge among dentists across the world regarding protocols for the emergency management of TDIs.[11,12] Cınar *et al.*[13] found limited knowledge among Turkish dentists about the management of TDIs regarding the splinting time for avulsed teeth and the treatment approach for complicated crown fractures. Similarly, a recent study revealed a low level of knowledge about TDIs among dentists in Turkey.[14] Limited studies have assessed the knowledge level of Turkish dentists about TDIs based on their specialization status and experience. The aim of this cross-sectional study was to evaluate the knowledge level of general dental practitioners (GDPs) and dental specialists (DSs) from three cities in Turkey about the emergency management of TDIs.

MATERIAL AND METHODS

Study design and target population

This cross-sectional study was conducted from April to October 2019. The participants were dentists working at university clinics and public and private practice clinics. An online questionnaire was sent to the dentists in Adana, Kahramanmaras, and Mersin provinces, Turkey, whose contact information was obtained through e-mail or mobile phone. Ethical approval for the study was obtained from the Ethics committee for Non Invasive Researches, Faculty of Medicine, Çukurova University (ID: 86/35).

Data collection

The survey questions were modeled on a previously published study[13]. The questionnaire form was sent to a Turkish language expert in terms of linguistic validity and the form was finalized. A brief explanation of the purpose of the survey was provided on the first page of this questionnaire, and it was emphasized that participation was voluntary and that no individual dentist could be identified. The survey was divided into two sections. The first section consisted of six demographic questions, and the second section consisted of 12 multiple-choice questions (Table 1) regarding the participants' knowledge about emergency management of TDIs. A few participants submitted incompletely filled forms; therefore, they were excluded from the study.

Table 1. Questions regarding the emergency management of TDIs

1.If an intruded primary maxillary anterior tooth has been displaced toward the labial bone plate,	a. the tooth is left for spontaneous repositioning b. the tooth is immediately extracted c. do not know
2.If an immature permanent maxillary tooth has been intruded, the tooth should be…	a. left alone for spontaneous repositioning b. repositioned orthodontically c. repositioned surgically d. extracted immediately e. do not know
3.If a mature permanent maxillary tooth has been extruded, the tooth should be immediately repositioned and stabilised using a…	a. rigid splint for 4 weeks b. rigid splint for 2 weeks c. semi-rigid splint for 2 weeks in conjunction with root canal treatment d. semi-rigid splint for 2 weeks in conjunction with root canal treatment if pulp necrosis has occurred
4.What type of splint should be used for extruded permanent incisors?	a. semi-rigid with nylon wire b. stainless steel wire c. composite resin d. other
5.If a patient with an immature permanent maxillary tooth injury with pinpoint pulp exposure came to the clinic within 3 hours after the trauma, the treatment procedure would be…	a. do not treat but follow up b. pulp capping c. partial pulpotomy d. cervical pulpotomy e. pulpectomy f. do not know
6.If a patient with an immature permanent maxillary tooth injury with large pulp exposure came to the clinic more than 24 hours after the trauma, the treatment procedure would be…	a. do not treat but follow up b. pulp capping c. partial pulpotomy d. cervical pulpotomy e. pulpectomy f. do not know
7.If a patient with a mature permanent maxillary tooth injury with large pulp exposure came to the clinic more than 24 hours after trauma, the treatment procedure would be…	a. do not treat but follow up b. pulp capping c. partial pulpotomy d. cervical pulpotomy e. pulpectomy
8.Which of the following storage media are suitable for the storage of an avulsed tooth?	a. ice b. tap water c. paper tissue d. fresh milk e. patient's mouth
9.If the patient comes to the clinic with in 60 min after trauma, before replantation, the immature avulsed tooth should be…	a. rinsed with tap water b. cleaned with any type of solution c. left unwashed d. kept in doxcycline for 5 min e. scrubbed gently f. kept in fluoride solution for 20 min g. do not know
10.If the patient came to the clinic more than 60 min after trauma, for what period do you indicate the use of a splint for a mature avulsed tooth?	a. no splint b. 2 weeks c. 4 weeks d. 2 months e. 24 hours f. do not know
11.After replantation, do you prescribe antibiotic therapy?	a. yes, tetracycline (>12 years old) b. yes, penicillin c. no
12.Should avulsed primary teeth be replanted?	a. yes b. no

*Correct answers are written in bold.

The first section of the survey was used to determine the socio-demographic and professional profiles of the participants (gender, age, and years of dental practice experience, practice type, and education level). The second section of the survey consisted of questions regarding the emergency management of TDIs. The questions were associated with the following topics concerning TDIs.[13,15]

- The emergency management of intrusive and extrusive luxation injuries (Q1–Q4)

- The emergency management of complicated crown fractures in immature and mature permanent teeth (Q5–Q7)

- The emergency management of avulsion injuries (Q8–Q12)

The accuracy of the answers was determined on the basis of evidence from the current dental trauma guidelines proposed by the IADT.[16] The knowledge level of the participants was determined using a scoring system (0–12); one point was assigned for one correct answer. The categorization of knowledge levels according to the total scores received by participants was made as follows; 0-4 scores were described as low, 4-8 scores were described as moderate and 8-12 scores were described as high levels of knowledge.

Statistical analysis

After the collection of data, the raw data were entered in statistical Package for the IBM SPSS Version 23 software (New York, USA). Descriptive statistics were used to summarize the demographic information. Pearson's chi-squared test or Fisher's test was used to identify the correlation among gender, age, practice type, education level, and years of dental practice experience. Mann Whitney U test was used to compare continuous measurements between groups, and Kruskal Wallis test was used for more than two variable comparisons. The level significance was taken as 0.05 in all tests.

RESULTS

Demographic distribution of participants

From a total of 980, 199 (approximately 20.3%) participants answered the survey. Of the total participants, 113 participants (56.8%) were female, and 86 (43.2%) were male. The majority of participants (61.8%) were between 25 and 35 years old. 29.1% had 1-3years experience, 20.6% had between 3-6 years, 16.1% had between 7-10 years, 14.1% had 11-15 years, 8% had between 16-20 years and 12.1% had more than 20 years clinical experience. The distribution of participants according to the institutions they work in showed that 44.7% of participants work in public hospitals and 37.2% work in private practice. The percentage distribution of the participants in terms of their years of experience, age, and gender is summarized in Table 2.

Table 2. Demographic characteristics of participants

	n	%
Age		
<25	34	17.1
25-35	123	61.8
36-45	27	13.6
46<	15	7.5
Gender		
Male	86	43.2
Female	113	56.8
Years of experience		
1-3	58	29.1
3-6	41	20.6
7-10	32	16.1
11-15	28	14.1
16-20	16	8.0
>20	24	12.1

n=sample size, %= percentage.

Of the total 199 participants, 145 were GDPs and 54 were DSs. The majority of participants had no post-graduate degree (72.9%). The specialty areas of DSs were Endodontics (5.5%), Prosthodontics (5.5%), Orthodontics (5%), Pediatric dentistry (4%), Oral and maxillofacial surgery (3.5%), Periodontics (2%) and Restorative dentistry (1.5%), respectively. The professional characteristics of all participants are shown in Table 3.

Table 3. Professional characteristics of the participants

	n	%
Main practices		
Public	89	44.7
Private	74	37.2
University	30	15.1
not specified	6	3.0
Specialization		
No	145	72.9
Yes	54	27.1
Profession		
General dental practice	145	72.9
Oral and maxillofacial surgery	7	3.5
Pediatric dentistry	8	4.0
Periodontics	4	2.0
Endodontics	11	5.5
Orthodontics	10	5.0
Prosthodontics	11	5.5
Restorative dentistry	3	1.5

n=sample size, %= percentage.

Knowledge of Emergency Management of Traumatic Dental Injures

Question 2 (treatment about intruded immature permanent teeth) and Question 7 (treatment procedure about a complicated crown fracture in mature teeth) had the highest rate of correct answers (69.8% and 83.4%, respectively). In contrast, Question 6 (treatment procedure about a complicated crown fracture in immature teeth) and Question 10 (splint time for a mature avulsed tooth) had the lowest rate of correct answers (30.7% and 38.2%, respectively). The percentage distribution of all participants' answers regarding the management of TDI is shown in Table 4.

Table 4. Percentage distribution of all participant's answers about emergency management of the TDI

Questions	n	%
Q.1		
The tooth is immediately extracted	94	47.2
The tooth is left for spontaneous repositioning	94	47.2
Do not know	11	5.5
Q.2		
repositioned surgically	17	8.5
extracted immediately	3	1.5
left alone for spontaneous repositioning	139	69.8
repositioned orthodontically	34	17.1
Do not know	6	3.0
Q.3		
rigid splint for 2 weeks	6	3.0
semi-rigid splint for 2 weeks with root canal treatment if pulp necrosis has occurred	118	59.3
semi-rigid splint for 2 weeks with root canal treatment	62	31.2
rigid splint for 4 weeks	13	6.5
Q.4		
composite resin	42	21.1
semi-rigid with nylon wire	111	55.8

stainless steel wire	37	18.6
other	9	4.5
Q.5		
pulp capping	115	57.8
pulpectomy	12	6.0
cervical pulpotomy	58	29.1
do not treat but follow up	9	4.5
do not know	5	2.5
Q.6		
partial pulpotomy	61	30.7
pulp capping	11	5.5
pulpectomy	68	34.2
cervical pulpotomy	48	24.1
do not treat but follow up	4	2.0
do not know	7	3.5
Q.7		
partial pulpotomy	10	5.0
pulp capping	1	0.5
pulpectomy	166	83.4
cervical pulpotomy	8	4.0
do not treat but follow up	7	3.5
do not know	7	3.5
Q.8		
ice	3	1.5
patient's mouth	72	36.2
paper tissue	1	0.5
fresh milk	123	61.8
Q.9		
kept in fluoride solution for 20 min	25	12.6
kept in doxcycline for 5 min	119	59.8
cleaned with any type of solution	5	2.5
rinsed with tap water	11	5.5
scrubbed gently	5	2.5
left unwashed	15	7.5
do not know	19	9.5
Q.10		
2 months	10	5.0
2 weeks	76	38.2
24 hours	2	1.0
4 weeks	91	45.7
no splint	5	2.5
do not know	15	7.5
Q.11		
yes. tetracycline	86	43.2
yes. tetracycline (>12 years old)	86	43.2
no	27	13.6
Q.12		
no	180	90.5
yes	19	9.5

Q= question, n=sample size, %= percentage.

Comparing the numbers of correct answers to the questions among those who are GDP and DSs, the median value for correct answers for the GDPs is 7 (between 3-11 correct answers) and for the DSs is 9 (between 4-12 correct answers). It was found that there was a statistically significant difference in the mean correct answers given to the questions between those who were GDPs and DSs (p=0.002). When we compared the correct answers to the questions between DSs and GDPs, it was found that DSs had higher correct answers in Questions 4 and 8. This difference was also found to be statistically significant (p=0.036 and p=0.014, respectively). The distribution of the number of correct answers according to the specialist status is shown in Table 5 and Table 6.

Table 5. The number of correct answers according to the specialist status

	n	Median (Min-Max)	
specialization			
no	145	7 (3-11)	p=0.002
yes	54	9 (4-12)	

*Statistically significant at p<0.05, n=sample size Min=minimum, Max=maximum.

Table 6. Distribution of the number of correct answers according to the specialist status

	GDP (n=145)		DS (n=54)		
	N	%	N	%	p
Q 1					
correct	63	43.4	31	57.4	0.110
Q 2					
correct	96	66.2	43	79.6	0.082
Q 3					
correct	86	59.3	32	59.3	1.000
Q 4					
correct	74	51.0	37	68.5	0.036
Q 5					
correct	81	55.9	34	63.0	0.421
Q 6					
correct	43	29.7	18	33.3	0.609
Q 7					
correct	123	84.8	43	79.6	0.396
Q 8					
correct	82	56.6	41	75.9	0.014
Q 9					
correct	86	59.3	33	61.1	0.872
Q 10					
correct	66	45.5	25	46.3	1.000
Q 11					
correct	123	84.8	49	90.7	0.356
Q 12					
correct	128	88.3	52	96.3	0.107

*Statistically significant at p<0.05, Q= question, n=sample size, GDP= general dental practitioner, DS= dental specialist.

When we compared the numbers of correct answers to the questions according to the clinical experience of dentists, it was found that dentists with <10 years' experience had the highest rate of correct answers compared to other dentists (8 correct answers). The dentists who had 16-20 years of experience, had a moderate knowledge level (6 correct answers) when compared with their younger colleagues. This difference was found to be statistically different (p=0.001). The number of correct answers according to clinical experience is shown in Table 7.

Table 7. The number of correct answers according to the years of experience

	n	Median (Min-Max)	
clinical experience			
<3	58	8 (4-11)	
3-6	41	8 (4-11)	
7-10	32	8 (5-12)	p=0.001
11-15	28	7 (4-10)	
16-20	16	6 (4-10)	
20<	24	6 (3-10)	

*Statistically significant at p<0.05, n=sample size, Min= minimum, Max=maximum.

DISCUSSION

The present study examined knowledge of TDIs, patient enrollment, and management regarding the IADT Guidelines for the management of TDIs among dentists in three cities of the Mediterranean region in Turkey. In this study, the mean knowledge score of GDPs was 7 and of DSs was 9 for 12 questions about emergency management of

TDIs. It was observed that there was a significant difference between the knowledge score of DSs and GDPs (p=0.002). A recently published study reported that an average of 5.87 correct answer was given by Brazilian dentists about TDIs and that specialist dentists, such as endodontists and pediatric dentists, had the highest knowledge level of TDIs.[17] Hu *et al*.[18] reported that dental trauma knowledge level of endodontists was higher than the GDPs in Brazil. Zafar *et al*.[19] found that the knowledge level about emergency management of tooth avulsion was significantly associated with the specialty of practice. Another study showed that specialists' knowledge level about emergency management of TDIs was higher than GDPs.[20] Similar results were also reported in a study among German GDPs.[21] Our results are comparable to the above studies with similar findings that knowledge about TDIs is in the moderate range. Less knowledge of TDIs may be explained by a lack of interest by clinicians regarding this topic because of the low incidence of experiencing trauma cases in their practice.

Dentists' professional education level, place of work and years of experience are crucial indicators of knowledge concerning the treatment of TDIs. In 2020, a study showed that the knowledge level of more experienced dentists was low in Turkey.[22] Similarly, another study reported that more new graduates knew the answers to most of the questions.[23] In this study, the dentists with fewer years of experience (<10 years) were more knowledgeable (8 out of 12 questions) than dentists with more than 10 years of experience (6 out of 12 questions). This difference among dentists with different years of experience, based on the mean knowledge of TDIs, may be related to updated dental education and in part, by younger dentists having easier access to academic websites for research, such as IADT guidelines. These findings supported the findings of previously published reports evaluating the knowledge level in different countries.[21,24,25]

Different treatment alternatives have been suggested for the management of intruded permanent incisors, such as spontaneous re-eruption, orthodontic extrusion, and surgical repositioning. The general consensus is that spontaneous re-eruption has been suggested for immature permanent teeth.[26,27] In the present study, 47.2% of dentists said they would leave intrusively luxated primary teeth for spontaneous repositioning, and 69.8% of dentists said that they would prefer to leave intrusively luxated permanent teeth to spontaneously erupt.

In the present study, 59.3% of participants stated that they would immediately perform corrective repositioning and provide a splint in conjunction with root canal treatment if pulp necrosis had occurred. Cınar *et al*.[13] reported that 50% of dentists responded that they would prefer a similar treatment approach. Similarly, another study reported that 47% of the dentists responded that they would base their decision more frequently on the result of a pulp test for extrusive and lateral injuries in their survey.[28] Comparing the percentage of correct answers to the questionnaire among DSs and GDPs regarding intrusive injuries of primary and permanent teeth, there was no significant difference between the correct answers of GDPs and DSs regarding luxation traumatic injuries (p≥0.005). A higher proportion of the participants showed inadequate knowledge of the treatment of intrusion and extrusion luxation injuries.

Comparing the percentage of correct answers to the questionnaire among DSs and GDPs regarding the type of splint material, there was a significant difference between the correct answers of GDPs and DSs (p=0.036). 68.5% of DSs and 51% of GDPs would provide a semi-rigid splint with nylon wire material. Cınar *et al*.[13] reported that DSs were also more aware than GDPs regarding splinting time and material for mature extruded permanent incisors teeth.

The prognosis of complicated crown fracture appears to depend on the extent to which the pulp is exposed and the stage of root development at the time of injury.[29] In mature and immature permanent teeth, if the amount of pulp exposure is small and treated within 24 hours, pulp capping has been suggested as the preferred treatment approach.[30] A partial pulpotomy is indicated if the amount of pulp exposure is large, if the pulp has been open to bacterial contamination or if too much time has elapsed after the injury.[28,31] In the present study, 57.8% of the participants preferred pulp capping a pin-point pulp exposure of an immature complicated crown fractured incisor as the correct answer. In contrast, 30.7% of participants preferred partial pulpotomy as the treatment for immature, complicated crown fractured incisors with large pulp exposure. Buldur and Kaplan reported that only 30.9% of their participants gave the correct answer.[14]. Alyasi *et al*.[32] showed that only 33.1% of the participants answered this question correctly regarding the management of complicated crown fracture in immature teeth. According to these findings, the participants' knowledge of the emergency dental treatment of complicated crown fracture with pulp exposure was unsatisfactory.

Pulpectomy should be performed to preserve the tooth if the pulp becomes necrotic in cases of complicated crown fractured incisors with complete root formation.[33] In the present study, the majority of participants (83.4%) stated that they would immediately perform root canal treatment (pulpectomy) for this type of injury if there were closed apices with large pulp exposure more than 24 hours after trauma. Cınar *et al*.[13] showed that 81.2% of participants would prefer root canal treatment, while Kostopoulu and Duggal[15] found that 78% of GDPs would perform pulpotomy for a complicated crown fractured with a large exposure and open apex. Comparing the percentage of correct answers to the questions among DSs and GDPs regarding the type of complicated crown fracture with pulp exposure, there was no significant difference between the correct answers of GDPs and DSs ($p \geq 0.005$).

The prognosis of avulsed teeth depends on whether appropriate emergency management procedures were performed.[10] Immediate replantation is the most appropriate treatment for avulsed teeth. When immediate replantation is not possible, the use of a storage medium, extra-oral time, and the management of avulsed teeth are important for long term prognosis. Several studies have reported that fresh milk is superior to saliva as a storage medium.[34,35] Zhao and Gong[36] reported that most dentists preferred saliva or saline solution as a storage medium. In the present study, 61.8% of participants preferred milk as a storage medium for an avulsed tooth and 36.2% of the participants chose the patient's mouth (saliva) as the storage medium. Cınar *et al*.[13] found that 63% of their participants preferred milk as storage, and Cohenca *et al*.[12] reported that 53.6% of their participants identified milk as a storage medium for avulsed teeth. In this study, there was a significant difference between the responses of GDPs and DSs regarding the storage medium of an avulsed tooth ($p=0.014$). While 75.9% of DSs chose fresh milk, 56.6% of GDPs chose fresh milk as the storage medium.

Doxycycline has anti-bacterial, anti-inflammatory effects and it could improve the prognosis and enhance the revascularization of avulsed teeth with an open apex.[37] Shaul *et al*.[38] stated that the use of root conditioning with doxycycline in avulsed teeth with closed apex resulted in complete healing at 16 months after the tooth replantation. Cınar *et al*.[13] reported that 39.6% of dentists preferred doxycycline. In the present study, 59.8% of the participants stated they would place the avulsed teeth with an open apex in a doxycycline solution.

The technique of splinting should ensure physiological movement of an avulsed tooth after the replantation and during the healing period. IADT guidelines recommend flexible splinting (2 weeks) for avulsed teeth with closed apex if the extraoral drying time is longer than 60 minutes.[16] In the present study, a low rate of the participants (38.2%) chose the 2 weeks splinting period for mature avulsed teeth. Kostopoulu and Duggal[15] reported that 10-30% of the dentists preferred a 2-week splinting time. According to these findings, the participants' knowledge of the splinting time for an avulsed tooth was unsatisfactory.

The use of an antibiotic is effective in preventing a bacterial invasion of the pulp and inflammatory resorption after the replantation of an avulsed tooth.[37] The IADT guideline also recommends the administration of systemic antibiotics, such as penicillin or doxycycline.[10] In the present study, the majority of the participants (96.4%) preferred antibiotics in cases of avulsion injuries. Similarly, a higher rate of all participants (90.5%) presented the correct answer regarding the replantation of avulsed primary teeth. A previous study has also reported that 83% of the dentists were unwilling to replant primary teeth.[12]

CONCLUSIONS

Based on our findings, the level of Turkish general dental practitioners' knowledge about the management of TDIs was found to be moderate and also it could be concluded that postgraduate continuing education programs need to improve their knowledge about the management of TDIs. Furthermore, the awareness of dentists should be raised regarding the availability of the Turkish version of the IADT guideline, which was updated in 2020 (www.iadt-dentaltrauma.org), as well as the mobile phone application (Tooth SOS).

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CONFLICTS OF INTEREST STATEMENT

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Türkiye'nin Bir Bölgesindeki Diş Hekimlerinin Travmatik Dental Yaralanmaların Yönetimi Konusunda Bilgi Seviyesi: Kesitsel Bir Çalışma

ÖZ

Amaç: *Bu çalışmanın amacı travmatik dental yaralanmaların (TDY) yönetimi konusunda genel diş hekimleri (GDH) ve uzman diş hekimlerinin (UDH) bilgi seviyelerini değerlendirmektir.* ***Gereç ve Yöntemler:*** *Çalışmaya Türkiye'deki üç şehrinden elektronik anketleri dolduran toplam 199 katılımcı dahil edildi. Anketin ilk bölümü diş hekimlerinin kişisel bilgilerini içerirken, ikinci bölüm diş hekimlerinin çocuklarda çeşitli dental travma tiplerinin yönetimindeki bilgi düzeyleri ile ilgili çoktan seçmeli sorulardan oluşturuldu. Elde edilen sonuçların istatistiksel analizi Ki-kare testi ya da Fisher's test ve Mann-Whitney U test ya da Kruskal Wallis testi kullanılarak yapıldı. Tüm testler için anlamlılık düzeyi 0.05 olarak alındı.* ***Bulgular:*** *Anketler 145 GDH ve 54 UDH tarafından tamamlandı. Tüm katılımcıların %29,1'inin (58) 3 yıldan daha az, %20,6'sının (41) 3-6 yıl arası, %16,1'inin (32) 7-10 yıl arası, %14,1'inin (28) 11-15 yıl arası, %8'inin (16) 16-20 yıl arası ve %12,1'inin (24) ise 20 yıldan daha fazla klinik tecrübesi vardı. Daha fazla klinik tecrübeye sahip diş hekimlerine göre daha az klinik tecrübeye sahip (10 yıldan az) diş hekimlerinin bilgi düzeyinin daha fazla olduğu bulundu (p=0,001). Ayrıca, UDH'nin bilgi düzeyi GDH'nin bilgi düzeyinden daha fazlaydı (p=0,002).* ***Tartışma:*** *Bulgularımız TDY'ın yönetiminde diş hekimlerinin bilgi düzeyinin orta seviyede olduğunu ortaya çıkarmıştır. Bu sonuçlar TDY'lardaki tedavi protokolleri hakkında diş hekimlerinin bilgi seviyesinin geliştirilmesi gerektiğini vurgulamaktadır.* ***Anahtar Kelimeler:*** *Davranış, dental travma, acil, bilgi düzeyi.*

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Original research

INFLUENCE OF DIFFERENT LED CURING-UNITS ON DEPTH OF CURE AND MICRO-HARDNESS OF NANO-HYBRID RESIN COMPOSITE

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ABSTRACT

Purpose: To evaluate the effect of two second generation LED Light curing units and a third-generation polywave LED Ligth curing unit at three different irradiation durations on surface microhardness and detpth of cure of nano-hybrid composite resin material.

Materials and Methods: Elipar™ S10, Elipar™ Deep Cure-S, VALO Cordless, was evaluated at 10s, 20s, 40s curing periods in this study. A nano-hybrid composite Filtek™ Z550 that contains camphorquinone as photoinitiator is used as test material. For microhardness test ninety 6 mm diameter, 4 mm deep cylindrical composite blocks in teflon molds were prepared. For each light source at each application times 10 specimen were prepared (n=10) and tested. Also ninety, 4 mm diameter, 6 mm deep cylindrical composite specimens in a split aluminum mold polymerized with three different light sources at three different durations (n=10) were tested for depth of cure measurement. Data were analyzed statistically by SPSS (Ver: 22.0) one-way ANOVA and multiple comparisons were performed by Tukey's post-hoc test. A p-value less than 0.05 was considered statistically significant.

Results: The values of cure depth were found significantly higher at 40 seconds of irradiation time for all light sources used ($p<0.05$). Elipar Deep Cure-S showed the higher top surface microhardness at 40s polymerization ($p<0.05$)

Conclusions: All light devices used in the study provided adequate polymerization of the nano-hybrid composite at all application durations in this study. The highest polymerization depth and microhardness values were achieved at 40 sec. polymerization time for all LCUs.

Keywords: Light Curing Unit, Depth of Cure, Micro-Hardness, Deep Cure-S.

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INTRODUCTION

Light activated composite resin restorations have become the most preferred restorative materials in the past decade due to their good esthetic properties, mercury-free contents, allow conservative cavity preparation, reinforce of remaining tooth structure, easy application, low cost and low technical sensitivity requirement.[1,2] Another main advantage is that the working time can be controlled by the operator.[3] More than two hundred and sixty million resin-based composite restorations are made every year worldwide.[4] And several studies have reported that the median longevity of posterior resin-based composite (RBC) restorations, is approximately six years.[5,6] Secondary caries and bulk fractures have been shown as the two common causes of failures.[5,7] Both this failures may be the result of inadequate photo-polymerization of the RBC. Inadequately photo-cured RBC will exhibit lower degree of conversion which is lead to adverse effects on physical properties and bond strength to preparation walls of RBC restorations.[8,9] Therefore to avoid these negativities the optimum curing conditions should be provided such as choosing correct light exposure time and irradiance level, precise positioning tip of the light curing unit (LCU) and curing with sufficient energy at correct wavelengths.

The irradiation with the LCU has an important effect on surface hardness and depth of polymerization.[10] Today there are various LCUs working on different physical principles such as quartz-tungsten-halogen (QTH) bulbs, laser, plasma arc lights, and light emitting diodes (LEDs). Led LCUs has became standard in modern dentistry at the present time due to they have low heat outputs, do not require cooling fan, can be used cordless and they are lighter and smaller.[11,12] In addition the LED lights efficiency of conversion of electrical energy to curing energy is higher than conventional halogen lamps.[13,14]

Camphorquinone is the most common photoinitiator in the content of RBCs which has absorbtion spectrum of approximately 460–470 nm. LED LCUs provides adequate curing of these composites. Nevertheless some RBCs contain alternative photoinitiators are most sensitive to the lower wavelengths of light below 420 nm, such as diphenyl (2,4,6-trimethylbenzoyl) phosphine oxide (TPO).[15,16] Today, different light devices are offered for use with different modes that provide higher light output powers. Manufacturers claim that these modes of application provide adequate polymerization in a shorter time.

Surface hardness test has been used in many studies since it is a good indicator of the degree of conversion of composites resin. There is a strong positive correlation between microhardness value and the monomer conversion degree. Depth of cure (DoC) measurement is one another reliably and widely used test to assess the relative degree of cure of RBCs.[17] According to the ISO 4049 standards DoC of composite resins can be evaluated with placing resin into a 4 mm diameter 6 mm depth of a stainless steel mold.[16] After light polymerization, the uncured composite is removed with a plastic spatula, and the height of the remaining composite is divided in half to determine the DoC.[18]

The aim of the study was to investigate the effect of two second generation LED LCUs and a third-generation polywave LED LCU at three different irradiation durations on surface microhardness and detpth of cure of nano-hybrid composite resin material. The null hypothesis tested was that different light curing devices and different curing periods do not affect polymerization depth and surface hardness.

MATERIALS AND METHODS

Ethics approval

Ethical approval was obtained from the Local Ethics Committee of the Sivas Cumhuriyet University, Sivas, Turkey (ID: 2021-02/55).

Restorative Materials and light curing units

Three different LED LCUs investigated in this study. Selected LCU's for resin polymerization were two second generation LED LCUs (Elipar™ S10 and Elipar™ Deep Cure-S; 3M ESPE, St. Paul, MN, USA) and a third-generation LED LCU (VALO Cordless; ULTRADENT, St Louis, MO, USA). A nano-hybrid composite resin (Filtek™ Z550) used as the restorative material. (Tablo 1,2)

Table 1. Restorative material used

Dental resin composite	Manufacturer	Type (Shade)	Composition	% Filler Wt/Vo	Lot Number
Filtek Z550	3M ESPE, St. Paul, MN, USA	Nanohybrid resin composite, light-cured, universal (A2)	Bis-GMA, UDMA, Bis-EMA, PEGDMA and TEGDMA Filler: Zirconia/silica, silica Partical size: 0.6 - 10 µ	82/68	N751485

Table 2. Light Curing Units used in study.

LCU	Manufacturer	Irradiance stated by manufacturer (mW/cm^2)	Peak Wavelength (nm)
Elipar™ S10	3M ESPE, St Paul, MN, USA	1200	430-480
Elipar™ Deep Cure-S	3M ESPE, St Paul, MN, USA	1470	430-480
VALO Cordless	Ultradent	1400	395–480

Microhardness measurement

Teflon molds with a circular shaped hole (6 mm diameter, 4 mm deep) was used to prepare samples for microhardness test. After teflon molds placed on a mylar strip and glass slide, composite resin was placed in the molds as it will be two layers. Molds was covered and compressed with another mylar strip and glass slide to provide a flat and smooth surface before polymerization. Three main groups were formed according to the light source used: Group1(Valo): VALO Cordless at 1000 mW/cm2, Group 2(Elipar S10): Elipar™ S10 at 1200 mW/cm2, Group 3(Deep Cure-S): Elipar™ Deep Cure-S at 1470 mW/cm2 (N=30). All LCUs used at their standart modes. LED sources was used at three different time intervals (10s, 20s, 30s) as a subgroup (n=10). Polymerization performed with the tip of the light guide 0.5 mm from the surface of composite resin. Following the polymerization Vickers microhardness test (Shimadzu HMV; Shimadzu Corporation, Tokyo, Japan), was performed at the top (depth=0 mm) and bottom (depth=4 mm) surfaces of each specimen (three indentations for each specimen), at a 50-g load for 15 seconds.

Depth of cure measurement

According to the LCUs, three main groups (N=30) and for each time period (10s, 20s, 40s) three subgroups (n=10) were formed as in microhardness test. A half split aluminum mold with a circular shaped hole (4 mm diameter, 6 mm deep) was used for depth of cure measurement. Restorative material was placed into the mold and compressed with mylar strip and glass slide from bottom and top to achieve a flat surface. Then the resin was photo-polymerized as in groups. Dept of cure of the composite resin was determined using a standardized technique (ISO 4049:2000).[16] Immediately after resin polymerization, specimens removed from the mold and uncured material from the bottom scraped away with a plastic spatula. Remaining height of cylinder measured via electronic micrometer to an accuracy of ±0.01 mm and results divided by two.

Statistical analysis

The obtained data were analyzed by SPSS (Ver: 22.0) using one-way ANOVA and multiple comparisons were performed by Tukey's post-hoc test. A p-value less than 0.05 was considered statistically significant.

RESULTS

When each light source was evaluated within itself, the difference between the average polymerization depths was not found to be statistically significant at all application periods (10s, 20s, 40s). Deep Cure-S showed highest polymerization depth at 40 s.

Comparison of light sources according to application periods showed that there was no statistical difference between the light sources during the application period of 20 seconds, and 40 s however there was a difference between the Valo and the other light sources at 10 second. The highest polymerization depth values were observed in Deep Cure-S group at all application times. (Table 3)

Table 3. Depth of cure means and standard deviations of groups according to irradiation times.

Gruplar	10 s x̄±ss	20 s x̄±ss	40 s x̄±ss	
Valo	1.849±0.121^{A,a}	2.002±0.167^{A,a}	2.516±0.072^{A,b}	F=69.1 p=0.001*
Elipar S10	2.042±0.116^{B,a}	2.217±0.164^{A,a}	2.678±0.202^{A,b}	F=38.39 p=0.001*
Deep cure-S	2.078±0.093^{B,a}	2.153±0.245^{A,a}	2.699±0.177^{A,b}	F=34.82 p=0.001*
	F=12.27 p=0.001*	F=3.60 p=0.058	F=3.87 p=0.063	

In each column, groups with the same capital superscripts are not significantly different and in each row, groups with the same lower case superscripts are not significantly different (p > 0.05).

For each light source, mean top surface microhardness values at 40s was found higer than 20s and 10s. However only in Deep Cure-S group 20s, 40s microhardness values were significantly higher than 10s. The highest surface hardness was found in Deep Cure-S group at 40s. When the light sources were compared according to the duration of application, no statistically difference was observed between the light sources in all application periods. (Table 4)

Table 4. Top (0 mm) surface microhardness means and standard deviations of groups according to irradiation times

Gruplar	10 s x̄±ss	20 s x̄±ss	40 s x̄±ss	
Valo	98.937±5.021^{A,a}	98.712±4.606^{A,a}	98.875±7.088^{A,a}	F=0.001 p=0.994
Elipar S10	96.850±4.415^{A,a}	96.175±5.132^{A,a}	99.300±2.931^{A,a}	F=1.33 p=0.295
Deep cure-S	94.387±7.170^{A,a}	104.075±5.539^{A,b}	106.037±6.215^{A,b}	F=6.29 p=0.011*
	F=1.29 p=0.295	F=4.99 p=0.506	F=13.97 p=0.054	

In each column, groups with the same capital superscripts are not significantly different and in each row, groups with the same lower case superscripts are not significantly different (p > 0.05).

According to bottom surface microhardness values in Valo and Elipar S10 groups examined after 20s and 40s curing, microhardness values were significantly higher than 10s curing duration. The highest bottom surface hardness value was found in Deep Cure-S group at 40s. As aresult of examination of light sources according to the duration of application, there was statistically difference between the light sources in the 40s period, but no statistically difference between the light sources at the 10s and 20s. (Table 5)

Table 5. Bottom (4 mm) surface microhardness means and standard deviations of groups according to irradiation times

Gruplar	10 s x̄±ss	20 s x̄±ss	40 s x̄±ss	
Valo	83.437±6.166^{A,a}	90.275±4.715^{A,b}	92.262±5.269^{A,b}	F=7.59 p=0.005*
Elipar S10	86.137±5,773^{A,a}	93.787±5.352^{A,b}	94.112±3.171^{A,b}	F=6.58 p=0,008*
Deep cure-S	86.137±3.381^{A,a}	95.150±5.262^{A,b}	104.525±5.121^{B,c}	F=30.85 p=0.001*
	F=0.70 p=0.506	F=1.92 p=0.506	F=16.37 p=0.001*	

In each column, groups with the same capital superscripts are not significantly different and in each row, groups with the same lower case superscripts are not significantly different (p > 0.05).

Bottom and top surface hardnesses of the groups were compared within each application period and the results showed that the mean surface hardness values of the bottom and top surface of S10 group at 20s and Deep Cure-S group at 40s were found to be statistically insignificant. Mean hardness values of lower and upper surface of all other groups were found to be statistically significant. (Table 6)

Table 6. Microhardness means and standard deviations of top (0 mm) and bottom (4 mm) surfaces of groups according to irradiation times.

Groups	Irradiation time/ detpth (mm)	Means	Standart deviation	
VALO	10s/4mm	83.4375[a]	6.16695	t=7.90
	10s/0mm	98.9375[b]	5.02165	P=0.001*
	20s/4mm	90.275[a]	4.71525	t=7.20
	20s/0mm	98.7125[b]	4.60665	P=0.001*
	40s/4mm	92.2625[a]	5.26957	t=3.44
	40s/0mm	98.875[b]	7.08877	P=0.011*
Elipar S10	10s/4mm	86.1375[a]	5.77307	t=4.49
	10s/0mm	96.85[b]	4.41523	P=0.003*
	20s/4mm	93.7875[a]	5.35255	t=0.86
	20s/0mm	96.175[a]	5.13218	P=0.415
	40s/4mm	94.1125[a]	3.17105	t=2.74
	40s/0mm	96.321[a]	2.9316	P=0.029
Deep Cure-S	10s/4mm	86.1375[a]	3.38186	t=3.05
	10s/0mm	94.3875[b]	7.17026	P=0.015*
	20s/4mm	95.15[a]	5.26254	t=3.60
	20s/0mm	104.075[b]	5.53966	P=0.009*
	40s/4mm	104.525[a]	5.12187	t=0.71
	40s/0mm	106.0375[a]	6.2154	P=0.496

The same lower case superscripts in each column indicate no statistically significant difference between groups.
P values in the last column indicate t-test's results.
*P< 0.05.

DISCUSSION

Adequate polymerization is one of the main important factors influencing the physical and mechanical properties of composite resins. Degree of conversion and depth of cure analyzes are important tools to estimate the physical and mechanical properties of composite resin restorations.[18,19] Microhardness evaluation at specific depths is a widely used method to determine the depth of polymerization of resin-based restorative materials. For adequate polymerization depth, it is recommended that the bottom surface hardness is about 80% of the upper surface hardness value.[20, 21]

Also another standardized technique defined by ISO 4049 standard has been used determining of cure depth. The ISO 4049 standard evaluates DOC by placing composite resin into a 6 mm deep and 4 mm diameter opening of a split stainless steel mold. Immediately after light polymerization, the uncured resin material is removed with a plastic spatula, the height of the remaining composite is divided in half. These values recorded as the ISO depth of cure must be higher than 1.5 mm.[18, 22]

The irradiation time is very important for optimum polymerization of the resin at increased depth, although there is no major factor in the polymerization at the surface.[23] Time-saving applications are an ongoing request for restorative practices and significant improvements in technology of LED light sources allow shorter clinical application times.[12,24] Some recent studies have emphasized the potential of these LED curing lights to reduce the irradiation time without a significant loss in the mechanical properties of the RBCs.[23,25]

In this study, microhardness and polymerization depths of a camphorquinone photo-initiator containing resin-based composite material that photo polymerized with two different second generation and a third generation LED light sources at three different irradiation times were evaluated.

The null hypothesis was partially rejected because there are significant differences between the light curing periods in terms of polymerization depth and surface hardness however the top surface hardness values of Valo and S10 groups has showed no statistically changes at 10s and 20s light curing periods ($p>0.05$). And also DeepCureS-40s subgroup has showed significantly higher top and bottom surface hardness values than other LCUs ($p<0.05$).

Although all the LCUs perform adequate polymerization depth according to ISO 4049 depth of cure measurement (scraping test) at the 10 s irradiation time, VALO group showed statistically lower polymerization depth values than the other groups ($p<0.05$). This difference may be due to using VALO Cordless at 1000 mW/cm^2 output power so three light sources has a 1.2x-1.47x difference in the emitted power depending on the brand of LCU. In addition VALO has a different structural design of tip than the other light sources that may lead less polymerization at 10 s.

In a study evaluating the effects of Elipar DeepCure-S and Valo LCUs on the amount of residual monomer released from different composites; the amount of residual monomer released from composites polymerized with the Elipar DeepCure-S light device was found to be less than the groups polymerized with the Valo light device, similar to our study.[26] In another study investigating the effect of LCUs on the bonding strength in the repair of different composites with bulk-fill composites, the Elipar DeepCure-S provided better bonding strength than the Valo light device, and this was attributed to the Elipar DeepCure-S light device providing better polymerization at the bottom of the composite.[27]

All light curing units used in the study has provided significantly high polymerization depths at 40 second compared to 10 and 20 seconds ($p<0.05$). This can be explained by prolonged curing times allow the formation of additional cross-links in higher depths of restorative material and lead to a more homogeneous polymer network.[10] In addition, although shortened light curing durations provide sufficient polymerization, radiant exposure of the restorative material at 40 s light curing mode will be more than shorten curing times.[21] Altough there is a slightly difference of output powers of LCUs there was no statistically significant difference was found between the DoC values when comparing the depth of polymerization of the LCUs at the 20s and 40s periods. This has shown that the increased polymerization time can compensate the output power difference between the LCUs at used parameters.

When the surface microhardness values were compared, there was no difference in microhardness between the irradiation times in the Valo and Elipars S10 groups, while an increase in the exposure times of 20 and 40 seconds was observed in the Deep Cure-S group. This result can be explained by the fact that the energy output power of the Deep Cure S device is higher than the other devices (1470 nm/cm2) and different optical tip design. Differences in tip area can causea large effect on the calculated radiation.[16, 28]

The bottom microhardness results of the groups showed that 20s and 40s irradiation values are higher than 10s groups in all devices. However, in the Deep Cure-S group, there is no statistically significant difference between the surface and bottom microhardness values of the nanohybrid composite at 40s irradiation time. This can be explaned that light beam profile of Deep Cure-S deeper and more homegenous then the other light sources used.[16,28]

CONCLUSIONS

All light sources used in this study provide adequate polymerization of the nanohybrid composite which includes camphorquinone as a photoinitiator in all application time mods. The highest polymerization depth and microhardness values were achieved with 40 sec. polymerization time for all LCUs and Deep Cures S light devive provided statisticaly same microharnes values between top an bottom surfaces at 40s.

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CONFLICT OF INTEREST

There is no conflict of interest.

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Review

INFECTIVE ENDOCARDITIS PROPHYLAXIS IN DENTISTRY: CURRENT PERSPECTIVE

ABSTRACT

Infective endocarditis (IE) is a important heart disease with high morbidity and mortality. Current guidelines suggest antibiotic prohylaxis (AP) to individuals having high risk of IE. These high risk patients include the patients with background of IE, biological or a mechanical prosthetic valve, or a surgically constructed systemic or pulmonary conduit/ shunt. The restriction of AP is due to concerns about increased comprehension regarding antibiotic resistance and daily incidence of bacteraemia. Many researchers have examined the effect of restricting AP on the incidence of IE and found different results. Since these studies are mostly observational, researchers could not establish a causal link between the limitation of AP and the change in the incidence of IE. Until the subject is clarified with randomized-controlled studies, dental professionals should periodically visit guidelines for updates on AP.

Keywords: Infective endocarditis, antibiotic prophylaxis, dentistry.

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INTRODUCTION

Although infective endocarditis (IE) is a form of endocarditis usually caused by bacteria, other microorganisms may also be involved. Annual incidence ranges from 3 to 9 cases per 100,000 of the population, based on results reported in developed countries.[1] IE affects newborns, infants, children, young adults, and pregnant women, and the incidence increases after the age of 30, exceeding 10 per 100,000 over the age of 50.[2] The clinical picture of IE is not specific and includes high fever, weakness, weight loss, shortness of breath, new or changed heart murmurs, and skin rash. Although findings such as Roth spots in the eyes and Osler nodes and Janeway lesions on the skin can be seen rarely in young children, extracardiac symptoms such as septic embolization and thromboembolic complications are common in young people.[3]

Because of the significant mortality and morbidity associated with increased IE, the first guideline was published in 1955 by the American Heart Association (AHA). To prevent IE, prophylactic administration of antibiotics is generally considered appropriate in patients with predisposing cardiac conditions who have undergone invasive procedures causing bacteraemia.[4] AP recommendations changed over time. Before 2007, AHA guidelines recommended AP for those who underwent invasive dental treatments considered to be high or intermediate risk for IE. In AHA and European guidelines published after 2007, it was reported that it should be given only to people at high risk.[4-7] However, in 2008, the UK's National Institute of Health and Clinical Excellence (NICE) guidelines took a more radical decision, recommending discontinuation of AP for all patients undergoing dental and other invasive procedures.[8] The decision to AP restrictions or to cease altogether is mainly based on the absence of placebo randomized controlled trial results to determine assessments on the effectiveness and cost of AP. Other reasons include the emergence of bacterial resistance strains and the risk of drug side effects.[7,9]

However, a trend towards an increased incidence of IE was reported in some studies done in the UK after the 2008 NICE guidelines and in the US and Germany following the implementation of the 2007 and 2009 guidelines. This suggests that invasive dental procedures may be effective in the development of IE.[10-12] The purpose of this review is to evaluate the change in the incidence of IE after guideline revisions since 2007 and the current antibiotic prophylaxis approach in dentistry.

METHOD

This review was prepared in accordance with the PRISMA statement.

Focus question; What is the result of the guideline changes after 2007 for AP of IE before invasive dental procedures in high-risk patients?

Search strategy; The systematic way was performed to look up for relevant information through several kinds of literature and search engines with great concern to main question. This investigation was accomplished in December 2019 and applauded with new information until April 2020. A web search was conducted with terms and/or different combinations (infective endocarditis, antbiotic prophylaxis, dentistry, guideline, incidence) through search engines such as PubMed, Ovid Medline, Clinical key, Google Scholar and Google.

Inclusion criteria; Articles, review, meta-analysis, randomised controlled trial, publications carried out on human subjects from offcial organisation and guidelines relased within 13 years from 2007 to 2020 with English Language.

Exclusion criteria; Articles that involved the different clinical applications of AP excluding dental treatments and case reports

Review articles; Articles were categorized into two main groups (free and restricted). Free-ones have been downloaded directly by the URLs generated from the database. The restricted group has been downloaded by the institutional access of the Sivas Cumhuriyet University library. Even though some articles didn't match the main idea, they have been reviewed again and decided to be either relevant or irrelevant. The reference was checked to identify any studies that haven't been covered by electronic searches.

Epidemiology, Risk factors and Microbiology of Infective Endocarditis

IE is the fourth leading infectious cause of death worldwide, following sepsis, pneumonia and intra-abdominal abscesses[12] with the incidence of 3-9 cases per 100.000 people.[1] The incidence of IE varies significantly by countries and regions.[13] This may be sourced from genetic tendency, poor dental hygiene, immunologically host susceptibility, congenital and rheumatic heart disease, intravenous drug usage, degenerative or prosthetic valve disease, intracardiac devices, adherence of guideline rules and development state of countries. However, it is reported that 50% IE cases has not cardiac valvular lesion before.[14]

IE is an acute disease with a relatively high mortality rate and often characterized by Staphylococcus aureus infection. Given the antimicrobial resistance of Staphylococcus aureus, including vancomycin, this pathogen, which may be a potentially fatal infection source, is of concern.[15]

The incidence study of IE has not been conducted in Turkey, but it may be suggested to be higher. Because high-risk groups have frequent presence of predisposing cardiac disorders and higher rates of nosocomial bacteraemia. But, unlike developed countries IE more often seen in young population in Turkey.[16] A evalution of epidemiological characteristics of IE cases in Turkey and the USA and Europe is seen in Table 1.

Table 1: Evalution of epidemiological and clinical characteristics of patients with infective endocarditis in Turkey and USA/Europe[16]

Feature	Turkey	USA/ Europe
Age, years (mean)	47	61
Male (%)	60	65
Predisposing conditions (%)		
Acute rheumatic fever	37	1.85
Prosthetic valve	28	10-30
Intravenous drug use	2	24
Cardiac implantable electronic device	7	15
Chronic hemodialysis	9	13
Causative microorganisms (%)		
Staphylococcus auerus	21	32
Viridans streptococci	19	18
Coagulase negative staphylococci	10	11
Enterococcus spp.	9	11
Brucella spp.	7	-
Blood culture negative (%)	37	8
Nosocomial endocarditis (%)	25	25
Mortality (%)	24	19

The microbiology of IE has changed over time, and staphylococci, often associated with healthcare contact and invasive procedures, have surpassed streptococci as the most common cause of the disease.[17] The most common causative bacteria are Staphylococcus aureus, streptococci, coagulase-negative staphylococci, and enterococci, both in Turkey and USA/Europe (Table 1). Gram-negative bacilli and fungi are generally causative pathogens of healthcare-associated IE. For patients who have been implanted with an intracardiac prosthetic device such as a prosthetic heart valve in the last decade, Mycobacterium chimaera is a possible pathogen for IE.[14] Also, it is thought that the collagen binding protein of Streptococcus mutans that is the cause of dental caries, may be one of the potential important factors associated with the pathogenesis of IE.[18]

Pathogenesis and Mortality of Infective Endocarditis

Normal healthy endocardium lining of the heart naturally is resitant to colonization by bacteria to adhere to the these surfaces. However, once endothelial injury occurs via turbulent flow of blood such as through a stenotic valve or congenital lesion, prosthetic heart valve, previous history of endocartditis, or may be provoked by electrodes, catheters, or repeated intravenous injections by drug users. These make release of inflammatory substances, including cytokines and other tissue factors, lead to platelet and fibrin-rich thrombus formation, which serves as a nidus for bacterial infection called nonbacterial thrombotic endocarditis (NBTE). Mucosal surfaces of the body are populated by endogenous microflora and damage to these surfaces (caused by dental or medical procedures or daily activities such as chewing or brushing) creates a pathway for microbes to enter the bloodstream. When bacteria are introduced into the bloodstream by this way, they can adhere to the platelet-fibrin thrombus and replicate within the NBTE. Bacteria also stimulate further fibrin and platelet deposition and endothelial injury, leading to formation of a vegatation. Complication and progression of the vegatation cause impaired valve function, valve perforation, abscess formation, chordal rupture, conduction system involvement, embolization and heart failure.[7,19]

In Turkey, the mortality rate in patients with IE is higher than in developed countries and is close to 30%.[20] It is doubtless that mortality rates can be reduced by eliminating the lack of knowledge of the physicians who follow these patients and by establishing and implementing standard diagnosis and treatment protocols. Moreover, the role of dentists in preventing this disease should not be forgotten.

The Impact of Changing Antibiotic Prophylaxis Guidelines after 2007-2008

The guidelines suggesting AP for prevention of IE are based on three main observation; 1- bacteraemia has been accepted as a reason of IE, 2- Viridans group streptococi (VGS) can be cause serious bacteremia and, 3- these microorganism are susceptible to commonly used antibiotics. But, there was no placebo randomized controlled trial evidence to support the efficacy of AP and their assesment of the lack of cost effectiveness and other reasons include developing of bacterial resistance strains and risk of adverse drug reactions.[7,9]

Due to the paradigm change that started in the guidelines on AP in 2007, some researchers have tried to investigate the effect of this change on the incidence of endocarditis. After the implementation of the new guidelines, some studies did not show an increase in the incidence of IE[21-25], although other studies have raised concerns about the increased incidence of IE.[10-12,26,27] After complete AP cessation in England with NICE guideline in 2008, the incidence of IE significantly increased within 5 years. Therefore, they made a subtle change in 2016 to indicate that AP shouldn't be "routinely" recommended for dental procedures.[28] Because daily activities such as regular tooth brushing can cause recurrent bacteraemia from the oral flora, which almost certainly poses a greater risk of IE than a single dental procedure.[8]

In the studies dealing with VGS which is commonly accepted as a indicator of oral cavity etiology of IE, Bizmarck *et al.*[29] reported a significant increase in IE caused by VGS for ages 10 to 17 after guideline changes, but no impact on IE incidence comparing pre & post guideline in US in the period 2001–2012. Another study[11] from US in period of 2000 to 2011 reported significantly increase in IE incidence caused by streptococci. Also, it was reported an increase from Netherland in the years from 2005 to 2011.[26] However, there were no change or increase about VGS in the etiology of IE in other studies involving the impact of guideline changes.[23-25,30-32] Rheumatic heart disease caused by streptococci and acute rheumatic fever are important public health concerns worldwide, and there is still a significant burden of disease, especially in developing countries.[33] Most paediatric cardiologists have encountered children with bicuspid aortic valve affected by IE, due to VGS, who showed a clinical course similar to that of high-risk patients and resulted in increased need for surgery. In the light of these data, Zegri-Reiriz *et al*.[34] reported that these patients should be considered as "high risk " group and should be treated under AP administration. However, all of the researches after guideline changes contain one or more shortcomings of the following: Small sample size, short follow-up time, subpopulation researches with different risk factors, or exposure to invasive dental treatments compared to the general population, difficulties in accurately identifying IE caused by oral VGS and lack of data on AP administration. So, it is difficult to shown any causal link between restriction of AP and incidence of IE from any one or a combination of these studies. However, Dayer *et al*. stated that the evidence was taken as a whole, and that it was impossible to exclude the possibility of AP's influence, albeit small. In addition, there are serious concerns about the development of antibiotic resistance (AR) and increasing healthcare costs. But AP is low-priced and the recommended doses of antibiotics are likely to minimise the development of AR. In other words AP, especially amoxicillin, appears to be safe.[35,36]

The American Academy of Pediatric Dentistry has published guidelines stating that it is preferable to complete all dental treatments before starting immunosuppressive therapy in patients who will be treated with immunosuppressive and/or radiation therapy. Also stated that elective dental care should not be performed during the period of immunity suppression.[37] The neutrophil count can guide the decision to necessity AP during dental treatments. It was recommended to consider AP in patients with absolute neutrophil counts between 1000-2000/mm^3 according to AHA guidelines. If the patient's neutrophil count is less than 1000/mm3, dental treatments should be delayed or it is recommended to discuss necessity of AP with the medical team before continuing treatment.[38] Also, chlorhexidine mouthwash alone should not be recommended as a prophylaxis against IE to patients at risk of IE undergoing dental procedures.[8]

According to current guidelines, intermediate and low risk patients should probably avoid AP for dental procedures that involve manipulation of the gingiva or periapical region of the teeth or involve perforation of the oral mucosa. But, AP is strongly recommended in high risk patients undergoing medical procedures with bacteraemia. The recommended regimen for AP is shown in Table 2.

Table 2: Current guidelines on antibiotic prophylaxis to prevent infective endocarditis (IE)[39]

2007 AHA Guidelines	2015 ESC Guidelines	2015 NICE Guidelines with 2016 Amendment
Those Recommended for Antibiotic Prophylaxis Cover		
Those at highest risk of an adverse outcome from IE	Those at highest risk of IE undergoing a high-risk procedure	Antibiotic prophylaxis against infective endocarditis is not recommended routinely for people undergoing dental [or other] procedures. (‘routinely’ added 2016)
Those at Highest Risk of Adverse Outcome from IE	**Those at Highest-Risk of IE**	**Those At Risk of Developing IE**
• Prosthetic cardiac valve or prosthetic material used for valve repair • Previous IE • Unrepaired cyanotic CHD, including palliative shunts and conduits • Completely repaired congenital heart defect with prosthetic material	•Patients with any prosthetic valve, including a transcatheter valve, or those in whom any prosthetic material was used for cardiac valve repair •Patients with a previous episode of IE •Any type of cyanotic CHD •Any type of CHD repaired with	• Acquired valvular heart disease with stenosis or regurgitation • Valve replacement • Structural congenital heart disease, including surgically corrected or palliated structural conditions, but excluding isolated atrial septal defect, fully repaired ventricular septal defect or fully repaired patent

or device, whether placed by surgery or catheter intervention during the first 6 months after the procedure • Repaired CHD with residual defects at the site or adjacent to the site of a prosthetic patch • Cardiac transplantation recipients who develop valvulopathy	a prosthetic material, whether placed surgically or by percutaneous techniques, up to 6 months after the procedure or lifelong if residual shunt or valvular regurgitation remains after the procedure	ductus arteriosus, and closure devices that are judged to be endothelialised • Previous infective endocarditis • Hypertrophic cardiomyopathy.
Moderate/Intermediate-Risk		
	•Patients with a previous history of rheumatic fever •Patients with any other form of native valve disease (including: bicuspid aortic valve, MVP and calcific aortic stenosis) •Patients with unrepaired congenital anomalies of the heart valves	
High-Risk Procedures for which Antibiotic Prophylaxis Should Be Considered		
• All dental procedures that involve manipulation of the gingival tissue or the periapical region of teeth or perforation of the oral mucosa*. • Procedures on respiratory tract or infected skin, skin structures or musculoskeletal tissue	Antibiotic prophylaxis should only be considered for dental procedures requiring manipulation of the gingival or periapical region of the teeth or perforation of the oral mucosa*.	Advice not given
Recommended Antibiotic Prophylaxis Regimen (for those not allergic to penicillin)		
Amoxicillin 2g orally 30-60 mins before the procedure**	Amoxicillin 2g orally 30-60 mins before the procedure**	Advice not given
Recommended Antibiotic Prophylaxis Regimen for those Allergic to Penicillin		
Clindamycin 600mg orally 30-60 mins before the procedure**	Clindamycin 600mg orally 30-60 mins before the procedure**	Advice not given

However, some dental procedures do not require AP. Examples of these are routine anesthetic injections into non-infected tissues, dental x-ray, placement of removable prosthesis or orthodontic appliances, adjustment of orthodontic appliances and placement of orthodontic brackets. Also, the dentists should emphasise the importance of maintaining good oral health to patients. For optimal oral health, moderate-risk patients are recommended to be examined once a year, while high-risk patients should receive professional dental care twice a years.[6]

CONCLUSIONS

Consequently, dentists may not always aware of the IE risk in their patients because of unavailable medical documentation and insufficient anamnesis. From the legal framework, a collaboration with cardiologist and follow up current guidelines is important to achive the goal of IE prevention in dentistry.

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None

CONFLICT OF INTEREST STATEMENT

None

ÖZ

Enfektif endokardit (EE), yüksek morbidite ve mortaliteye sahip önemli bir kalp hastalığıdır. Mevcut kılavuzlar, yüksek EE riski olan bireylere antibiyotik profilaksisini (AP) önermektedir. Bu yüksek riskli hastalar, EE geçmişi, biyolojik veya mekanik prostetik kapak veya cerrahi olarak oluşturulmuş sistemik veya pulmoner kanal/ şant olan hastaları içerir. AP'nin kısıtlanması, antibiyotik direnci ve günlük bakteremi insidansı ile ilgili artan kavrayışla ilgili endişelerden kaynaklanmaktadır. Birçok araştırmacı, AP'yi kısıtlamanın EE insidansı üzerindeki etkisini incelemiş

ve farklı sonuçlar bulmuştur. Bu çalışmalar çoğunlukla gözlemsel olduğundan, araştırmacılar AP'nin sınırlandırılması ile EE insidansındaki değişim arasında nedensel bir bağlantı kuramadılar. Konu randomize-kontrollü çalışmalarla netleşene kadar, diş hekimleri AP ile ilgili güncellemeler için periyodik olarak kılavuzları ziyaret etmelidir.

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Case Report

A MULTIDISCIPLINARY APPROACH FOR THE RESTORATION OF A CROWN-ROOT FRACTURE WITH THE INVOLVEMENT OF SUPRACRESTAL ATTACHED TISSUES A CASE REPORT WITH A 7-YEAR FOLLOW-UP

ABSTRACT

Restoration of crown-root fractures with the involvement of supracrestal attached tissues represents difficulties for clinicians, as these types of fractures require a multidisciplinary approach for adequate treatment and successful prognosis. Depending on the location of the fracture, different treatment approaches, such as periodontal crown lengthening procedures, rapid orthodontic or surgical root extrusion or tooth extraction followed by fragment reattachment, direct composite restorations, veneers, and crown restorations, have been indicated.

This case report describes the management and long-term follow-up of the reattachment of a crown-root fracture using unidirectional fiber reinforcement after periodontal crown lengthening. Clinical and radiographic examinations of the reattached tooth after 7 years revealed favourable functional, physiological, and aesthetic outcomes and healthy surrounding periodontal structures, showing the success of the multidisciplinary treatment approach.

Keywords: Dental trauma, complicated crown-root fracture, reattachment.

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INTRODUCTION

Dentoalveolar traumas are mainly caused by falling, fighting, sports, and car accidents and usually affect maxillary anterior teeth.[1,2] Crown fractures have been documented to account for up to 92% of all traumatic injuries in permanent dentition[3]; however, the incidence of crown-root fractures is reported to be approximately 5%.[4] Restorative treatment of crown-root fractures is difficult due to inaccessible subgingival fracture margins and the complex nature of the injury.[5] The fracture line level, the length of the remaining root segment, and the presence and condition of the tooth fragment determine the type of treatment.[7] Therefore, depending on the location of the fracture, different treatment approaches, such as periodontal crown lengthening procedures, rapid orthodontic or surgical root extrusion or tooth extraction followed by fragment reattachment, direct composite restorations, veneers, and crown restoration, have been indicated. Among these treatment approaches, priority should always be given to the reattachment procedure when the crown fragment after trauma is relatively intact and adapts well to the remaining tooth structure.[8,9] Reattachment is the most conservative treatment option for various restorative techniques and also offers colour, morphology and translucency matches, surface texture, and wear of the incisal edge at the same rate as the adjacent teeth. Moreover, it results in a positive psychological response in the patient and offers a reduction in the treatment costs.[7,9] Clinical success has been reported for the reattachment of tooth fragments using resin composites or cements with/without fiber reinforcement.[10,11]

With the development of adhesive systems and resin-based materials, during the treatment of crown fractures, the support of a post system placed into the root canal is not always mandatory. However, when the fracture involves more than two-thirds of the crown or when the patient exhibits a large overjet and/or parafunctional habits, post-placement should be considered.[9,12,13] Fiber-reinforced composites have been introduced at the beginning of the '90s and offer several advantages, such as aesthetics, reliable bonding to enamel and dentin, and a modulus of elasticity similar to that of dentin. Materials that have an elastic modulus similar to dentin (18.6 GPa) may enhance the clinical longevity of restorations[14], as they reveal a more balanced stress distribution under functional forces.[15]

The present case describes the successful multidisciplinary treatment of a complicated crown-root fracture of a maxillary central incisor with the involvement of supracrestal attached tissues over a 7-year follow-up period.

CASE REPORT

A 30-year-old female was referred to the Department of Restorative Dentistry with a fractured maxillary right incisor that was splinted after a car accident one week previously (Figure 1).

Figure 1: Initial situation of the crown-root fracture.

Clinical and radiographic examinations revealed that the tooth had a complicated crown-root fracture extending subgingivally at the buccal side and a loose palatal splint with inflammatory periodontal tissues due to heavy plaque accumulation (Figure 2).

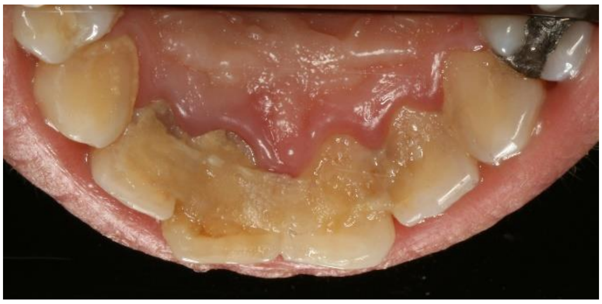

Figure 2: Palatal view revealed a loose splint with inflammatory periodontal tissues due to heavy plaque accumulation.

The tooth fragment was still attached by a soft tissue junction around the buccal aspect. The treatment alternatives were discussed with the patient, and upon agreeing on the reattachment of the crown fragment to the remnant tooth, informed consent was obtained from the patient.

Following local anaesthesia with 2% lidocaine and 1:80,000 epinephrine, the crown-root fragment (Figures 3, 4) was removed with minimal force from its soft tissue attachment and was stored in a physiological saline solution until the reattachment procedure.

Figure 3: Buccal view of the detached crown-root fragment.

Figure 4: Palatal view of the detached crown-root fragment

As the fracture was subgingivally located and extended apically to the bone crest, open flap surgery with osseous resection was performed. For the open flap procedure, an internal bevel incision was made at the buccal and palatal aspects of the involved tooth, and the incision was extended horizontally on each side. Then, a sulcular incision was made for gingival tissue removal. Following the reflection of the full-thickness mucoperiosteal flap, the distance between the fracture line and the alveolar bone crest was measured to be approximately 1 mm, violating the supracrestal attached tissues (Figure 5).

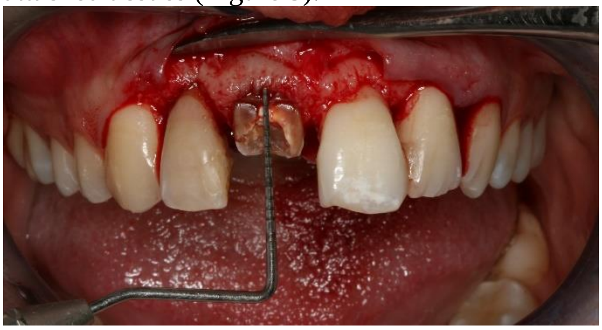

Figure 5: The distance between the fracture line and the alveolar bone is approximately 1 mm, violating the supracrestal attached tissues.

After osseous resection with a low-speed handpiece using copious amounts of saline irrigation was performed to remove and recontour the bone until a 3-mm distance between the bone crest and the fracture line (Figure 6), the base material in the pulp chamber was carefully removed with a high-speed air turbine.

Figure 6: Recontouring of the bone until there was a 3-mm distance between the bone crest and the fracture line.

Meanwhile, the tooth fragment was cleaned from all residual soft tissue and base material and was checked for its close adaptation to the tooth structure for reattachment. As freehand fragment alignment could be problematic, a thermoplastic stent was attached to the fragment during the checking and reattachment procedures (Figures 7, 8).

Figure 7: Attachment of a thermoplastic stent to the crown-root fragment for checking and reattachment procedures.

Figure 8: Removal all residual soft tissue and base material to expose enamel and dentin.

Then, a haemostatic agent (ViscoStat; Ultradent) was applied around the remnant root, which was followed by a self-etching primer application (Clearfil SE Bond Primer; Kuraray) for 20 seconds on the dentin surfaces. The enamel margins of the crown fragment were etched with phosphoric acid (K etchant; Kuraray, Japan) for 30 seconds, rinsed thoroughly with water and dried, whereas the self-etching primer (Clearfil SE Bond; Kuraray, Japan) was applied for 20 seconds on dentin and air-dried. Then, Clearfil SE Bond adhesive (Clearfil SE Bond Adhesive; Kuraray, Japan) was applied on both the enamel and dentin surfaces of the crown fragment and on the dentin of the remnant root and polymerized for 10 seconds using an LED light-curing unit with an intensity of 650 mW/cm2 (Bluephase; Ivoclar Vivadent, Schaan, Liechtenstein). A thin layer of a flowable composite (Clearfil Majesty Flow; Kuraray, Japan) was applied to the remnant root canal without polymerization, and a unidirectional preimpregnated fiber (EverStick C&B; GC) was pressed into the unpolymerized flowable composite (Figure 9).

Figure 9: Application of a unidirectional preimpregnated fiber into the unpolymerized flowable composite on the root fragment.

A micro-hybrid composite (G-aenial anterior; GC) was applied to the crown fragment, and then the fragment was placed on the fracture site and carefully aligned. After checking the smoothness of the margins, the composite was polymerized through the attached tooth for 60 seconds from both the facial and palatal sites (Figure 10).

Figure 10: Re-attachment of the crown-root fragment.

The surgical flaps were then closed with simple interrupted sutures (Figure 11).

Figure 11: Closure of the surgical flaps with simple interrupted sutures.

Thereafter, the occlusion was checked and finishing and polishing procedures were accomplished using fine burs (Acurata G+K Manhardt Dental 544#018) and polishing rubber (Enhance/PoGo, Dentsply).

Postoperatively, the patient was instructed to follow a soft diet and avoid brushing or biting in the operated area for 1 week. An antibiotic (amoxicillin-clavulanate, 1000 mg, twice a day for 5 days), analgesic (naproxen sodium, 550 mg, every 8 hours, as necessary) and mouth rinse (chlorhexidine gluconate 0.2%, twice a day for 4 weeks) were prescribed to prevent infection and pain. Sutures were removed after 1 week, and the patient was recalled every week for 1 month. A soft toothbrush was suggested with a roll technique. The clinical situation of the reattached tooth was confirmed by clinical assessments at 1 (Figures 12, 13), 2 (Figures 14, 15), 5 (Figures 16, 17) and 7 years (Figures 18, 19, 20, 21).

Figures 12 and 13: Clinical situation of the reattached tooth at 1 year.

Figures 14 and 15; Figures 16 and 17; Figures 18, 19, 20, and 21: The clinical situation of the reattached crown-root fragment at 1 year, 2 years, 5 years and 7 years, respectively.

DISCUSSION

For the treatment of traumatized teeth, several factors, such as the extent and pattern of fracture, pulpal involvement, stage of root development, alveolar bone fracture, involvement of supracrestal attached tissues, soft tissue injuries, fractured tooth fragment, occlusion and aesthetic properties, should be considered.[1,16,17] Regarding complicated crown-root fractures, there are several proposed treatment options, including periodontal crown lengthening surgery with open flap and osseous resection and orthodontic or surgical extrusion, which are followed by reattachment of the fractured tooth fragment, direct composite restorations, veneers, or crown restorations.[18,19]

Surgical crown lengthening and orthodontic or surgical extrusion of the remaining root are the most preferred methods for the re-establishment of supracrestal attached tissues. However, all of the described techniques have both advantages and disadvantages. Orthodontic or surgical extrusion will shorten the root length[20], while crown lengthening may create aesthetic problems.[21,22] In the present case, the fracture line was above the alveolar bone crest but extended subgingivally on the buccal aspect. Additionally, as the patient had limited time and an almost 1:1 width to length ratio in her maxillary teeth, open flap surgery with osseous resection was preferred. The first treatment option for the rehabilitation of a crown fracture should be reattachment when the crown fragment is retrieved following the trauma, is relatively intact, and adapts well to the remaining tooth structures.[7,8,9] Reattachment is the most conservative treatment option for various restorative techniques, as it offers colour, morphology and translucency matches, surface texture, and wear of the incisal edge at the same rate as the adjacent teeth. Reattachment of fractured incisal fragments using new-generation adhesive systems is considered to be effective against shear stresses, comparable with intact teeth.[23,24,25] Moreover, it results in a positive psychological response in the patient and offers a reduction in the treatment costs.[7,9] The limitation of this technique is principally due to the involvement of supracrestal attached tissue, which is defined as the sum of the epithelial and connective tissue attachment lengths.[26] Whenever this occurs, flap surgery with minimal osteotomy and osteoplasty was suggested to convert the subgingival fracture surface to supragingival[7] and to create a space for supracrestal attached tissues. It has been shown that adhesive fragment reattachment in periodontally healthy teeth had no detrimental impact on periodontal health over a time course of 2 years.[27] However, the potential threat to tooth survival following crown-root fracture and subsequent restoration with a post-core-supported crown is higher due to the subsequent fractures emanating from the root canal.[28]

The prognosis of the reattached tooth depends on the fitness, contour, and surface finish of the subgingival restoration, which may increase plaque retention.[8,29] Moreover, patient cooperation and maintenance of oral hygiene also affect the long-term prognosis of the restored tooth.[30] In the present case, the patient did not strictly follow the oral hygiene instructions, especially around the reattached tooth, and as a result, mild gingival inflammation was still evident even after the 1-year follow-up (Figure 12, 13). During the follow-up period, even though full-mouth plaque control was optimal, substantial plaque accumulation was also observed around the treated tooth due to the patient's fear of dislocation of the restored tooth. However, there were no unfavourable soft tissue reactions other than mild gingival inflammation throughout the follow-up period (Figures 12, 14, 16).

Based on the results of in vitro studies, the internal dentin groove technique generated the highest bond strength recovery in the reattached teeth; however, this value did not exceed 60% of an intact tooth's strength.[31] Conversely, removal of the pulp dentin from the fragment before bonding showed a greater increase in fracture strength.[32,33] It has been stated that there was no significant difference between the retention of a flexible fiber-bundle post system and a rigid prefabricated fiber post system.[34] However, glass fiber posts that are shorter than the clinical crown length demonstrated root fracture under a significantly lower loading force.[15] Therefore, in this case, a prefabricated fiber post was avoided, and an individual fiber-bundle structure was inserted into the pulp chamber to enhance fragment attachment and to create an intermediate structure between the dentin and the luting composite that resists functional forces. The physical properties of fiber-reinforced composites are dependent on the type of matrix, the type of fiber, the fiber distribution, the fiber/matrix ratio and the diameter and length of the fibers.[35] EverStick C&B, with an elastic modulus of 27 GPa, is composed of unidirectional continuous Bis-GMA- and PMMA-impregnated glass fiber, that are 1.5 mm in diameter and have 4000 individual glass fibers.[36] Unidirectional preimpregnated fiber was preferred to increase retention of the crown fragment to the remnant tooth and to distribute homogeneous stress along the root. This approach has been reported in the literature and provides a conservative and aesthetic treatment strategy.[37] However, randomized controlled clinical trials with long-term follow-up periods are necessary to substantiate the efficacy of the treatment.

CONCLUSIONS

The present case represents the management and long-term success of a reattached crown-root fragment along with unidirectional fiber reinforcement after surgical crown lengthening.

Clinical and radiographic examinations of the reattached tooth after 7 years revealed favourable functional, physiological, and aesthetic outcomes and healthy surrounding periodontal structures, showing the success of the multidisciplinary treatment approach. However, randomized controlled clinical trials with long-term follow-up periods are necessary to substantiate the efficacy of this type of treatment.

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None

CONFLICT OF INTEREST STATEMENT

The authors deny any conflicts of interest related to this study.

ÖZ

Suprakrestal bağ dokusunu içine alan kuron-kök kırıkları doğru tedavi ve başarılı bir prognoz için multidisipliner tedavi yaklaşımı gerektirdiğinden klinisyenleri oldukça zorlamaktadır. Bu tip komplike kuron kırıklarının tedavi alternatifleri kırığın lokalizasyonuna göre: periodontal kuron boyu uzatma, ortodontik olarak kök boyunun uzatılması veya dişin kırık parçasının çekimini takiben fragman reataşmanı, direkt kompozit restorasyonları, vener restorasyonları veya kuron restorasyonlarıdır. Bu olgu sunumu, komplike kuron-kök kırığının periodontal kuron boyu uzatma işlemi sonrasında fiberle güçlendirilmiş kompozitle reataşmanını ve bu tedavinin uzun dönem takibini anlatmaktadır. Reataşman yapılan dişin 1, 2, 5 ve 7 yıllık klinik ve radyografik takibi, dişin sağlıklı periodontal dokular ile birlikte fonksiyonel, fizyolojik ve estetik olduğunu ve multidisipliner tedavi yaklaşımının başarılı olduğunu göstermektedir. ***Anahtar kelimeler:*** *Travma, komplike kuron-kök kırığı, reataşman.*

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Case Report

PLATELET-RICH FIBRIN USED AS A SCAFFOLD IN PULP REGENERATION: CASE SERIES

ABSTRACT

Regenerative endodontic treatment (RET) is a biologically-based treatment approach aimed at providing root development and improving the prognosis of teeth. The purpose of this case series was to evaluate the clinical and radiological results of RET using platelet-rich fibrin (PRF) in 4 immature teeth with necrotic pulps. At the end of a 18-24-month follow-up, no clinical symptoms were recorded. Apical closure was observed in 3 of the 4 teeth. All of the preoperative periapical lesions were healed. However, a calcified tissue formed in the middle third of the root in one case diagnosed with chronic apical periodontitis at the 3-month follow-up. PRF was successful as a scaffold and can be recommended for revascularization protocol of necrotic immature teeth. However, the prognosis of tooth can be attributed to many factors such as the duration of pulp necrosis, pretreatment status of the periapical region, and the viability of living tissues.

Keywords: Immature teeth, platelet-rich fibrin, pulp necrosis, pulp regeneration, scaffold.

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INTRODUCTION

Regenerative endodontic treatment is a series of procedures aimed at restoring the function of dentin, root, and pulp-dentin complex damaged by trauma or caries by the transplantation or the stimulation of stem cells into the root canal.[1,2] Galler[1] reported the advantages of regenerative endodontic treatments over calcium hydroxide apexification and MTA apexification as (i) immuno-response and interstitial tissue pressure against invading bacteria and toxins, (ii) pain perception as a warning system, (iii) completion of root formation in young patients to strengthen thin dentine walls and prevent long-term complications, and (iv) the restoration of sound periradicular tissues.

Regenerative endodontic treatment includes the procedures of disinfecting the root canal, formation of a suitable tissue scaffold, providing support for the newly formed tissues, and sealing the root canal with a biomaterial.[1-4]

Tissue scaffold formation is achieved by inducing bleeding into the root canal in current regenerative endodontic treatment procedures.[4] However, the procedure may have certain drawbacks such as failure to initiate bleeding or inadequate bleeding in the root canal. Another disadvantage of apical bleeding is the injury of the periapical tissues during the push and pull motion of the file.[5-7] Recent studies have reported that the use of autologous fibrin matrices (Platelet-rich plasma-PRP, Platelet-rich fibrin-PRF) as a tissue scaffold produced promising results in clinical and radiological examination.[6,8-12] Platelet concentrates are blood-derived products in which the platelets are concentrated in a limited volume of plasma.[13] Although the blood clot contains more stem cells as it is obtained by bleeding the periapical tissues, there are more healing factors in matrices such as PRP and PRF.[10,13] PRF is prepared by the centrifugation of venous blood for once without the need for an anticoagulant material.[13] As it contains more immune cells than blood clot and PRP, PRF is reported to be more efficient in controlling the infection.[10,13] Moreover, compared to PRP, the slower release of growth factors of PRF is congruous to the healing pattern of pulp-dentin complex.[2,9] However, there is a limited number of cases in the literature in which PRF is used as a tissue scaffold.[9,11,14-18]

The purpose of this case series is to present the long-term follow-up of regenerative endodontic treatments using PRF tissue scaffold in four necrotic immature permanent teeth.

CASE REPORTS

Case report 1

An 8-year-old male patient with night pain was referred to the Department of Pediatric Dentistry. The patient had no significant medical history. Dental anamnesis revealed that he had fell down at school 4 days earlier, fracturing right maxillary incisor tooth. The tooth was restored in a clinic a day after the trauma; however, it was reported that spontaneous pain started the same night. The clinical examination revealed a composite resin restoration in the tooth (Figure 1a).

Figure 1a: Preoperative view of Case 1

There was positive response to percussion and palpation, and lingering pain response to electric (Digitest; Parkell, Farmingdale, NY, USA) and cold sensitivity tests (Chloraethyl, Wehr, Baden, Germany). Periodontal probing was within normal limits. Radiographic examination revealed an immature root with an open apex but no evidence of periapical rarefaction. (Figure 1b).

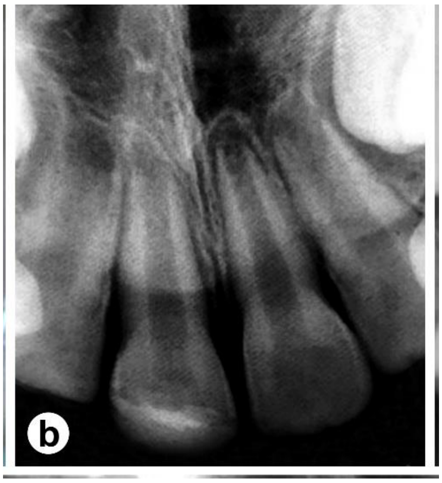

Figure 1b: Preoperative radiograph showing incompletely developed apex.

The tooth was diagnosed with acute apical periodontitis.

After informing the patient and his parents about the treatment modalities, regenerative endodontic treatment using PRF scaffold was planned. The American Association of Endodontists protocol was used as described below. Following the application of local anesthesia (2% lidocaine containing 1:100,000 epinephrine), the tooth was isolated with a rubber dam and the access cavity was prepared. The root canal was irrigated gently with 20 mL 1.5% sodium hypochlorite (NaOCl) solution followed by 20 mL sterile saline. The root canal was then dried with paper points. Equal proportions of ciprofloxacin (Cipro Biofarma, Istanbul, Turkey) and metronidazole (Flagyl Eczacibasi, Istanbul, Turkey) were ground and mixed with sterile saline to form a paste with a concentration of 0.1 mg/ml. This antibiotic paste was placed in the root canal below the cementoenamel junction by using a dental syringe. The access cavity was temporarily sealed with a sterile cotton pellet and restorative glass ionomer cement (Ionofil, Voco, Cuxhaven, Germany). After 3 weeks, the patient was asymptomatic. The tooth was anesthetized using mepivacaine without vasoconstrictor. After applying a rubber dam, the access cavity was reopened, the antibiotic mixture was removed by irrigation with 20 mL sterile saline, 20 mL 17% EDTA following by 5mL sterile saline and the root canal was dried with paper points.

For the PRF preparation, 10 mL of the patient's venous blood was collected in sterile tubes. The tubes were centrifuged for 10 minutes with a speed of 3,000 rpm. The fibrin matrix formed after centrifugation was taken from the tube and placed up to 2-3 mm apical of the cementoenamel junction with the help of a handpiece. The access cavity was then sealed with Biodentin (Septodont, Saint Maur des Faussés, France) and the tooth was permanently restored with reinforced glass ionomer cement (Ketac ™ Molar Easymix, 3M ESPE, Seefeld, Germany) and composite resin (Clearfil Majesty, Kuraray, Japan) (Figure 1c).

Figure 1c: The immediate post-treatment periapical radiograph

The patient was followed up regularly (Figure 1d-h). In the clinical and radiological controls, no symptoms were recorded, the periodontium was radiographically normal and apical closure was observed at the 18th month control. The patient is scheduled for further follow-up.

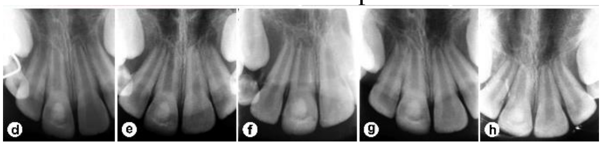

Figure 1d-g: 3-12-month follow-up radiographs
Figure 1h: At the 18-month follow-up, apical closure was evident

Case Report 2

A 9-year-old girl consulted to the Department of Pediatric Dentistry with the complaint of swelling in gums and pain. She had no significant medical history. The patient had a bicycle accident a year earlier, fracturing Tooth #11 which was restored 3 times in different dental clinics in one year. Intraoral examination revealed abscess formation in the gum and positive response in percussion and palpation at Tooth #11 (Figure 2a).

Figure 2a: Preoperative view of Case 2 showing an abscess formation in the gum of Tooth #11

Radiographic examination revealed the presence of a large periapical lesion with an immature root and an open apex (Figure 2b). The tooth was diagnosed with acute apical abscess.

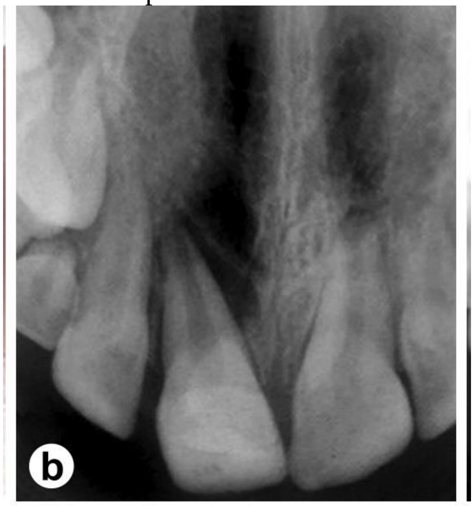

Figure 2b: Preoperative radiograph of Tooth #11 revealed the presence of a large periapical lesion with an immature root and an open apex

The patient and her parents were informed about treatment options and revascularization was planned by using PRF tissue scaffold. At first appointment, the access cavity was prepared, pus flow was provided through the root canal and the intraoral abscess was drained through the gum pocket. The root canal was irrigated with sterile saline and the tooth was sealed with a cotton pellet and Cavit (3M ESPE, Seefeld, Germany). The patient was recalled 2 days later and it was observed that the drainage of pus from the root canal stopped. The revascularization protocol was performed as specified in Case 1 (Figure 2c).

Figure 2c-g: 3-12-month follow-up radiographs

The patient was followed up regularly after the treatment (Figure 2d-h).

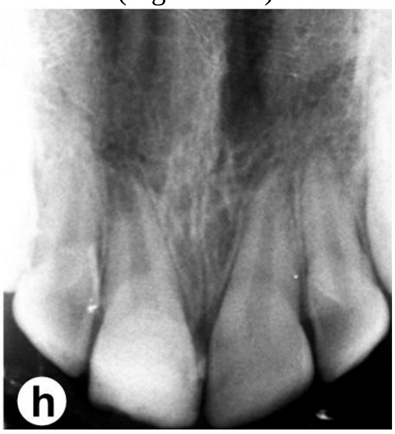

Figure 2h: At 18 months, complete healing of the periapical lesion can be appreciated, however no apical closure was observed.

Although the tooth functioned asymptomatically and radiographic healing at periapical lesion was present at the 12th month, apical closure has not been observed at the end of the 18th month. The patient's follow-up is still ongoing.

Case Report 3

A 9-year-old girl was referred to our clinic due to a fracture of the filling in the anterior tooth. The patient had no significant medical history. Her right maxillary incisor tooth was fractured in a bike accident 6 months earlier and the tooth was restored in a private clinic. Intraoral examination revealed that there were residues of pulp capping material on Tooth #11 (Figure 3a).

Figure 3a: Preoperative view of Case 3 showing a tooth fracture in Tooth #11

There was no history of pain in the tooth and no sensitivity to percussion or palpation. Teeth #11 and #21 did not respond to electric or cold sensitivity tests. Radiographic examination revealed that both teeth had periapical radiolucency with open apices (Figure 3b).

Figure 3b: Preoperative radiograph of Teeth #11 and #21 showing radiolucent lesions and open apices

The teeth were diagnosed with chronical apical periodontitis. After obtaining the informed consent, revascularization protocol was performed and PRF was used as a tissue scaffold (Figure 3c).

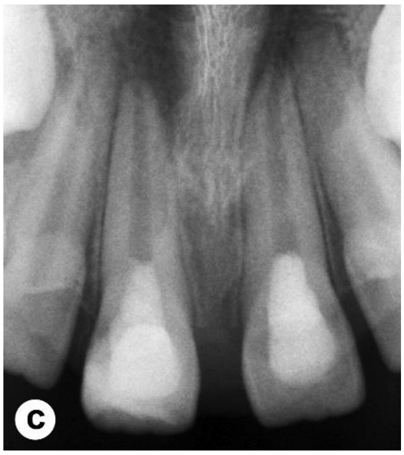

Figure 3c: Immediate post-treatment radiograph

At the end of the 24-month follow-up, it was observed that the periapical lesions were healed and root development was completed in both teeth, but a calcified tissue formed in the middle third of the root in Tooth #11 (Figure 3d-h). Follow-up examinations are continuing.

Figure 3d: 3-month follow-up radiograph revealed formation of a calcific barrier in the middle of the root at Tooth #11
Figure 3e: 6-month follow-up radiograph
Figure 3f: 12-month follow-up radiograph
Figure 3g: At the 18-month follow-up, bony healing was evident with complete root maturogenesis
Figure 3h: 24-month follow-up radiograph

DISCUSSION

Revascularization/revitalization treatment has generally been applied for young permanent teeth with immature apex and pulp necrosis as well as in the presence of periradicular lesions. Regenerative endodontic treatments are mainly performed in teeth diagnosed with pulpal infections that occur due to trauma, caries or developmental anomalies (e.g. dens evaginatus).[4] The requirements for regenerative endodontic treatment are the elimination of bacteria by effective canal disinfection, creation of a three-dimensional scaffold for the migration of stem/progenitor cells, and the prevention of bacterial reinfection with a good coronal seal.[1-3]

The bacteria remaining in the root canal after chemomechanical disinfection can be neutralized by root canal filling and a coronal sealing in conventional root canal treatments on mature teeth, whereas the clot formed in the root canal in revascularization treatments may promote residual bacteria to proliferate and develop bacterial biofilms. Therefore, long-term aseptic conditions should be provided in the root canal.[19,20] However, the most important disadvantage of revascularization is that canal disinfection involves only the use of chemical substances without mechanical preparation. It is known that the presence of residual bacteria has a critical negative effect on the outcome of root development.[20-22]

In most studies of regenerative endodontic treatments, successful clinical and radiographic results have been reported with long-term follow-up. However, intraoperative protocols regarding the use of intracanal medicaments for disinfection varies.[5,6,8,9,11,17,23] Low concentration of sodium hypochlorite, sterile saline solution and EDTA are generally used as irrigation agents and antibiotic mixtures or calcium hydroxide paste could be used for further disinfection. It is critical to maintain the viability of stem cells while ensuring adequate disinfection.[20,21] In this case series, following the irrigation protocol in line with the recommendations of AAE[4], double antibiotic paste that does not contain minocycline was preferred. A mixture of aerobic and anaerobic species of bacterial communities participates in the infection of the root canal system resulting in the subsequent periapical inflammation in immature permanent teeth with an open apex. Therefore, topical use of the combination of antibiotics disinfects the canal more effectively and at the same time reduces the possibility of developing antibiotic resistance.[24] Researchers have warned that the use of high concentrations of antibiotics in regenerative endodontic therapy may be toxic to the living tissue.[2,7] For these reasons, double antibiotic paste used in this case series was prepared in a form diluted at the rate of 0.1 mg/ml. Successful treatment results in the long-term follow-up of the cases indicate that the necessary disinfection is provided.

Several studies have reported successful results in regenerative endodontic treatments using blood clots induced by apical bleeding.[23,25] However, autologous platelet concentrates such as PRF and PRP could be used to create a tissue scaffold with or without blood clots.[8,9,11,17,26]

Although it has been reported that there is no difference in clinical success between the types of tissue scaffolds[8,11,16], it has been determined in histological studies that autologous platelet concentrates give better results due to the high rate of released healing factors.[2,10]

PRF releases growth factors at a slower rate than PRP, contains more immune defense cells, provides good support for the calcium silicate-containing agent to be placed on it, and does not require an external agent to coagulate.[10,13,16] PRF is also associated with slow and continuous increase in cytokine levels and contains more leukocytes compared to PRP and blood clot which makes PRF more effective in the presence of infection.[10] In this case series, the use of PRF as a tissue scaffold was deemed appropriate due to the presence of acute infection in two teeth and the presence of a chronic long-term infection in two teeth.

In a meta-analysis comparing the clinical results of PRF, PRP and blood clot, it was reported that the rate of apex closure was higher in the PRP and PRF groups compared to the blood clot group after one-year follow-up.[27] However, there are also cases where no obvious changes in root wall thickness, root length or apex closure was observed using PRF scaffold.[17] It is considered that the severity of apical periodontitis and trauma, and the duration of pulp necrosis could reduce regeneration capacity as a result of the possibility of increased damage to the living tissues required for regeneration in case of long-term necrosis.[28,29] Kahler *et al.*[29] have reported that the apical closure was assessed as incomplete in 47.2% of cases in a clinical study carried out on 16 teeth. Considering the studies that claimed that the root growth potential depends on the viability of Hertwig epithelial root sheath cells, the success of the treatment depends on the history of trauma and duration of pulp necrosis.[6,28,29] Although the use of PRF tissue scaffold is preferred to accelerate the healing, there is a long history of trauma and pulp necrosis in Case 2 depending on the periapical lesions observed, where there is no closure at apex after long-term follow-up.

The primary goal of the regenerative endodontic treatments is described to be the elimination of symptoms and the evidence of bone healing. The secondary goal is to obtain increased root wall thickness and/or increased root length which are defined as desired but not mandatory. It is stated that the presence of bone healing and disappearance of symptoms in the apical region is an acceptable success even without completed root development.[3,4] Lin *et al.*[30] have reported that, whilst further root maturation is considered a successful outcome for teeth treated with revascularization/revitalization procedures, the primary objective should be the resolution of the signs and symptoms of apical periodontitis. It has also been reported that it is possible to deem the procedure a success by having the tooth act as a space maintainer until a suitable restorative option is available. Sensation of pain, the appearance of pathological findings in soft tissue or increased apical radiolucency are considered to be failure.[1,3] In this case series, although root development was not completed in Case 2, no further treatment was needed and the patient was followed due to the absence of signs of a progressive infection in periapical tissues and no clinical symptoms.

In Case 3, a calcific barrier was observed in the middle third of the canal. This result is a complication reported in previous studies.[8,31] It has been reported that in cases where pulp tissue is completely lost periodontal tissue cells from the apical opening may migrate into the canal and stem cells may be a pioneer in the formation of cement-like tissue.[31] As the Biodentine material used in the treatment is mainly composed of calcium and silica, the release of Ca ion forms the basis of the bioactivity reactions of the material. This stimulates the formation of cell group in the osteogenic phenotype, and it might have resulted in the formation of the calcific barrier in the middle third of the canal.[32]

CONCLUSIONS

Although PRF has certain disadvantages such as need for special tools and blood collection from young patients, on the basis of long-term clinical and radiographic observations, it was found to be useful in constructing a scaffold for revascularization in the successful treatment of necrotic immature teeth with trauma history. However, prognosis of tooth can be attributed to many factors such as duration of pulp necrosis and viability of living tissues. Further clinical studies are needed to authorize the best tissue scaffold related to the pretreatment status of the tooth and the surrounding periapical tissues.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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None.

ÖZ

Rejeneratif endodontik tedavi, kök gelişimi tamamlanmamış ve pulpa nekrozu gerçekleşen genç daimi dişlerde kök gelişiminin devamını sağlamak ve dişlerin uzun dönem prognozunu arttırmak amacıyla uygulanan biyolojik temele dayalı bir tedavi yaklaşımıdır. Bu vaka serisinde, nekrotik pulpalı 4 immatür dişte trombositten zengin fibrin (PRF) kullanılarak uygulanan rejeneratif endodontik tedavinin klinik ve radyografik takiplerinin sunulması amaçlanmıştır. 18-24 aylık takipler sonucunda tedavi öncesinde görülen periapikal lezyonların tamamının iyileştiği ve 4 dişin 3'ünde apikal kapanmanın sağlandığı gözlemlenmiştir. Ancak kronik apikal periodontitis tanısı alan bir olguda 3. ayda kökün orta üçlüsünde kalsifiye doku oluşumu saptanmıştır. PRF'nin nekrotik dişlerin revaskülarizasyon protokolünde doku iskelesi olarak kullanımının başarılı sonuçlar verdiği; ancak dişin prognozunun pulpa nekrozunun süresi, dişin tedavi öncesi durumu ve periapikal bölgedeki dokuların canlılığı gibi birçok faktöre bağlı olduğu düşünülmektedir. ***Anahtar Kelimeler:*** *İmmatür diş, plateletten zengin fibrin, pulpa nekrozu, pulpa rejenerasyonu, doku iskelesi.*

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