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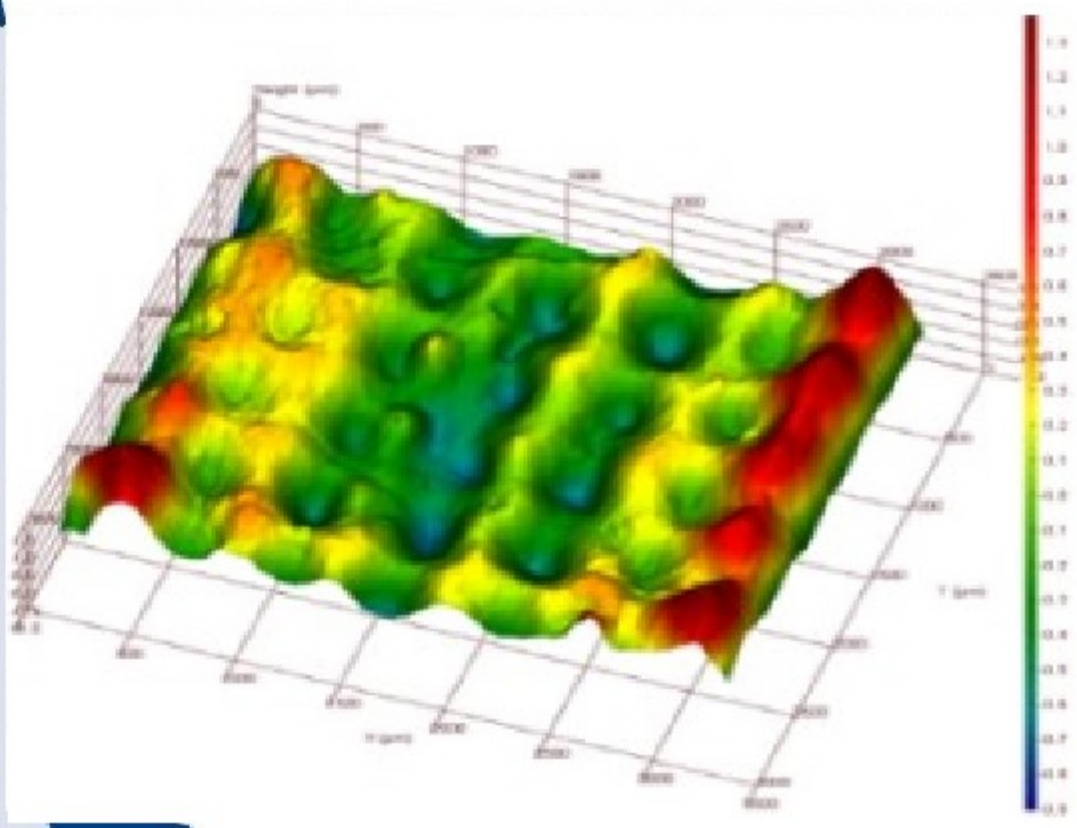

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Investigation of the Effect of Mouthwash on Bonding Temporary Crown Materials with Various Temporary Cements

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ABSTRACT

Objectives: This study aimed to investigate the effects of surface treatments and mouthwash on the shear bond strength of various temporary restorative materials using temporary cements.

Material and Methods: A total of 252 samples, measuring 10 mm in diameter and 2 mm in thickness, were prepared from three different temporary restorative materials, including polymethylmethacrylate with the CAD/CAM technique (Tempo Cad). and polymethylmethacrylate with the conventional method (Imicryl), nano-filled bis-acrylic composite (Protemp). Each temporary crown material was randomly divided into three separate groups, and surface treatments were applied. (Group1: no surface treatment, Group 2: air abrasion, Group3: hydrofluoric acid etching.) Two types of temporary cements (Tempbond and Dycal) were bonded to the surfaceof samples. Half of them were kept in mouthwash, while the other half were kept in distilled water as a control group (n=7). Shear bond strenght values of specimens were measured. To analyze the data, the Shapiro-Wilk test was used to assess compliance with a normal distribution. The data was then evaluated using a 3-Way Variance Analysis and a post-hoc multiple comparison test.

Results: The analysis of variance revealed that the interaction between the material used, the type of cement, and the material*cement*mouthwash was statistically significant ($p<0.001$). Additionally, the interaction between the mouthwash, material*mouthwash, and the mouthwash*cement was also found to be statistically significant ($p<0.05$).

Conclusions: Within the limitations of this in vitro study, it was found that sandblasting surface treatment increased shear bond strength. Mouthwash had a positive effect on the shear bond strength of polymethylmethacrylate-based temporary crown materials when calcium hydroxide-based temporary cements were used (CAD/CAM Group 1Bd, Group 2Bd and Imicryl Group 1Bd, Group 2Bd, Group 3Bd).

Keywords: Temporary Dental Restoration, Luting Agents, Dental Bonding, Surface Properties, Mouth Wash.

Gargaranın Geçici Kron Malzemelerinin Çeşitli Geçici Simanlarla Bağlanmasına Etkisinin Araştırılması

Süreç

Geliş: 02/01/2023
Kabul: 13/12/2023

ÖZ

Amaç: Bu çalışma farklı geçici restoratif materyallerin geçici simanlarla bağlanma dayanımına yüzey işlemleri ve ağız gargarasının etkisinin değerlendirilmesi amacıyla yapılmıştır.

Gereç ve Yöntemler: Üç farklı geçici restoratif materyal (polimetilmetakrilat esaslı CAD/CAM ile üretilen (Tempo Cad.) ve polimetilmetaktilat esaslı konvansiyonel metodla üretilen (Imicryl), kompozit esaslı (Protemp)) kullanılarak 10 mm çapında ve 2 mm kalınlığında toplam 252 örnek hazırlandı. Her bir geçici kuron materyali rastgele üç ayrı gruba ayrıldı ve yüzey işlemleri uygulandı (Grup 1: yüzey işlemi uygulanmayan grup, Grup 2: kumlama uygulanan grup ve Grup 3: hidroflorik asit uygulanan grup). Her yüzey işlem grubunun yarısına Tempbond, diğer yarısına Dycal geçici simanı uygulandı. Bu alt grupların da yarısı gargarada bekletildi; diğer yarısı distile suda bekletildi (n=7). Bağlanma dayanımı testi uygulandı. Normal dağılıma uygunluğu, verilerin Shapiro-Wilk testi ile incelenen verilerin analizi 3'lü varyans analizi ve çoklu karşılaştırma testi ile değerlendirildi.

Bulgular: Varyans analizi sonucunda; kullanılan materyal, siman türü ve materyal*siman*gargara etkileşiminin anlamlı ($p<0,001$), gargaranın, materyal*gargara ve gargara*siman etkileşimin istatistiksel olarak anlamlı ($p<0,05$) olduğu saptanmıştır.

Sonuçlar: Bu in vitro çalışmanın sınırlamaları dahilinde, kumlama yüzey işleminin, bağlanma dayanımını artırdığı tespit edilmiştir. Ağız gargarası, kalsiyum hidroksit esaslı geçici simanların kullanıldığı polimetilmetakrilat esaslı geçici kuron materyallerinde bağlanma dayanımına olumlu etki göstermiştir (CAD/CAM Grup 1Bd, Grup 2Bd and Imicryl Grup 1Bd, Grup 2Bd, Grup 3Bd).

Anahtar Kelimeler: Geçici restoratif materyaller, Geçici simanlar, Bağlanma dayanım direnci, Yüzey işlemi, Ağız gargarası.

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Introduction

Fixed prosthesis applications mostly involve tooth preparation using acrylic until the permanent restoration is delivered. In some cases, temporary restorations made of composite resin may be used. Temporary restorations serve to protect the prepared teeth from external factors and maintain the proper positioning of the teeth, ensuring the continuity of chewing function. It is essential for temporary restorations to maintain their physical integrity in the mouth in order to preserve the continuity of soft tissues and ensure the success of the planned treatment.[1]

Materials that can be used for fixed temporary prosthesis include polymethylmethacrylate (PMMA), urethane dimethacrylate (UDMA), polyethyl methacrylate, polyvinyl methacrylate, and bis-acryl composite resin materials.[2] PMMA and bis-acryl composite resin materials are commonly used in prosthetic dentistry.[3] These temporary restorative materials can be produced using conventional methods and can be polymerized using chemical, light, or both light and chemical methods.[4] Conventional methods for production include direct production in the oral environment or indirect production in the laboratory.[5] Additionally, digital design and production with CAD/CAM have significantly increased in recent years.[6]

Tooth preparation for fixed prosthetic restorations may be terminated at the gum margin or at the subgingival or supra-gingival margin. In tooth preparation, it is important to preserve the gingival tissues until the fixed prosthesis is cemented. The continuity of periodontal tissues is important for achieving an aesthetic appearance and ensuring the longevity of restorations. Thus, a proper temporary restoration is just as important as developing the patient's home care skills. In cases where oral hygiene cannot be maintained, the presence of gingival inflammation can lead to the deterioration of periodontal health. This can also result in the functional and aesthetic failure of restorations, as it can alter the color and shape of the gingiva.[7]

Mouthwashes with antimicrobial activity are used to control infections in the mouth, as well as to manage plaque and maintain the health of periodontal tissues. For this purpose, mouthwashes containing chlorhexidine gluconate and benzydamine hydrochloride are frequently preferred.[8] During prosthetic rehabilitation, especially for individuals who have undergone radiotherapy and chemotherapy, where the prevention of infection is crucial, the use of antibacterial agents such as mouthwash may be necessary until the final prosthesis is attached to the mouth after tooth preparation.[9]

Mouthwashes, which can be obtained from pharmacies without a prescription, contain organic acids, salts, antimicrobial agents, and dyes.[10] The hydroxyl groups found in alcohols such as Zr+4, Si+4 and Zn+2 can react with the cations of the composites. They dissolve in liquids and cause material loss.[11,12] Additionally, it is believed that benzydamine hydrochloride, an organic acid, can alter the surface of ceramic composites.[12]

Adhesive cements play a crucial role in enhancing the durability of restorative materials against the forces exerted during chewing in the oral environment.[13] Temporary cements, typically composed of a base and catalyst, commonly include calcium hydroxide and zinc oxide. There are also dual-cure temporary cements that are considered translucent resins.[14]

Cements should provide sufficient adhesion and sealing properties and should not be affected by fluids in the oral cavity. When removing restorations, it is preferable for the cements to remain on the restoration rather than the tooth, and for them to be easy to clean outside of the mouth.[14] This is why it is important to choose temporary cements that bond well to the restoration but have a weaker bond to the dentin. This helps to reduce the time spent with the patient during the trying on session.

Many factors are important for the success of restorations. Although *in vitro* studies have investigated the shear bond strength of cements to restorative materials, no study has been found that evaluates the effect of mouthwashes, which are frequently used in clinical practice, on this resistance. It is also observed that the impact of various surface treatments on the adhesion of temporary cements to temporary restorations has not been assessed. However, it is important to determine whether the use of a mouthwash, intended for maintaining the health of periodontal tissues, affects the shear bond strength when different surface treatments are applied. This is particularly relevant in the treatment of gingival damage that may occur both prophylactically and during the initial preparation period while temporary prostheses are in place in the oral cavity.

The aim of the current study was to assess the impact of surface treatments and mouthwashes on the shear bond strength of various temporary restorative materials using temporary cements.

The null hypothesis (H0) of this study is that the use of mouthwash will decrease the shear bond strength between temporary cements and temporary restorations. The H1 hypothesis is that surface treatments will enhance the shear bond strength.

Material and Methods

This study was approved by the Ethics Committee during the meeting held at Atatürk University Faculty of Dentistry (Date: 03.09.2021 Issue No: 50).

In the main hypotheses of the research, the differences, and interactions between multiple-group independent parameters (with 8 degrees of freedom and 3 parameters) were planned to be investigated, and the sample size was calculated at a 95% confidence level using the G Power-3.1.9.2 program. According to the analysis result, the minimum sample size calculated as 249, based on a theoretical power of 0.80, α value of 0.05, and a standardized effect size of 0.25. The sample size was taken as 252 to ensure that the number of observations in the groups was equal.

In the study, a total of 252 specimens were prepared from three different temporary restorative materials. Each specimen had a diameter of 10 mm and a thickness of 2 mm. The specimens were divided into three groups, with 84 pieces of Tempo Cad., 84 pieces of Imicryl, and 84 pieces of Protemp. Sample sizes were controlled by measuring with a digital caliper (Muva Dijital Kumpas IP54).

With the CAD/CAM technique, samples were prepared from polymethylmethacrylate (PMMA) blocks (Tempo Cad., On-Dent Ltd, Izmir, Turkey) following digital design.

In the conventional method, materials were prepared according to the manufacturer's instructions and then placed in metal molds with circular cavities. Cadmium-free polymethylmethacrylate (Imicryl Imident, Konya, Turkey) was prepared using this method.

Nano-filled bis-acrylic composite (3M ESPE Protemp™ 4, 3M Deutschland GmbH Dental Products, Carl-Schurz-Str. 1, 41453 Neuss, Germany) was prepared by mixing with an automatic mixer.

In order to eliminate any irregularities on the surfaces of the samples and achieve a smooth surface, the specimens were polished using a 600-grit silicon carbide paper under water for 15 seconds. After polishing, the specimens were cleaned in a distilled water bath using ultrasonic waves for 5 minutes. The temporary restorative material groups were then randomly divided into three groups (n=28) for surface treatment: no treatment, air abrasion, and hydrofluoric acid etching.

- Group 1 (No Surface Treatment): No surface treatment was applied to the samples.
- Group 2 (Air Abrasion): The samples were sandblasted using an abrasion device (Zhermack, Rovigo, Italy) for 10 seconds. 50 µm aluminum oxide (Al2O3) particles were applied at a pressure of 2.8 bar from a distance of 10 mm.
- Group 3 (Hydrofluoric Acid Etching): After applying a 4% hydrofluoric acid gel as a thin layer (Porcelain etchant, Bisco, Schaumburg, IL, USA) to the samples for 120 seconds, they were washed for 120 seconds and dried.[15]

Two different temporary cements (Temp-Bond, Dycal) are applied to the samples after surface treatments. The descriptions of the cement and temporary restorative materials included in this study are summarized in Table 1.

Temporary cements containing eugenol (Temp-Bond™, Kerr, Italy) and calcium hydroxide cement (Life Regular Set, Kerr, Italy) were mixed and prepared according to the manufacturer's recommendations. To apply the cement, a silicone mold with an inner cavity diameter of 5 mm and a height of 4 mm was prepared. The cylindrical mold was prepared and positioned in the center of the samples. The cement was then placed in each mold, covered with cellulose tape, and left to harden while the same operator applied pressure with a finger. By cutting the silicone mold with a scalpel, the samples were carefully removed and placed in distilled water at 37°C for 24 hours.

Half of the samples (n=7) were soaked in distilled water at 37°C for one week before measuring the shear bond strength. This group served as the control group. The other half of the samples (n=7) were soaked with mouthwash for four minutes daily for one week. They were kept in 20 ml of mouthwash (Kloroben, Drogsan, Turkey) for a total of 28 minutes, which is considered equivalent to the same time.[16] This procedure resulted in 12 different treatment subgroups for each temporary restorative material, as shown in Figure 1.

Samples were prepared using auto-polymerizing acrylic resin (Imicryl, SC, Konya, Turkey) in silicone molds with a diameter of 15 mm and a height of 20 mm. The samples were embedded in accordance with the test device in which the experiment would be conducted. Subsequently, they were washed in an ultrasonic cleaner for 15 minutes and dried with blotting paper.

To measure the shear bond strength, the samples were affixed to the bottom of the universal tester (Instron, Model 2710-003, Instron Corp., USA). A knife-edge tip was placed on the opposite end of the test device. Loading was done with a head speed of 0.5 mm/min. The maximum load was recorded when the fracture occurred. Shear bond strength was calculated by using the following formula.[15]

The shear bond strength (σ) is calculated using the formula $\sigma = F / A$, where σ represents the shear bond strength in MPa, F represents the load at failure in N, and A represents the repaired area in mm^2.

Statistical Analysis

Statistical analysis was performed using the SPSS Statistics 20.00 software (SPSS Inc., Chicago, IL, USA) at a 95% confidence interval and a significance level of p=0.05. The normal distribution conformity of the variables was examined using the Shapiro-Wilk test, which is one of the analytical methods, and it was found to be appropriate. The data obtained in this study were evaluated using a 3-Way Variance Analysis and a post-hoc multiple comparison test.

Results

According to the analysis of variance (Table 2), a significant triple interaction was found between material type, mouthwash, and cement ($p<0.001$). The interactions between mouthwash and material, mouthwash and cement, and material and mouthwash had a statistically significant effect on the shear bond strength ($p<0.05$). Other interactions were not significant ($p>0.05$).

The mean shear bond strength values and the corresponding standard deviations for all groups are presented in Table 3. The highest shear bond strength (0.85 MPa) was found in the Imicryl Group 3Bd samples, while the lowest shear bond strength (0.11 MPa) was determined in the Protemp Group 3Ac samples.

As a result of the multiple comparison (Tukey) test conducted on the samples adhered with Tempbond (a cement containing eugenol), a statistically significant

difference was observed at the p<0.001 level in the following cases:

- In the CAD/CAM Group 1Ad samples,
- In the Imicryl Group 3Ad samples,

As a result of the multiple comparison (Tukey) test of the samples adhered with Dycal (calcium hydroxide cements), a statistically significant difference was detected at the p<0.001 level in the following variables:

- In the CAD/CAM Group 3Bc samples,
- In the CAD/CAM Group 3Bd samples,
- In the Protemp Group 1Bc samples,
- In the Protemp Group 3Bd samples,
- In the Imicryl Group 3Bd samples,

As a result of the multiple comparison (Tukey) test of the interaction between material, mouthwash, and cement, a statistically significant difference was detected at the p<0.001 level in the following variables:

- In the Imicryl Group 1Bd samples,
- In the Imicryl Group 3Bd samples,
- In the Imicryl Group 2Bd samples,
- In the Imicryl Group 2Bc samples,
- In the Protemp Group 2Bc samples.

Figure 2 shows the distribution of the shear bond strength among the subgroups in this study.

In the polymethylmethacrylate material prepared with CAD/CAM, the highest bond strength value was obtained as 0.84 MPa in Group 1Bd samples, and the lowest bond strength value was obtained as 0.12 MPa in Group 3Ad samples.

In the polymethylmethacrylate-based Imicryl material prepared by the conventional method, the highest bond strength value was obtained in Group 3Bd samples (0.85 MPa), while the lowest bond strength value was obtained in Group 1Ad samples (0.33 MPa).

In bis-acrylic composite-based Protemp samples, the highest bond strength value was obtained in Group 2Bc samples (0.67 MPa), while the lowest bond strength value was obtained in Group 1Ad and Group 3Ac samples (0.11 MPa).

The highest bond strength value in the control group (Group 1), where no surface treatment was applied, was obtained in the CAD/CAM Group 1Bd samples (0.84 MPa). This group was followed by Imicryl Group 1Bd (0.73 MPa) and Protemp Group 1Bd (0.39 MPa).

Among the sandblasted Group 2 samples, the highest bond strength value was obtained as 0.78 MPa in the CAD/CAM Group 2Bd and Imicryl Group 2Bc samples. These groups were followed by Imicryl Group 2Bd with a value of 0.75 MPa and Protemp Group 2Bc with a value of 0.67 MPa.

The highest bond strength value in Group 3 samples treated with hydrofluoric acid was obtained in Imicryl Group 3Bd samples (0.85 MPa). This group was followed by Protemp Group 3Bc (0.59 MPa) and CAD/CAM Group 3Bd (0.47 MPa).

Discussion

The null hypothesis (H0) of this study was rejected because it was found that the use of mouthwash had varying effects on the bond strength of temporary cements to temporary restorations. In some groups, it increased the bond strength, while in others, it decreased it. Sandblasting surface treatment increased the shear bond strength. However, the hydrofluoric acid applied groups yielded lower results compared to the control group. As a result, the H1 hypothesis was partially accepted and partially rejected.

The type of luting cement used and the surface properties of the temporary material, as well as the liquids they are exposed to in the mouth, can affect the performance of temporary restorative materials, preventing them from being dislodged during their time in the mouth.[17] This study's findings confirm this situation and establish that the type of material, the cement used, and the use of mouthwash are statistically significant factors. The temporary restorative materials used in this study are polymethylmethacrylate-based and composite-based materials. These temporary restorative materials are frequently used in the clinic.[3] As temporary cement, it is preferred to use cements that are easy to apply and readily available in every clinic. Sandblasting is an easy-to-apply and effective surface treatment method used to increase bond strength.[18] It has been found to enhance the bond strength between the polymer and the surface by promoting micromechanical adhesion.[19,20,21]

The study has shown that the application of hydrofluoric acid softens the surface of polymethylmethacrylate and makes it smoother.[15] In this study, it was found that the bond strength increased in CAD/CAM Group 3Ac compared to CAD/CAM Group 1Ac, but decreased in CAD/CAM Group 3Bc and Group 3Bd when using calcium hydroxide cement. A decrease in cement bond was detected in Protemp Group 3Ac. An increase in cement bonding was observed in Protemp Group 3Ad when mouthwash was used. This may be due to the difference in the chemical composition of the cements and their potential interaction with mouthwash, rather than the surface properties of the samples.

Cements containing calcium hydroxide are tissue-friendly cements that can neutralize acids. It acts as a barrier by preventing the passage of acid through neutralization and blocking agents such as methyl methacrylate from entering the pulp. These cements contribute to the remineralization of the carious dentin structure and exhibit antibacterial activity when the calcium hydroxide (CaOH) present in the cement is released.[22] Eugenol-containing cements harden through the substitution of eugenol with water. It has several disadvantages, including low strength, poor abrasion resistance, and dissolution in oral liquids.[23] Chlorhexidine binds to surfaces in the oral cavity and continues to have an effect through slow release.[24] A study found that Chlorhexidine significantly reduced bond strength, which was attributed to the increase in chlorine detected in the

SEM and EDS analyses conducted for surface analysis.[25] It has been suggested that chlorine reduces the connection through chemical interaction. It has also been reported that chlorhexidine increases the release of calcium from dentin surfaces and leads to a decrease in calcium levels.[25] However, another study found that chlorhexidine did not have any negative impact on shear bond strength.[26]

In this study, the bond strength of CAD/CAM Group 3Ac samples (0.40 MPa) increased compared to the bond strength of CAD/CAM Group 1Ac samples (0.23 MPa). However, the bond strength of CAD/CAM Group 3Bc samples using calcium hydroxide cement (0.27 MPa) decreased. It was determined that the bond strength of group 1Bc samples decreased by 0.37 MPa. It is observed that the decrease in bond strength is proportionally greater when using mouthwash (CAD/CAM Group 1Bd: 0.84MPa, CAD/CAM Group 3Bd: 0.47MPa). The presence of chlorhexidine in mouthwash may have had a detrimental impact on the bond strength by causing the release of calcium from the calcium hydroxide-based cement.

In this study, an increase was found in the shear bond strength of all the sandblasted samples compared to the samples in the control group. This finding is consistent with studies that have indicated that sandblasted surfaces create micro-retention areas by enhancing the adhesion of cements through mechanical locking.[27-29]

In a study assessing the retentive properties of various temporary cements on temporary crowns, it was found that calcium hydroxide cements exhibited greater retention on polymethylmethacrylate resins compared to Tempond (Ca(OH)2: 795 kPa; Temp-Bond: 714 kPa).[30] The study also revealed that the shear bond strengths of calcium hydroxide cements, with the exception of CAD/CAM Group 3Bc and Imicryl Group 3Bc, were higher than those of Tempbond. The fact that the temporary crown is more retentive may be related to proper preparation, as well as its shear bond strength.

According to the results of this in vitro study, the choice of material type and cement should be made in accordance with each other. It is known that cements containing eugenol are incompatible with resin polymers.[17] As Protemp is based on bis-acrylic composite, it has been advised not to use a cement that contains eugenol should not be used.[29] The findings of this study support this recommendation. It was also found in this study that the sandblasting surface treatment applied to the bisacryl composite-based temporary restorative material increased the bonding of the eugenol-containing cement.

Only one type of mouthwash was used in the study. Mouthwash containing 0.12% chlorhexidine gluconate and 0.15% benzydamine hydrochloride was used because it is considered the "gold standard" in such studies and is widely used in the clinic.[8] Chlorhexidine gluconate is a commonly used agent known for its high antimicrobial activity against bacteria, viruses, and fungi.[31,32]

In previous studies, it has been stated that exposing the samples to a mouthwash for 24 hours is equivalent to gargling for two minutes twice a day for one year.[16] The chosen 28-minute period in this study corresponds to one week of use. According to the manufacturer's instructions, it is recommended not to use the mouthwash for longer than one week.[33] It is important to note that prolonged use of mouthwash may result in taste disturbances and allergic reactions, in addition to tooth and restorative material discoloration.[34] It was observed that while the use of mouthwash decreased shear bond strength in certain samples, it actually increased it in others.

If mouthwash is not used, there are numerous foods and beverages that can increase acidity at different temperatures. One limitation of the research is that it was an *in vitro* study, which means it was unable to fully simulate the conditions inside the mouth. However, the use of the shear test is important for ensuring the reliability of the study, as shear bond strength results are commonly used in testing.[35]

Conclusions

It is important to consider changes that may adversely affect the shear bond strength of temporary restorative materials. Many factors, other than the use of mouthwash, can cause changes in the teeth and restorative materials in the mouth. Better bond strength can be achieved in temporary crowns with sandblasting compared to those without any surface treatment. In cases where mouthwash is recommended, it is advisable to use sandblasting surface treatment. Additionally, it is preferable to use temporary crown materials that are based on polymethylmethacrylate, and temporary cements that are based on calcium hydroxide. It is necessary to support the potential surface treatments with alternative temporary crown materials and conduct additional studies that encompass various temporary cements.

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Conflicts of Interest Statement

The authors have no conflicts of interest

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Table 1. Compositions, manufacturers and manufacturing type of the cement and temporary restorative materials used in the study.

	Compositions	Manufacturer	Manufacturing Type
Temporary Restorative Materials	polymethylmethacrylate	Tempo Cad., On-Dent Ltd, Izmir, Turkey	CAD/CAM
	cadmium-free polymethylmethacrylate	Imicryl Imident; Konya, Turkey	Conventional Method (powder and liquid)
	nano-filled bis-acrylic composite	3M ESPE Protemp™ 4, 3M Deutschland GmbH Dental Products Carl-Schurz-Str.1 41453 Neuss-Germany	Conventional Method (with gun system that provides automatic mixing)
Temporary Cements	containing eugenol	Temp-Bond™, Kerr, Italy)	Self-curing(base and catalyst)
	calcium hydroxide cement	Life Regular Set, Kerr, Italy	Self-curing(base and catalyst)

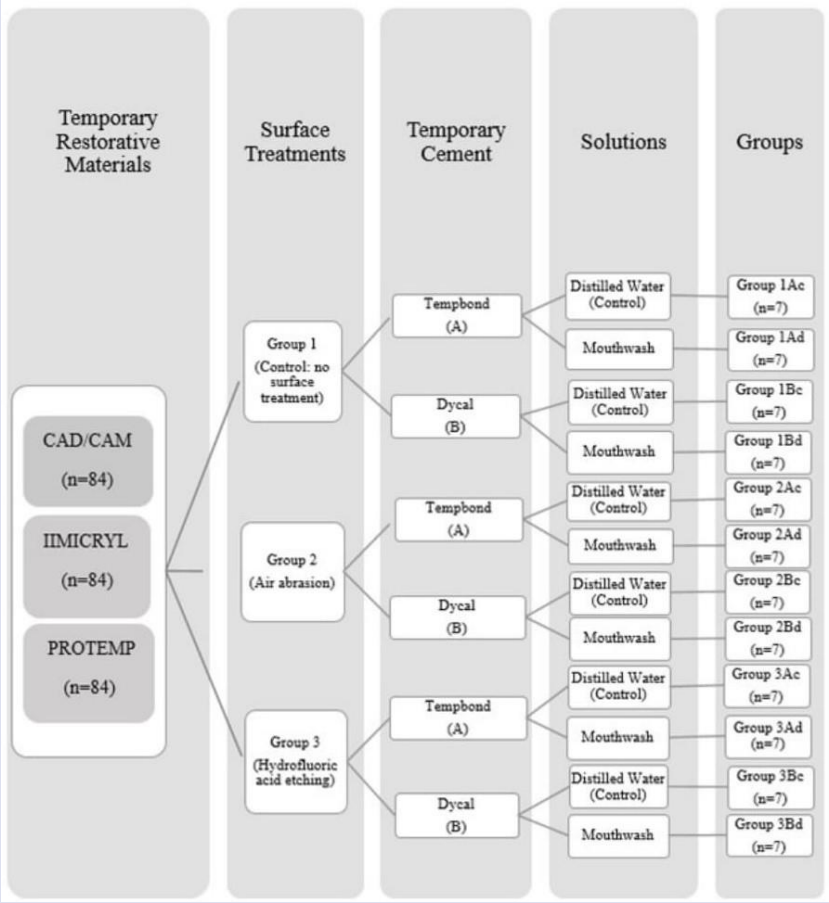
Table 2. Varyans analys of shear bond strenght

	Sum of Squares	df	Mean Square	F	p
Material	4.62	8	0.58	12.70	< .001
Mouthwash	0.25	1	0.25	5.48	0.020
Cement	2.49	1	2.49	54.72	< .001
Material x Mouthwash	0.76	8	0.10	2.09	0.038
Material x Siman	0.39	8	0.05	1.07	0.384
Mouthwash x Siman	0.25	1	0.25	5.59	0.019
Material x Mouthwash x Cement	1.56	8	0.20	4.30	< .001

Table 3. Mean (MPa) and standard deviation results of the obtained data.

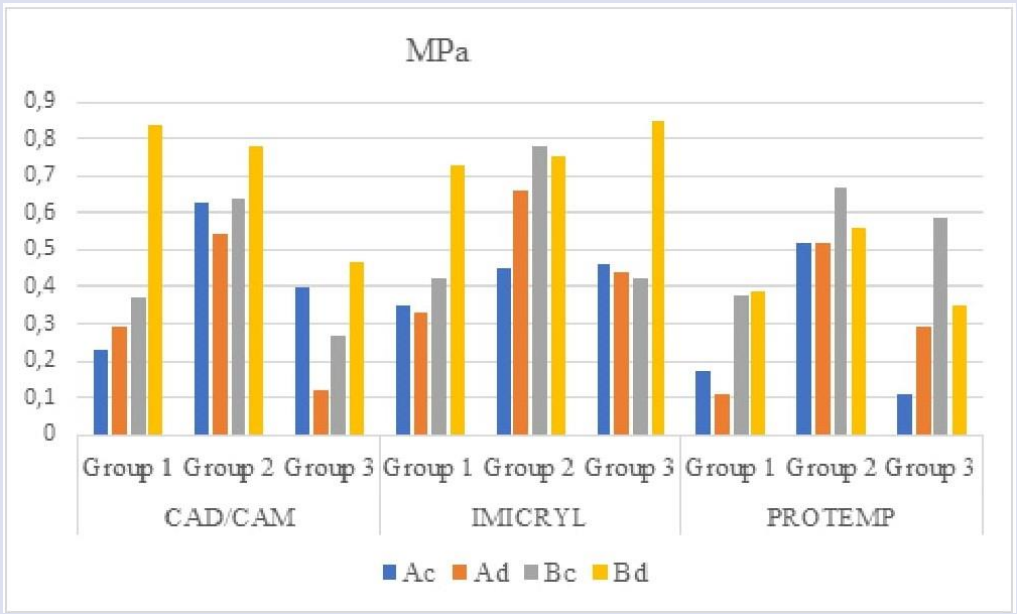
		Tempbond (A)				Dycal (B)			
		Distilled Water (Ac)		Mouthwash (Ad)		Distilled Water (Bc)		Mouthwash (Bd)	
MATERIALS	SURFACE TREATMENTS GROUPS	Means	SD	Means	SD	Means	SD	Means	SD
CAD/CAM	Group 1	0.23	0.13	0.29	0.13	0.37	0.26	0.84	0.13
	Group 2	0.63	0.18	0.54	0.13	0.64	0.19	0.78	0.37
	Group 3	0.40	0.16	0.12	0.04	0.27	0.12	0.47	0.27
IMICRYL	Group 1	0.35	0.18	0.33	0.14	0.42	0.23	0.73	0.24
	Group 2	0.45	0.22	0.66	0.20	0.78	0.9	0.75	0.27
	Group 3	0.46	0.10	0.44	0.29	0.42	0.14	0.85	0.29
PROTEMP	Group 1	0.17	0.21	0.11	0.13	0.38	0.16	0.39	0.20
	Group 2	0.52	0.20	0.52	0.14	0.67	0.23	0.56	0.36
	Group 3	0.11	0.14	0.29	0.22	0.59	0.14	0.35	0.15

((Group1: no surface treatment, Group 2: air abrasion, Group 3: hydrofluoric acid; A: Tempbond, B: Dycal; C: distilled water, d: mouthwash)



(A: Tempbond, B: Dycal; c:distilled water, d: mouthwash code)

Figure 1. Procedures overview of the study



(Group1: no surface treatment, Group 2: air abrasion, Group 3: hydrofluoric acid; Ac: Tempbond in distilled water, Ad: Tempbond in mouthwash, Bc: Dycal in distilled water, Bd: Dycal in mouthwash)

Figure 2. Distribution of bond strength of luting cements

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The Quantitative Method for Following Radiologic Healing in Endodontic Retreatment; 1-Year Follow-up Study and Retrospective Analysis

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ABSTRACT

Objectives: This study aimed to quantitatively evaluate the changes in the internal bone structure at the periapical bone regions after retreatment in endodontics using fractal analysis method on periapical radiographs.

Materials and Methods: In this retrospective study, 29 single-rooted, asymptomatic, single-visit retreatment teeth with apical lesion were included. All teeth included in the study were selected from the maxilla anterior region. Periapical radiograph (T0) was taken for baseline diagnosis at the start of retreatment. Second periapical follow-up radiograph (T1) of the patients was taken at the end of 1 year. The first evaluation phase of the 1-year results of endodontic retreatment is based on the periapical index (PAI). Fractal dimension (FD) was calculated by box-counting method. Comparing T0 and T1 FDs was done using the paired-sample t-test. To compare FD changes between the gender, the independent samples t-test was used. The significance level was set to 0.05.

Results: PAI scores were found to be statistically significantly decreased in T1 radiographs compared to T0 ($p<0.001$). The mean FD value increased statistically significantly in T1 radiographs compared to T0 radiographs ($p<0.001$). No significant difference was found in the T0 and T1 radiographs of FDs in gender comparison ($p>0.05$).

Conclusion: At the end of the 1-year follow-up, FD increased in the periapical lesion area, which is interpreted as the healing of the lesions. Fractal analysis is recommended as a method that will benefit clinicians in the follow-up of retreatment recovery.

Keywords: Fractals, Retreatment, Diagnostic imaging, Periapical Periodontitis, Radiography

Endodontik Yeniden Tedavilerde Radyolojik İyileşmenin Takibi İçin Kantitatif Yöntem; 1-Yıllık Takip Çalışması

Süreç

Geliş: 20/02/2023
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ÖZ

Amaç: Bu çalışmada endodontide retreatment sonrası periapikal kemik bölgelerinde internal kemik yapısında meydana gelen değişikliklerin fraktal analiz yöntemi kullanılarak periapikal radyografiler üzerinde kantitatif olarak değerlendirilmesi amaçlanmıştır.

Gereç ve Yöntemler: Çalışmaya apikal lezyonu olan 29 adet tek köklü, asemptomatik, tek seans retreatment yapılan dişler dahil edildi. Çalışmaya dahil edilen tüm dişler maksilla anterior bölgesinden seçilmiştir. Retreatment başlangıcında temel tanı için periapikal radyografi (T0) çekildi. Hastaların 1. yıl sonunda ikinci periapikal kontrol grafileri (T1) çekildi. Endodontik retreatmentın 1 yıllık sonuçlarının ilk değerlendirme aşaması periapikal indekse (PAI) dayalıdır. Fraktal boyut (FB), kutu sayma yöntemiyle hesaplandı. The paired-sample t-testi T0 ve T1 FB'leri karşılaştırmak için kullanıldı. Cinsiyetler arasındaki FD değişikliklerini karşılaştırmak için bağımsız örneklem t testi kullanıldı. Anlamlılık düzeyi 0.05 olarak kabul edildi.

Bulgular: PAI skorları T1 grafilerde T0'a göre istatistiksel olarak anlamlı derecede düşük bulundu ($p<0.001$). Ortalama FB değeri T1 grafilerde T0 grafilere göre istatistiksel olarak anlamlı artış gösterdi ($p<0.001$). FB'lerin T0 ve T1 grafilerinde cinsiyet karşılaştırmasında anlamlı fark bulunmadı ($p>0,05$).

Sonuç: 1 yıllık takibin sonunda periapikal lezyon bölgesinde FB artışı lezyonların iyileşmesi olarak yorumlanmaktadır. Fraktal analiz, retreatment sonrası iyileşmenin takibinde klinisyenlere fayda sağlayacak bir yöntem olarak önerilmektedir.

Anahtar Kelimeler: Benzer elemanların oluşturduğu şekiller, Yeniden tedavi, Tanısal görüntüleme, Periapikal Apse, Radyografi

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Introduction

The main purpose of root canal treatment is to clean and shape the root canal system and fill the canal in three dimensions to prevent re-infection of the tooth.[1] Although the rate of success is high after the first root canal treatment, failures may occur over time after the treatment.[2] The main causes of failure are poorly formed canals, incomplete removal of infected pulp, persistent infections in the dentinal tubules or complex irregularities of the root canal system, and inadequate irrigation.[1,3] Therefore, non-surgical root canal treatment applications are performed with a goal of making the tooth functional again. The main purpose of retreatment is the proper cleaning, reshaping, and refilling of the root canal system and the complete removal of filling materials, residues, and microorganisms from the first treatment.[4] It is reported to be cost-effective and provides satisfactory results.[5]

During endodontic treatments, clinicians routinely use periapical radiographs because of advantages such as ease of use, detail and resolution, and low radiation dose.[6] Clinicians often prefer periapical radiographs, especially for diagnosis, treatment, and postoperative follow-up. For most endodontic treatments, 1-year is considered as a sufficient time for a follow-up.[6] Various radiographic indices are used to evaluate the development of periapical tissues on radiographs following root canal treatment.[7,8] The periapical index (PAI) is one of the commonly used radiographic indices in healing follow-up; however, the acquired data remain subjective.[7,8] Fractal analysis (FA), a new technique that has just come into use, calculates the complexity of the structure in the region of interest (ROI) and converts it into a numerical value. As a result, FA stands out as a method that allows for a quantitative evaluation.[9,10] FA has also been employed as a bone density analysis tool and is now widely used because of how simple and accessible it is.[11,12] It has been claimed that an increase in a structure's fractal dimension (FD) corresponds to an increase in the structure's complexity. Whereas low FD structures have a simpler internal design, high FD structures are more complex.[9,10] The intricacy of the trabecular structure as a result of angiogenesis and bone remodeling is the explanation for increased FD.[13] In addition, it is reported that FA can be used in the follow-up of patients after the treatment.[10,14]

To the best of the author's knowledge, there is no study in the literature comparing the change in fractal size with non-surgical retreatment of single-root and canal teeth in the anterior maxilla and a 1-year follow-up. In this study, the authors aimed to quantitatively evaluate the changes in the internal bone structure in the periapical bone regions after retreatment in endodontics by fractal analysis method on periapical radiographs. The null hypothesis of the study is that there is no statistically significant difference between the FD of the end of the retreatment and the FD of the follow-up one year later.

Materials and Methods

Sample selection

This study was designed retrospectively. Ethical approval was obtained from the Local Ethics Committee (2022/710). The study protocol was carried out in accordance with the principles of the Declaration of Helsinki. The sample size was determined via power analyses of previous studies data. According to the power analysis (G*Power, ver. 3.1.9.2, Franz Faul; Universitat Kiel, Germany), a total sample size of 29 is required when $\alpha = 0.05$, and the effect size is 0.45, which would yield a power of 0.80.[15]

Periapical radiographs (T0) and 1-year follow-up radiographs (T1) taken immediately after retreatment of 29 individuals who were admitted to the endodontic clinic between 2020 and 2021 with indications for retreatment were used.

Inclusion criteria for the study;

i) The individual does not have any systemic disease affecting bone metabolism,
ii) The tooth with an indication for retreatment is a single root and single canal tooth located in the anterior maxillary region,
iii) Asymptomatic of the involved tooth and radiographically determined as PAI score 3 or 4,
iv) Absence of missing teeth,

Exclusion criteria from the study;

i) The use of drugs that affect the individual's bisphosphonate-type bone metabolism,
ii) Symptomatic tooth with an indication for retreatment,
iii) Those who have disclosed having neurological and psychological disorders, alcoholism, and drug addiction diseases,

Retreatment Procedure

All retreatment procedure was completed in one visit by the same endodontist (S.D.). The tooth was isolated with a rubber dam after being anesthetized with Ultracaine® D-S (Sanofi Aventis, Levent, Istanbul). A high-speed handpiece was used to prepare an endodontic access using a round diamond bur No. 2 and an Endo-Z bur (Dentsply Maillefer, Ballaigues, Switzerland). The D1, D2, and D3 retreatment instruments (Dentsply Maillefer, Ballaigues, Switzerland) were used, with a 2-Ncm torque and 500-rpm speed, to remove primary root canal fillings. In a crown-down motion, the implements were used to brush against the canal sides. The working length was determined with an apex finder (ProPex Pixi, Dentsply Maillefer) and verified by radiography after all root filling had been removed. ProTaper rotary files (Dentsply Maillefer, Ballaigues, Switzerland) were then used to form the root canals up to an F5 (size 50) master apical file size. Using a side vented NaviTip irrigation needle, the canals were irrigated with 2 mL 2.5% sodium hypochlorite (NaOCl) between each file size (Ultradent, South Jordan, UT). Following the preparation, the canal was irrigated with 2 mL of 17% EDTA for 1 minute and then irrigated

with 2 mL of distilled water. Root canals were dried with paper points and obturated with gutta-percha (Dentsply Sirona) and resin-based sealer utilizing the cold lateral compaction technique (AH Plus, Dentsply Sirona). Resin composite was used to repair the coronal access cavity (3M ESPE, St Paul, MN, USA).

Radiographic Procedure

All periapical radiographs from the anterior maxillary region were obtained using the same device (Kodak 2100 Intraoral X-Ray System (Kodak, New York, USA)) with the same exposure parameters (60 kV, 7 mA, and 0.32 s radiation time). Also, size 2 (31×41 mm^2) same phosphor plate is used. For maxillary anterior teeth, projection geometry was standardized with a film-retaining appliance, and images were taken in parallel technique in the same way. Latent images on phosphor plates were scanned and digitized. (Express; Instrumentarium, Tuusula, Finland). Images are saved as tagged image file format (TIFF).

1-Year Follow-up Evaluation

The first evaluation phase of the 1-year results of endodontic retreatment is based on the PAI.[16] PAI is a 5-scores evaluation system. The PAI score for each subject was made according to the following definitions:

PAI 1: Ligament: Narrow and uniform width of the ligament space./Lamina dura: Radiopaque border uniform and regular.

PAI 2: Ligament: Slight increase of the width of the ligament space in and at foramen./Lamina dura: Border almost continuous.

PAI 3: Ligament: Slightly larger more irregular widening of the ligament space at foramen and/or around excess canal filling related to the demineralization process./Lamina dura: Loss of continuity of the bone border and disappearance at the foramen

PAI 4: Ligament: Well defined balloon-like radiolucency around apex and/or excess canal filling./ Lamina dura: Complete disappearance od the bone border.

PAI 5: Ligament: Shell like configuration around the radiolucency with extensions toward the radiolucent area around apex and/or excess canal filling. / Lamina dura: Complete disappearance od the bone border.

An experienced endodontist (S.D.) and dentomaxillofacial radiologist (S.Y.) evaluated the radiographs separately as T0 and T1 according to the PAI scoring system. Similar to earlier research, PAI scores were categorized as "healed" (PAI < 3) or "not healed" (PAI ≥ 3) at the baseline or 1-year follow-up.[15,17,18]

Fractal Analysis

Images were obtained using a Dell Precision T5400 workstation with a 19-inch 1920 x 1080 resolution screen (Dell, Round Rock, TX, USA) (Dell E190S, China). A blinded dentomaxillofacial radiologist (S.Y.) performed fractal measurements after identifying ROIs from the subjects' periapical radiographs. The 64-bit Java-based open-source program Image J, version 1.53 was used to evaluate hard tissue (National Institutes of Health, Bethesda, Maryland, USA). For standardization, all periapical radiographs were adjusted to have a width and height of 878x1144 pixels. ROI was selected from maxillary anterior teeth with apical lesions as in Figure 1 for baseline and 1-year follow-up radiographs. A square-shaped ROI of 30x30 pixels was placed in the geometric center of the apical lesion. The ROI was placed 1 mm more apical than the root of the tooth and not in contact with any anatomical structure such as the lamina dura. FD was performed using the customized method designed by White and Rudolph using the box-counting method[19]. Each image has been cropped and duplicated after the selection of ROI. This process has eliminated the brightness variance brought on by overlapping soft tissues and different bone densities. The outcome image has been taken away from the starting image. Binary was created by thresholding on a brightness value of 128 and adding a grey value of 128. After being eroded and dilated, the image was inverted. The image was skeletonized towards the end (Figure 2). The FD of the skeletonized image was calculated by using the box-counting method. The intra-observer reliability was assessed using 15 radiographs that were chosen at random. Two weeks following the initial assessment, the same dentomaxillofacial radiologist underwent a second examination for the intra-observer reliability while keeping them blind to the initial measurements.

Statistical Analysis

Software called SPSS v.23 was used to do the statistical analysis (IBM Statistical Package for Social Sciences, version 23.0; SPSS Inc., Chicago, Illinois, USA). Mean and standard deviation were used to summarize continuous variables. Frequencies and percentages were used to display categorical variables. The inter-observer Cohen's kappa coefficient with a 95% confidence interval was calculated for the PAI scores. Values 0 were defined as no agreement by Landis and Koch, whereas 0-0.20, 0.21-0.40, 0.41-0.60, 0.61-0.80, and 0.81-1 were classified as slight, fair, moderate, substantial, and virtually perfect agreement, respectively.[20] The ICC value was used to assess the accuracy of repeated intra-observer fractal dimension assessments. Values less than 0.5, between 0.5 and 0.75, between 0.75 and 0.9, and greater than 0.90 are indicative of poor, moderate, good, and exceptional dependability, respectively, according to the 95% confidence range of the ICC estimate.[21] Shapiro-Wilk and Kolmogorov-Smirnov tests were used to figure out how the data were distributed. In radiograph ROI changes and independent samples t-tests, gender differences were assessed. Comparing T0 and T1 FDs was done using the paired-sample t-test. The PAI score changes were compared using the Wilcoxon test. The threshold for significance was set at 0.05.

Results

The demographic information about the patients is shown in Table 1. The mean age of the individuals by gender was 42.1±11.9 for males and 36.3±10.7 for females. PAI scores were found to be statistically significantly decreased in T1 radiographs compared to T0

radiographs (p<0.001). On T0 radiographs, a PAI score of 4 was observed in 15 teeth and a PAI of 3 in 14 teeth. PAI scores in all retreatment teeth show a pattern of healing (PAI 1 and PAI 2) at 1-year follow-up (Figure 3). On T1 radiographs, a score of PAI 2 was observed in 8 teeth, and a score of PAI 1 in 21 teeth. The kappa coefficient used for interobserver reliability during PAI scoring was 0.927 (almost perfect). The mean FD value increased statistically significantly in T1 radiographs compared to T0 radiographs (p<0.001) (Table 2). No significant difference was found in the T0 (p=0.906) and T1 (p=0.478) radiographs of FDs in gender comparison. As a result of repeated in-observer measurements for FD, the ICC ranged from 0.914 to 0.972 with excellent reliability.

Discussion

Fractal analysis is a method that quantifies the complexity of bone trabeculation. An increase in FD indicates increased complexity, while a lower FD value indicates less trabeculation in the region of interest.[22] It is reported in the literature that FD decreases when bone density decreases and FD increases when bone density and trabeculation increase.[8-10,23] However, in order to accurately evaluate the change in FD, it should be supported by other findings such as clinical and radiographic improvement. In similar studies, repeated radiological evaluations using full-scale PAI have been shown to have an important long-term prognostic value in periapical disease follow-up.[8] Therefore, in this study, periapical conditions were evaluated with PAI to determine whether the change in FD values after retreatment was due to the newly formed trabecular pattern or decalcification. There was a significant decrease in PAI scores after retreatment. Therefore, the reason for the significant increase in the FD value after retreatment was due to the increased trabeculation due to recovery.

According to the PAI system, which is the commonly used index in the literature in the analysis of radiographic findings, PAI 1 and 2 scores are reported as healing in most of the studies.[8,15-17] In this study, the same scores were taken as a reference. A healing pattern (PAI 1 and PAI 2 scores) was observed at the end of 1 year in all 29 teeth included in this study. The success rate of endodontic retreatment ranges from 40% to 100%.[24] Although this study is compatible with these data, we think that the reason for the healing activity in all teeth is that only teeth with PAI 3 and PAI 4 scores were included in the study. The appearance of clinically symptomatic teeth in PAI 5 individuals was a reason for exclusion. In this study, the authors aimed to evaluate how fractal analysis would show results as a quantitative method for apical recovery. Therefore, the authors selected teeth with indications for retreatment from close classes based on observation, which are relatively more difficult to diagnose and follow-up healing. In other studies, the authors think that the healing score could not be reached within 1 year after the retreatment of PAI 5 teeth. In addition, in other studies, retreatment was applied to teeth with two roots and more than one canal.[15,17] In this study, retreatment was applied only to maxillary anterior single root and single canal teeth. The higher bone healing potential in the maxilla than in the mandible is another reason for the higher healing rate of the teeth in this study. In addition, the absence of a study in which healing was followed by fractal analysis with a similar retreatment in the maxilla reveals the originality of this study and its difference from other studies.

It has been reported that fractal analysis results are affected by the location and size of the ROI.[8] In order not to be affected by this situation, ROI was placed in the same size and in the same location (1 mm away from the tooth apex to the lesion center) on T0 and T1 radiographs. In addition, the ROI was chosen not to include surrounding anatomical structures such as tooth roots and lamina dura.[9] Thus, changes occuring only in the lesion area were evaluated. In addition, T0 and T1 radiographs should be taken with similar projection angles and image quality.[15] Therefore, when taking periapical radiographs, the conditions that would affect FD in follow-up radiographs were eliminated by taking images with the same devices and phosphor plates in the same exposure parameters, with the parallel technique film holding apparatus and patient positioning the same. The parallel technique is primarily recommended for endodontic periapical radiographs as it allows projections with minimal geometric distortion and has a high level of repeatability which is useful for comparison with other radiographs throughout a procedure.[6] Periapical trabecular pattern changes can be determined by using fractal analysis in the early healing period in endodontic treatments and developments can be evaluated with numerical data[8]. Compared to other quantitative methods such as subtraction radiography, fractal analysis is a more objective and less restrictive method.[10] In addition, it reduces possible inter-investigator variation.[24] For this reason, as in many studies, fractal analysis was used in this study to reduce the disadvantages of traditional evaluation methods.[22,24]

In previous studies, researchers reported that FD can be used to beneficially monitor healing and reveal structural changes in trabecular bone after root canal treatment.[24] In addition, the investigators noted that FD values increased significantly around the root apex and adjacent to the apical lesion, respectively, after 1 year following the root canal treatment for cases that eventually healed completely.[24] In similar studies, it has been reported that FD increases significantly in follow-up radiographs in teeth with lesions that underwent root canal treatment or retreatment.[8,10] In this study, a statistically significant difference emerged in the baseline and 1-year follow-up radiographs of FD. The mean FD value of the 1-year follow-up radiographs was higher than the FD value of the baseline radiographs. This shows that with the increase in FD, the re-trabeculation seen in the apical region and the healing in the complexity of the region are provided.[10] In similar studies, the authors reported that FD increased in one-year follow-up in single-

visit and multi-visit retreatment. In these studies, follow-up results of retreatment of posterior mandibular teeth were revealed.[15,17] In the case of lesions compatible with apical periodontitis in both roots, the root with a high PAI score was included in the study.[15,17] It is controversial whether different factors affect the healing process, such as the fusion of apical lesions, the fact that the roots have more than one canal, and the inclusion of symptomatic and asymptomatic teeth in the study. Therefore, in this study, retreatment applied exclusively on anterior maxillary single-rooted and single-canal teeth were included. Also, the authors consider that standardization and limiting environmental factors will create higher accuracy of results. This study has results consistent with other similar follow-up FD studies in the literature. In this study, there was no significant gender difference between T0 and T1 follow-up radiographs of FD values. Similarly, studies in the literature have shown that FD does not differ by gender.[8,15,17] However, there are also studies reporting that the recovery following root canal treatment is lower in male than in female, and on the contrary, a higher success rate in male.[25] Differences in these results can be explained by differences in population, age range, evaluation method, follow-up time, lesion diameter, and tooth group. According to results, the null hypothesis was rejected.

Conclusion

At the end of the 1-year follow-up, FD increased in the periapical lesion area, which is interpreted as the healing of the lesions. It is reported that fractal analysis quantitatively reveals the changes in the trabeculations of the damaged periapical bone before retreatment. Fractal analysis is recommended as a method that will support clinicians in the follow-up of retreatment recovery.

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Conflict of interest

The authors declare no conflict of interest.

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Table 1: Demographic Data

Variable	Frequency	Percent	Mean ± SD
Age (years)			39.2 ± 11.3
Patient (n)	29	100	
Gender (m/f)	11/18	37.9/62.1	

Table 2: Changes in T0 and T1 radiographs in FD after endodontic retreatment

Factor	Male (n = 11)	Female (n = 18)	p value	Total (n = 29)
T0 FD value	1.201	1.205	0.906	1.204
T1 FD value	1.288	1.307	0.478	1.300
p value	0.001*	0.001*		0.001*

*T0: Baseline Radiograph; T1: 1 Year Follow-up Radiograph; *p<0.05*

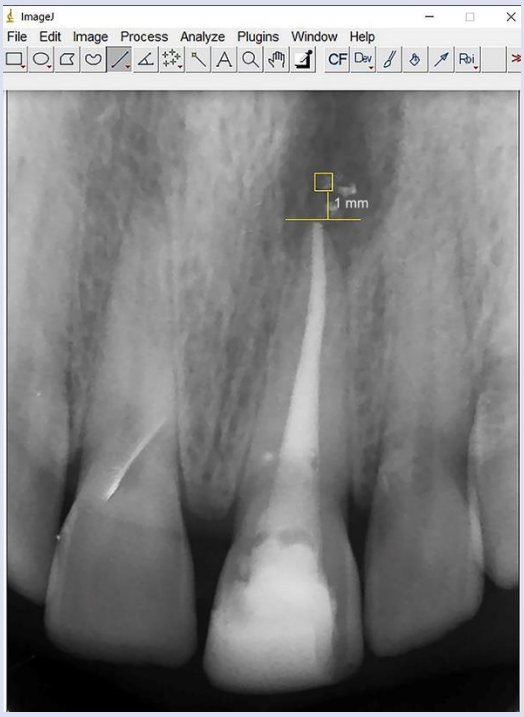

Figure 1: A square-shaped ROI of 30x30 pixels was placed in the geometric center of the apical lesion and 1 mm more apical than the root of the tooth.

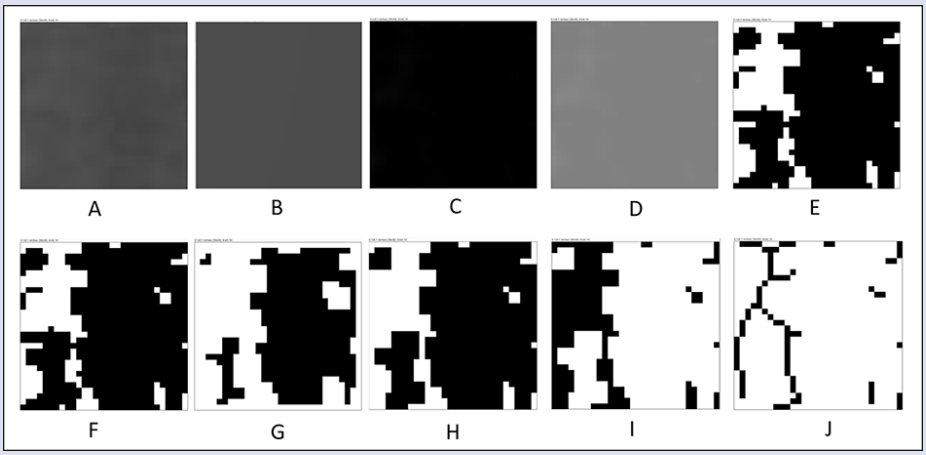

Figure 2: The process of fractal analysis, (A) cropped ROI, (B) blurred image of duplicated ROI, (C) subtraction of blurred image from the original image, (D) grey value of 128 to each pixel was added, (E) threshold, (F) binary, (G) erode, (H) dilate, (I) invert, and (J) skeletonize.

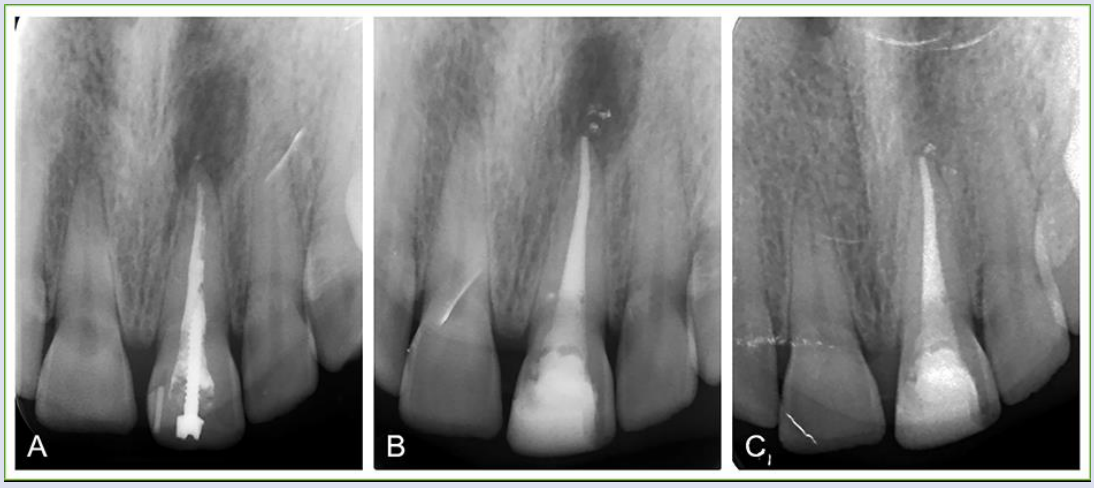

Figure 3: Radiographic evaluation of a case. (A) diagnostic periapical radiograph, PAI 4 (B) periapical radiography taken immediately after retreatment, PAI 4 (C) 1-year follow-up periapical radiograph, PAI 1.

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An Oversampling Technique for Handling Imbalanced Data in Patients with Metabolic Syndrome and Periodontitis

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ABSTRACT

Objectives: Periodontitis has been suggested to be associated with several systemic diseases and conditions including obesity, metabolic syndrome, diabetes, chronic renal disease, respiratory disorders, and cardiovascular diseases. Metabolic syndrome (MetS) is a collection of impairment and is a risk factor for type 2 diabetes and cardiovascular disease. Our study is aimed to handle MetS unbalanced data using the synthetic minority over-sampling technique (SMOTE) to increase accuracy and reliability.

Materials and Methods: Six metabolic syndrome patients and 26 systemically healthy subjects with periodontitis were recruited in this study. Clinical parameters (Plaque index (PI), gingival index (GI), probing pocket depth (PPD), clinical attachment loss (CAL), and bleeding on probing (BOP)) were obtained, smoking status and body-mass index (BMI), systemic diseases, fasting glucose levels, hemoglobin A1c (HbA1c) levels and serum advanced glycation end-products (AGE) levels were recorded by one examiner. First, the data was pre-processed by removing missing values, outliers and normalizing the data. Then, SMOTE technique was used to oversample the minority class. SMOTE works by creating synthetic data points that are similar to the existing minority class instances. The experimental dataset included numerous machine learning algorithms and assessed accuracy using both pre- and post-oversampling methods.

Results: Our findings suggest that by increasing the sample size of a study, researchers can gain more accurate and reliable results. This is especially important when studying a population with a lower sample size, as the results may be skewed.

Conclusions: SMOTE may result in over fitting on numerous copies of minority class samples.

Key Words: Chronic Periodontitis; Metabolic Syndrome; Over-Sampling; Synthetic Minority Over-Sampling Technique.

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Introduction

Periodontitis (PD) is a chronic inflammatory condition that affects supportive tissues and is linked to periodontal pathogens.[1] Previous studies have shown positive association between periodontitis and systemic alterations such as low-grade glucose intolerance, inflammation[2], insulin resistance[3], a pro-coagulant state[4], endothelial dysfunction[5] and vascular dysfunction.[6] Some other studies have indicated a possible relationship between lipid abnormalities, arterial blood pressure and periodontitis.[7, 8]

Metabolic syndrome (MetS) is a condition with many risk factors including impaired glucose tolerance, hypertension, abdominal obesity, atherogenic dyslipidemia, insulin resistance and dyslipidemia that predispose to cardiovascular disease and diabetes mellitus.[9] National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) diagnosis criteria for metabolic syndrome includes the presence of three or more of the following abnormal states: atherogenic dyslipidemia, hypertension, abdominal obesity, and hyperglycemia/insulin resistance.[10]

Persistent low-grade inflammatory state in periodontal disease may cause the progression of insulin resistance and the imbalance of the interaction between cytokine and periodontium.[11, 12] Chronic systemic inflammation in individuals with periodontal disease may predispose to the development of MetS components or vice versa.[13] The most common limitation of the studies investigating this relationship in literature is the insufficient number of cases. The test and control groups are unbalanced due to a lack of participants in the case group. In statistical analyses, this scenario leads to type 2 errors and statistical insignificance.

It is necessary to handle the imbalance of the dataset before training a model. There are numerous methods to handle the imbalance of the datasets (e.g., oversampling, under-sampling, or a combination of both). Oversampling can be categorized as Random Oversampling and

Synthetic Oversampling. Random oversampling replicates the minority class samples and balances the data without loss of information.[14] Due to the replication of the same data, the dataset is prone to overfitting. At this point, to balance the dataset Synthetic Minority Oversampling Technique (SMOTE) generates new synthetic samples using the k-nearest neighbor technique. SMOTE works by creating new synthetic examples that are similar to existing minority class examples, but the new synthetic examples may not reflect the accurate distribution of the data.[15] This means that if the same minority class examples are used repeatedly to generate new synthetic examples, then the model may become overly familiar with those examples, resulting in overfitting.

In this study, the oversampling method was used to avoid reduction to the group with lower sample size. With this method, the sample size of the group with fewer samples was increased by using all features of the data set, and thus the imbalance in the groups was eliminated. The descriptors of the initial version and the increased sample size data set which was simulated with oversampling method showed that there was no bias in the data set in terms of variables. As a final process, data mining methods were applied for the original data set and the data set simulated with oversampling method and it was shown that the results were significant for the simulated data.

Patients with small sample sizes, such as those with rare disorders or study conducted during unusual times like pandemics, may face difficulties in accessing patients and obtain their data.

To address this issue, researchers can use alternative methods such as virtual studies, online surveys, and data mining from existing databases. Additionally, researchers can collaborate with other research groups to pool data and increase sample size.

The goal of this study is to keep the properties of the dataset that are rare or have small sampling size for various reasons, and to acquire reliable results by increasing the number of cases enrolled, hence boosting the study's power, and statistically preventing type 2 mistake. To achieve this goal, the study will employ a variety of methods, such as oversampling, where oversampling involves randomly duplicating instances of the minority class in the dataset to balance out the class distribution. Synthetic data generation involves creating new data points based on existing data points in the dataset.

Materials and Methods

Patients

Six metabolic syndrome patients with periodontitis (MetS-P group) and twenty-six systemically healthy individuals with periodontitis (H-P group) were included in the study who applied to the Department of Periodontology, School of Dentistry, and the Department of Endocrinology, School of Medicine, at Ankara University. The periodontal diagnosis was based on the World Workshop on Periodontal and Peri-Implant Diseases and Conditions (2017).[16] The periodontitis group included patients with Stage III generalized periodontitis. The study was approved by the Ankara University Faculty of Dentistry Human Research Ethics Committee, (No: 9/1, on 08.01.2011) and was conducted in consistency with the Helsinki Declaration. All participants were asked to sign the informed consent form.

Inclusion criteria (for MS group):

1) fasting glucose level <126 mg/dL and >100 mg/dL

2) 2-hour glucose tolerance test glucose level <200 mg/dL;

3) HbA1c >5.7% and <6.4%.

Exclusion criteria for all groups:

Pregnant and lactating mothers, obese individuals, patients with systemic disorders including diabetes, cardiovascular disease, and cancer, or antibiotics or anti-inflammatory drug usage, or medication with calcium channel blockers, phenytoin, or cyclosporine, or patients who had received non-surgical periodontal therapy in the previous 6 months and surgical periodontal therapy in the previous 12 months all excluded.

Smokers of 10 or more cigarettes per day for at least the last five years were defined as smokers. Individuals who never smoked or quit smoking at least two years ago were defined as non-smokers.

Evaluation of Periodontal Status and Metabolic Syndrome

Clinical periodontal parameters including plaque index (PI)[17], gingival index (GI)[18], probing pocket depth (PPD), clinical attachment loss (CAL), and percentage of bleeding on probing sites (BOP%) were recorded from six different sites for all teeth except third molars at first visit in the Department of Periodontology and Department of Endocrinology.

Body mass index, fasting glucose (mg/dl; hexokinase method DXC, Beckman Coulter) and HbA1c (%; HPLC kit, Immuchrome GmbH, Germany) were recorded; waist and hip circumferences were measured, and waist-hip ratio was calculated for all participants.

Saliva and Serum samples

Unstimulated saliva samples were obtained after a 12-hour fasting period, in the early hours of the day. Whole saliva (2 ml) was collected using sterile polypropylene tubes. The samples were centrifuged at 10000 ×g for 10 minutes.[19]

Blood samples were collected from antecubital vein by venipuncture. The samples were centrifuged at 4000 ×g for 10 minutes. Saliva and blood samples were preserved at -80°C until the day of the analysis.[20]

Measurement of Advanced Glycation End-products (AGE)

AGE was determined using OxiSelect™ and Oxiselect™ AGE Adduct kits (Cell Biolabs, Inc. San Diego, CA, USA), respectively. ELISA tests were conducted according to the manufacturer's instructions. SynergyTM HT Microplate Reader (Bio-Tek Instruments, Winooski, WT, USA) was used to measure the color change at 450 nm.

Synthetic Minority Oversampling Method

It is not logical to decrease the sample size of the group which has higher number of patients when the minority class sample size is too small. In our study Synthetic Minority Oversampling Technique (SMOTE) method was used for small minority class samples. The SMOTE algorithm uses an oversampling strategy to rebalance the initial training set which introduces synthetic examples instead of just replicating instances of the minority class. In the medical disciplines, imbalanced data is a concern because there are permanent data for patients more than healthy data. The SMOTE is a method to create artificial instances by operating in "feature space" as opposed to "data space." This lessens the risk of overfitting and enhances the accuracy of the results.[21]

The steps of SMOTE algorithm are:

1. For each minority instance, k number of nearest neighbors are found;

$$k = (SMOTE\%)/100$$

2. One of these neighbors are chosen and a synthetic point is placed anywhere on the line joining the point under consideration and its chosen neighbor

3. A new synthetic sample is generated by interpolating between the selected minority class sample and the randomly selected neighbor.[15]

With this method, the sample size of the minority class was increased by using all the features of the data set, and thus the imbalanced problem in the groups was eliminated. With the initial version of the data set and the oversampling method, the descriptors of the increased sample size were given, and it was shown that the data set did not cause any bias in terms of variables. Finally, data mining methods have been applied for the original data set and the oversampling replicated data set, and the results have been shown to be better for the replicated data.

Statistical Analyses

The data were evaluated using WEKA 3.7 and SPSS 11.5 software. The number of patients (percent) for qualitative variables; mean ± standard deviation and median (minimum-maximum) for quantitative data were utilized as descriptors. The Mann-Whitney U test was used because there was no statistically significant difference between the categories of the two-category qualitative variable in terms of the quantitative variable and there was no assumption about the normal distribution. Chi-square and Fisher-exact tests were used to determine the association between the two qualitative variables. All tests have been conducted with a significance level of α=0.05. In WEKA program, Multilayer Perceptron, J48 and Support Vector Machine, which are Classification methods, were used. While 10-fold Cross Validation test option was used for evaluating the data set; Accuracy, F-Measure, MCC and Precision-Recall Curve (PRC Area) were used as data mining performance criteria.

Results

Since there are so many variables in the data set, the importance of the variables and the values added to the data set were examined using the Info Gain Attribute Eval, Gain Ratio Attribute Eval and Chi-Squared Attributed Eval methods in WEKA and variables, that were determined to be insignificant by the three methods and considered to be of essential importance for clinical information were excluded from the dataset. The data set contained a total of 10 variables: 9 independent variables and 1 dependent variable. These variables are gender, smoking, BMI, HbA1c, hypertension, other disease, other medication, PD, serum levels of AGE and metabolic syndrome. Percentages of variable importance of 9 independent variables according to metabolic syndrome, which is the dependent variable, are given in Figure 1.

Twenty-six periodontally healthy MetS patients (H-P group; 10 female and 16 males), 6 MetS patients with periodontitis (MetS-P group; 4 female and 2 males) were the original dataset. Analysis results of the original data set are presented in Table 1. Three patients among MetS-P group, 15 patients among H-P group were smokers. BMI, HbA1c level and having other medications were significantly higher in MetS-P group ($p<0.05$). No significant differences were found in terms of hypertension and other diseases between MetS-P and H-P group ($p>0.05$). While PD was significantly higher in H-P group; serum levels of AGE were significantly higher in H-P group. The difference was statistically significant between group regarding BMI, HbA1c, other medications, PD, and serum levels of AGE (respectively $p=0.018$, $p=0.012$, $p=0.038$, $p=0.010$, $p=0.031$).

Analysis results of the original data set is presented in Table 2. Thirteen patients among MetS-P group were smokers. BMI, HbA1c level and having other diseases and other medications were significantly higher in MetS-P group compared to systemically healthy group ($p<0.001$). No significant difference was found between MetS-P and H-P group in terms of hypertension ($p>0.05$). While PD was significantly higher in H-P group; serum levels of AGE were significantly higher in H-P group. The difference was statistically significant between MetS-P and H-P groups in terms of serum variables of gender, BMI, HbA1c, other diseases, other medications, PD, serum AGE levels (respectively $p=0.026$, $p<0.001$, $p<0.001$, $p<0.001$, $p<0.001$, $p<0.001$, $p<0.001$).

When Tables 1 and 2 were compared, it was seen that gender and other diseases, which had not been significantly different in Table 1, became significant in Table 2. This suggests that the presence of other diseases may influence the gender differences in the prevalence of the disease. In addition, it was seen that the p values of other variables that were significant in Table 1 also increased in significance. In Table 2, it was observed that all identifiers/properties of the variables were preserved from Table 1 and that the p-values for each variable were slightly lower than in Table 1. This indicates that the variables in Table 2 are slightly more reliable than those in Table 1. This suggests that the variables in Table 2 are more reliable and should be considered when making decisions.

In Table 3, performance criteria of data mining methods for real and simulated data sets were given. In

the real data set, it is seen that the performance criteria of the MetS group were lower than systemically healthy group. The reason for this was that the sample size of this group was less than the other group. In the simulated data set, when the sample number of this group was made equal to the H-P group, increases in the performance criteria were observed. For example, while the accuracy value for the multilayer perceptron method in the real data set was 0.667 in the MetS-P group, this value increased to 0.923 in the simulated data set. The reason for this was that data mining methods, like basic statistical methods, were also affected by the uneven distribution between groups and the number of samples. When this value was close to 1 for all performance measures, that made the classification more successful.

Discussion

The objective of the study was to use the oversampling method to increase the amount of data in the MetS-P group (n=6) and balance it with the data set in the H-P group (n=26). In addition to the gender and other disease factors, which were not *p*-significant, balancing the data sets revealed an increase in the existing *p*-significance values. The oversampling method was utilized for the first time in dentistry with study.

El-Sayed *et al.* (2015), in their study on 100 autistic and 15 non-Autism individuals, performed SMOTE to 15 non-Autistic individuals, increased the number of this group to 60 and avoid the imbalance between groups. They applied Support Vector Machine, J48, Naive Bayes and Multilayer Perceptron, which are data mining algorithms, were performed to the balanced groups and the results were compared. The results showed that there was an improvement in performance criteria.[21]

Shin *et al.* (2020), used the SMOTE to eliminate the strong imbalance between the healthy group and depression group. Cross-validation approach was used while creating the model, and the current data set was randomly divided into three different data sets, and each was considered independently.[22]

Ramezankhani *et al.* (2016) balanced the minority class with oversampling method, due to imbalance of the diabetic and non-patient group totally including 6647 individuals (1st group 729 patients, 2nd group 5918 patients). They created 100%, 200%, 300%, 400%, 500%, 600% and 700% training sets from the original data and as a result, they showed that the data group with 700% oversampling rate had the best performance.[23]

Fotouhi *et al.* (2019) used data analysis in cancer diagnosis in their study. However, unbalanced data distribution between classes caused erroneous interpretation of the results. Incorrect results to be obtained because of false evaluation may cost patients' lives. Therefore, it is very important in medicine to solve the class imbalancement problem. Fotouhi conducted a study on the results of the unbalanced data problem and compared the results of these methods by considering the undersampling and oversampling methods. They used RIPPER, MLP, KNN and C4.5 as data mining method and reported the best method for each combination obtained. They used AUC as a performance criterion and emphasized that the performance of their classifiers for different unbalanced cancer datasets improved in 90% of cases when the data became balanced. They also reported that oversampling methods have better results than undersampling methods.[24]

Nguyen *et al.* (2019) studied on the data set which were obtained from 9948 patients' records for, 1904 were diagnosed with Type 2 Diabetes. The diabetes estimation for 2012 is based on data from prior years. (2009–2011). Using the SMOTE method for the unbalanced class in the data set, the data was produced, and the data set became 1: 2 and 1: 1. They compared performance criteria by applying the data mining algorithm they developed for the new data sets and the original data set. They emphasized that the use of 150% and 300% SMOTE did not improve AUC, but resulted in an increase in sensitivity (49.40% and 71.57%, respectively).[25]

In the study performed by Cui *et al.* (2019), a total of 230 variables were examined in samples obtained from 106 lung cancer patients. In the study, SMOTE was applied to cope with unbalanced and small data sets in radiotherapy toxicity modeling, they concluded that there was an improvement in the results and that it was more appropriate to interpret the data performed with SMOTE.[26]

In rare diseases or extraordinary situations such as COVID-19 pandemic, the number of the collected data may not be balanced. The purpose of the oversampling method is to make the group with a small number of data sets closer to the group with a larger number of data sets, that is, to make the data sets balanced. Thus, it will be possible to interpret the data. There are many studies in the literature in which the oversampling method is applied in the field of medicine/health. While searching the literature, it was seen that in some data sets one group had quite high n values (Ramazankhi *et al.* (2016), 1st group 729 patients, 2nd group 5918 patients). In some studies, on the other hand, it was observed that there were smaller sample sizes in all groups in data sets (El-Sayed *et al.* (2015), 100 autistic and 15 non-Autism individuals). The reason for this difference; the high data groups created by scanning the previously recorded data and the lower data groups created by recording one-to-one in the clinic. Since our study consisted of data recorded in the clinical setting, the n number was obtained relatively lower.

When applying the oversampling method, there is no numerical lower limit in the data sets. However, researchers should keep the data numbers as high as possible when planning studies. This method is a reliable method that can be used not for studies where standard data can be obtained, but for duplication of data obtained in small numbers in pandemics and rare diseases. The purpose of the method is not to obtain false data, but to increase the value of existing scientific data.

Similarly, there were changes in data mining performance criteria when comparing the real and simulated data sets in Table 3. In terms of the study's significance, using simulation approaches to generate data for rare and significant groups is critical, as shown in our study.

As can be shown in our study, completing the data in the lower sample size groups eliminates the statistical significance resulting from the sample size for the clinically known factors and makes the study more beneficial by retaining the distribution and properties of the data. Consequently, the study provides both clinical and statistical significance.

Conclusions

Researchers should consider the most appropriate methods for collecting data, such as surveys, interviews, or focus groups. They should also consider the most appropriate way to analyze the data, such as statistical analysis or qualitative analysis. The purpose of researchers should be to use the data obtained to answer questions, draw conclusions, and make recommendations. This could include developing new treatments, understanding the causes of a disease, or identifying risk factors for a particular condition. Researchers should also strive to ensure that their research is conducted ethically. In extreme cases, such as pandemics, it may be impossible to include the number of patients who should be included in the research when designing scientific studies. The reality of Covid has reminded us of what we need to reconsider while doing our work in the scientific field, as well as in all aspects of our lives.

The goal of this study's planning is not to demonstrate that this can be used as an alternative method in every situation. This is how we can use statistical science in scientific studies, where it is a valuable alternative method that may bring a different approach that can be used not to miss cases for special conditions and diseases. Researchers should keep in mind that power analysis will normally be conducted before the data collection while designing a study and calculating statistical power is a crucial step in determining the sample size. Our study intends to demonstrate how this method works in a study group that we expect will be easily followed by everyone, rather than establishing the association between metabolic syndrome and periodontitis.

Conflict of interest

The authors declare that they have no conflicts of interest.

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Table 1. Original dataset statistics

Variables		Groups		
		MetS-Periodontitis	Healthy-Periodontitis	p value
Gender, n (%)	Female	4 (66.7)	10 (38.5)	0.365a
	Male	2 (33.3)	16 (61.5)	
Smoking, n (%)	Smoker	3 (50.0)	15 (57.7)	1.000a
	Non-smoker	3 (50.0)	11 (42.3)	
BMI, n (%)	Normal	2 (33.3)	8 (30.8)	0.018a
	Pre-obese	0 (0.0)	13 (50.0)	
	Obese-1	4 (66.7)	5 (19.2)	
HbA1c	Mean ± SD	5.62±0.88	4.81±0.32	0.012b
	Median (Min.-Max.)	5.80 (4.00-6.40)	4.80 (4.30-5.50)	
Hypertension, n (%)	No	5 (83.3)	26 (100.0)	0.188a
	Yes	1 (16.7)	0 (0.0)	
Other diseases, n (%)	No	3 (50.0)	21 (80.8)	0.148a
	Yes	3 (50.0)	5 (19.2)	
Other medications, n (%)	No	2 (33.3)	21 (80.8)	0.038a
	Yes	4 (66.7)	5 (19.2)	
PD	Mean ± SD	3.04±0.68	3.93±0.61	0.010b
	Median (Min.-Max.)	2.86 (2.34-4.07)	3.93 (2.85-4.97)	
AGE Serum	Mean ± SD	0.68±0.28	0.39±0.07	0.031b
	Median (Min.-Max.)	0.87 (0.35-0.90)	0.39 (0.28-0.61)	

Abbreviations: BMI, body-mass index; HbA1c, hemoglobin A1c; PD, pocket depth; AGE, advanced glycation end-products; SD, Standard deviation; Min, Minimum; Max, Maximum. a: Fisher-exact test. b: Mann-Whitney U test

Table 2. Statistics of the duplicated data set using the SMOTE method

Variables		Groups		
		MetS-Periodontitis	Healthy-Periodontitis	p value
Gender, n (%)	Female	18 (69.2)	10 (38.5)	0.026a
	Male	8 (30.8)	16 (61.5)	
Smoking, n (%)	Smoker	13 (50.0)	15 (57.7)	0.578a
	Non-smoker	13 (50.0)	11 (42.3)	
BMI, n (%)	Normal	9 (34.6)	8 (30.8)	<0.001a
	Pre-obese	0 (0.0)	13 (50.0)	
	Obese-1	17 (65.4)	5 (19.2)	
HbA1c	Mean ± SD	5.61±0.78	4.81±0.32	<0.001c
	Median (Min.-Max.)	5.80 (4.00-6.40)	4.80 (4.30-5.50)	
Hypertension, n (%)	No	22 (84.6)	26 (100.0)	0.110b
	Yes	4 (15.4)	0 (0.0)	
Other diseases, n (%)	No	12 (46.2)	21 (80.8)	0.010a
	Yes	14 (53.8)	5 (19.2)	
Other medications, n (%)	No	8 (30.8)	21 (80.8)	<0.001a
	Yes	18 (69.2)	5 (19.2)	
PD	Mean ± SD	3.04±0.61	3.93±0.61	<0.001c
	Median (Min.-Max.)	2.86 (2.34-4.07)	3.93 (2.85-4.97)	
AGE Serum	Mean ± SD	0.68±0.25	0.39±0.07	<0.001c
	Median (Min.-Max.)	0.87 (0.35-0.91)	0.39 (0.28-0.61)	

Abbreviations: BMI, body-mass index; HbA1c, hemoglobin A1c; PD, pocket depth; AGE, advanced glycation end-products; SD, Standard deviation; Min, Minimum; Max, Maximum. a: Fisher-exact test. b: Mann-Whitney U test

Table 3. Performance matrix table of data mining methods that includes original and replicated data set

Data set	Methods		Accuracy	F-measurement	MCC	PRC Area
Original data set	Multilayer Perceptron	MetS-Periodontitis	0.667	0.727	0.675	0.787
		Healthy-Periodontitis	0.962	0.943	0.675	0.986
		Overall	0.906	0.903	0.675	0.948
	J48	MetS-Periodontitis	0.667	0.615	0.520	0.589
		Healthy-Periodontitis	0.885	0.902	0.520	0.961
		Overall	0.844	0.848	0.520	0.891
	Support Vector Machine	MetS-Periodontitis	0.333	0.444	0.395	0.347
		Healthy-Periodontitis	0.962	0.909	0.395	0.860
		Overall	0.844	0.822	0.395	0.764
Simulated data set	Multilayer Perceptron	MetS-Periodontitis	0.923	0.906	0.808	0.973
		Healthy-Periodontitis	0.885	0.902	0.808	0.978
		Overall	0.904	0.904	0.808	0.975
	J48	MetS-Periodontitis	0.846	0.880	0.772	0.889
		Sağlıklı Periodontitis	0.923	0.889	0.772	0.850
		Overall	0.885	0.884	0.772	0.869
	Support Vector Machine	MetS-Periodontitis	1.000	0.945	0.891	0.897
		Healthy-Periodontitis	0.885	0.939	0.891	0.942
		Overall	0.942	0.942	0.891	0.919

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Effects of Different Surface Treatments on Flexural Strength of Zirconium Oxide Cores

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ABSTRACT

Objectives: The aim of this study was to investigate the effect of different surface treatments on the biaxial flexural strength of zirconia and to determine phase transformation before and after sintering.

Materials and Methods: 150 cylindrical specimens with the dimensions 15 mm diameter and 1,3 mm height were obtained from semi-sintered Y-TZP blocks. These specimens were randomly separated into subgroups; sandblasting, Er:YAG laser, Nd:YAG laser, Er:YAG laser+sandblasting, Nd:YAG laser+sandblasting, fine grain bur, coarse grain bur. Half of the semi-sintered Y-TZP samples were treated before sintering and the others were treated after the sintering procedures. No treatment was performed in control group. Biaxial flexural strength test was performed to all samples. X-ray diffraction analysis (XRD) were performed to identify transformed monoclinic phase. The data were analyzed by Kruskal-Wallis, Man Whitney U test and Wilcoxon test.

Results: Specimens that were treated before sintering had lower biaxial flexural strength. The highest biaxial flexural strength values in all groups were seen in sandblasting groups and the lowest in grinding groups. According to the XRD analysis the highest phase transforme was determined in sandblasting groups. Sandblasting, Er-YAG laser+sandblasting and Nd-YAG laser+sandblasting were greatly increased the biaxial flexural strength of all the surface treatments after sintering. All the sandblasting treatments were found more monoclinic phase was found than other groups.

Conclusions: Surface treatments were found to affect both the mechanical properties and phase changes of zirconia.

Key Words: Zirconia, Flexural strength, Phase transformation, Sandblasting, Er:YAG laser, Nd:YAG laser.

Zirkonyum Oksit Alt Yapı Üzerine Uygulanan Farklı Yüzey İşlemlerinin Bükülme Dayanımına Etkileri

ÖZ

Amaç: Bu çalışmanın amacı, farklı yüzey işlemlerinin zirkonyanın iki eksenli bükülme dayanımı üzerindeki etkisini araştırmak ve sinterleme öncesi ve sonrası faz dönüşümüne etkilerini belirlemektir.

Gereç ve Yöntemler: Yarı sinterlenmiş Y-TZP bloklardan 15 mm çapında ve 1,3 mm yüksekliğinde 150 silindirik örnek elde edildi. Bu numuneler rastgele alt gruplara ayrıldı; Kumlama, Er:YAG lazer, Nd:YAG lazer, Er:YAG lazer+kumlama, Nd:YAG lazer+kumlama, ince grenli frez, kalın grenli frez. Yarı sinterlenmiş Y-TZP numunelerinin yarısına tam sinterleme yapılmadan önce, kalanlara ise tam sinterleme işlemi yapıldıktan sonra yüzey işlemlerine tabi tutuldu. Kontrol grubuna herhangi bir yüzey işlem uygulanmadı. Tüm örneklere iki eksenli bükülme dayanımı testi uygulandı. Monoklinik faz dönüşümünü tanımlamak için X-ışını kırınım analizi (XRD) yapıldı. Veriler Kruskal-Wallis, Man Whitney U testi ve Wilcoxon testi ile analiz edildi.

Bulgular: Tam sinterlemeden önce yüzey işlemi gören numuneler daha düşük iki eksenli bükülme dayanımı gösterdi. Tüm gruplarda en yüksek iki eksenli bükülme dayanımı değerleri kumlama gruplarında, en düşük değerler ise frezleme gruplarında görüldü. XRD analizine göre en yüksek faz dönüşümü kumlama grubunda görüldü. Tam sinterleme işlemlerinden sonra uygulanan kumlama, Er-YAG lazer+kumlama ve Nd-YAG lazer+kumlama yüzey işlemlerinin iki eksenli eğilme dayanımını büyük ölçüde artırdığı görüldü. Tüm kumlama işlemlerinde diğer gruplara göre daha fazla monoklinik faz değişimi görüldü.

Sonuç: Yüzey işlemlerinin zirkonyanın hem mekanik özelliklerini hem de faz değişimlerini etkilediği bulundu.

Anahtar Kelimeler: Zirkonyum Oksit, Bükülme Dayanımı, Faz dönüşümü, Kumlama, Er:YAG lazer, Nd:YAG lazer.

Süreç

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Introduction

The use of zirconia ceramics in aesthetic dentistry has been on the rise in recent years. Zirconia ceramics are widely used in prosthetic restorations due to their advantages such as high mechanical properties, biocompatibility, good dimensional stability and color compatibility. The preferred core material for prosthetic restorations is Yttria-Stabilized Tetragonal Zirconia Polycrystals (Y-TZP).[1,2] While zirconia is found in nature in polymorphic form, it has monoclinic form (m), tetragonal form (t) and cubic form (c). The melting point of zirconium is 2680 ^{0}C and it is in the cubic phase up to this temperature. If it falls below this level, it transitions from cubic phase to tetragonal phase. The tetragonal phase is stable up to 2370 ^{0}C. When it is lowered below 2370 ^{0}C, the tetragonal structure turns into tetragonamonoclinic phase and this phase transition takes place below 1170 ^{0}C. When passing from the tetragonal phase to the monoclinic phase, the volume of the crystals increases (4%-5%), which causes the appearance of microcracks or macrocracks and the loss of their mechanical properties.[3,4] Zirconia is fragile at room temperature in the monoclinic phase. Therefore, in technical applications, stabilization of the compound is required to prevent the transition from the tetragonal phase to the monoclinic phase. This stabilization is carried out with Yttrium trioxide.[3,5]

As a result, the properties of zirconia can change not only depending on its content and microstructure, but also depending on the production method. Zirconia restorations can be produced from partially sintered blocks and then subjected to the final sintering process, as well as from fully sintered blocks.[6,7]

Improvement in the mechanical properties of zirconia is linked to its long-term performance. However, the clinical success of prosthetic restorations depends largely on cementation. Different surface treatments have been tried to obtain micro-retaining area on the zirconia surface and to increase the surface area. These surface treatments ensured the connection between zirconia and resins, and between zirconia and ceramics, and the successful use of the restoration for a long time.[8,9] These applications are sandblasting[10], grinding[11], laser[10-12] or a combination of these. Surface defects can also occur on zirconia materials during laboratory or chairside procedures.[2,8]

In occlusal adjustments made on zirconia after grinding, it was stated that there was a decrease in stress relief and flexural strength in zirconia in long-term follow-ups. It has also been reported that this decrease is related to the degree of conversion from the tetragonal phase to the monoclinic phase.[13] Although there are many studies on the effect of laser and sandblasting on bond strength[8,10,12], there are limited studies on the effect of laser treatment applied to zirconia on biaxial flexural strength.[14,15] Therefore, the aim of the present work is to investigate the effect of different surface treatments applied to zirconia before and after sintering on the flexural strength and phase transformation. The null hypotheses are that all surface treatments will not affect flexural strength and that surface treatments will not alter phase transformation.

Materials and Methods

Semi-sintered Y-TZP zirconia block (Noritake Dental Inc, Japan) was used in this study. The disc-shaped specimens were designed and milled using a CAD/CAM system (Yenamak, Yenadent Ltd., Istanbul, Turkey). A total of 150 disc-shaped specimens, 15mm in diameter and 1.3mm thick, were obtained from these blocks (n=10). After preparation, half of the samples were surface treated before sintering and sintered according to the manufacturer's instructions. In the remaining samples, surface treatments were applied after sintering. The sintering process was completed in a total of 8 hours by allowing it to come back to room temperature from room temperature to 1375 °C in the sintering furnace (Protherm Furnaces, Istanbul, Turkey). After all samples were sintered, surface treatment was applied to the untreated samples. In this way, two main groups were created. The groups are listed as follows

Control (C): Not surface treated

Sandblasting (S): Surfaces of the samples were sandblasted with 110 µm Al_2O_3 particles at pressure of 0.5 MPa for 15s and distance of 10mm (Blastmate II; Ney, Yucaipa, CA, USA). After which the samples were washed and dried

Er:YAG Laser (E): It was applied to the sample surfaces by scanning them for 20 seconds with an optical fiber transport system. The distance is adjusted to 10 mm. Er:YAG laser (Smart 2940D Deka Laser, Florence, Italy) was applied by adjusting the beam settings to 150 mJ, 1.5 W and 10 Hz.

Nd:YAG Laser (N): Nd:YAG laser (Smarty A10 Deka Laser, Florence, Italy) was applied to the sample surfaces from a distance of 10 mm from a distance of 10 mm for 20 seconds. Beam settings were set to 100 mJ, 1 W, 10 Hz.

Er:YAG Laser and Sandblasting (ES): First, the above Er:YAG laser parameter was applied in the same way. Then the samples were washed and dried. Afterwards the surface was sandblasted in the same parameter.

Nd:YAG Laser and Sandblasting (NS): First, the above Nd:YAG laser parameter was applied in the same way. Then the samples were washed in running water and dried, and then surface was sandblasted in the same parameter.

Grinding (Fine Grained Bur) (FG): Diamond burs with 50 µm grain size (Meisinger, Hansemannstr, Neuss, Germany) were preferred for grinding the samples. The bur was attached to the handpiece and the rotation speed per minute was set to 20000. At the end of the grinding process, the sample thickness was thinned by 0.1 mm. The thickness was measured with a digital caliper.

Grinding (Coarse Grained Bur) (CG): Diamond burs with a 200 µm grain size (Meisinger, Hansemannstr, Neuss, Germany) were used for grinding the specimens. The other operations were performed in the same way as with the fine-grained bur.

Biaxial flexural strength

A Universal machine (Lloyd Instruments, LF Plus Segensworth, Fareham, UK) was used for the biaxial flexure test according to ISO 6872.

Three balls with a diameter of 3.2 mm were placed on a 10 mm diameter circle. The balls were positioned at an angle of 120 degrees with respect to the center of the circle (Figure1). The sample was placed on the balls with its center on the same axis as the piston. Force was applied to the sample surfaces with a cylindrical tip with a diameter of 1.4 mm (Figure 2). The crosshead speed was set to 0.5 mm/min. The strength has been calculated in accordance with the formulas below:

$S = - 0{,}2387\ P(X- Y)/d^2$

S: Biaxial flexural strength (MPa), P: Force at break (N), d: Sample thickness (mm)

$X = (1+ v)\ \ln(r_2/r_3)^2 + [\ (1-v)/2]\ (r_2/r_3)^2$

$Y = (1+ v)\ [1 + \ln(r_1/r_3)^2] + (1-v)\ (r_1/r_3)^2$

v: Poisson' ratio (0.25), r_1: The radius of the circle on which the support balls are located (mm), r_2: Radius of the force applied field (mm), r_3: Radius of sample (mm).

X-ray diffraction analysis (XRD)

Crystal analyzes of the samples were performed with an XRD device (Bruker AXS D8 Advance, UK) using monochromatic CuKα heat. Scanning was performed on the sample surface between 20-40 degrees (2θ) with a 0.01 degree step interval. Intensity values found as a result of X-ray diffraction were recorded. In each of the samples, the highest value observed in the denser regions and the 2θ angles at which these values were observed were recorded. Amount (XM) of the phase-changed monoclinic phase on the field of the surface-treated samples compared to the tetragonal phase was calculated according to the equation stated by Garvie and Nicholson.[16]

$$X_M = \frac{I_{M(111)} + I_{M(111^-)}}{I_{M(111)} + I_{M(111^-)} + I_T}$$

I: The highest value of the phase density

M(111) : Plane showing (111) crystal geometry belonging to the monoclinic phase

M(111-) : Plane showing (111-) crystal geometry belonging to the monoclinic phase

T: Tetragonal phase

Statistical analyses

The data was uploaded to the SPSS (ver: 14.0) program. Analysis of Variance, Tukey's test and the significance test of the peer-to-peer difference were used in the evaluation of the data since the parametric test assumptions were fulfilled (p=0.05).

Results

The result of the biaxial flexural strength test applied to the test groups are explained in Table1. While S group showed the highest flexural strength among all groups, the lowest was seen in group FG and CG, respectively. (p=0.001). Before sintering surface treatment applications decreased flexural strength in all groups compared to after sintering surface treatment applications and it was found statistically significant in all groups except group FG (p=0122) and CG (p=0.106).

The results of the monoclinic phase content values (%) are demonstrated in Table 2. While the monoclinic phase content is seen between 1% and 2% in the groups that have been surface treated before sintering, it is seen between 1% and 13% in the surface treatments applied after sintering. The highest amount of the monoclinical phase was found Group S, ES and NS respectively. After the surface treatments after sintering, monoclinic peaks were seen with M (111) orientation in the XRD model (Figure 3).

Discussion

The effect of surface treatments on biaxial flexural strength and phase transformation before and after sintering was investigated in this study. According to the results, there was significant difference among the biaxial flexural strength and phase transformation all groups before and after sintering. The hypothesis that surface treatments would not affect the flexural strength and change the phase transformation of zirconia was rejected.

The mechanical and chemical surface treatments applied on the zirconia allow to increase the surface roughness and porosity and improve the wettability.[17] Thus, it affects the bonding of the ceramic to be applied on the zirconia. İn addition, It is necessary to know whether there is a change in the physical properties of these applied surface treatments other than bonding.

In the literature, different results can be seen on Y-TZP zirconia in the grinding process, which is one of the surface treatments. In some studies, grinding triggers the t-m phase change and creates compression stress with approximately 4% volumetric expansion at superficial defect sites and prevents crack propagation.[13,18] In addition, in other studies, it has been stated that grinding causes a decrease in its mechanical properties by creating catastrophic defects on zirconia.[19] In study, the decrease in flexural strength in surface treatment with burs of different grain sizes shows parallelism with the above study.

Sandblasting process are the parameters frequently used in surface treatments. Some authors indicated that sandblasting increase the flexural strength on zirconia and seemed to result from the increase in monoclinic phase content.[20-22] Caglar *et al.*[14] reported that 110 µm Al_2O_3 particles for 30 seconds on zirconia increased the monoclinic phase and flexural strength in all groups. In study, the surface treatments increase the monolithic phase content and the monoclinic phase content in the sandblasting processes shows the highest values in flexural strength, which supports the above study. In the grinding groups, it was observed that there was less monoclinic phase transforme, but a decrease in durability. It can be said that this may be due to the heat arising in the grinding application and the presence of microcracks on the surfaces. In other studies, it has been reported that various surface treatments result in different rates of

phase transforme (t-m), but the flexural strengths are statistically similar.[21]

Laser has been used in dentistry since 1995. Many studies have been carried out to determine reliable values when using the ER:YAG laser on zirconia.[14,23,24] Cavalcanti *et al.*[23] reported that Er:YAG laser (200 mJ) was more trusted for zirconia ceramics between the 400 and 600 mJ densities.Akin *et al.*[24] reported that 150 mj Er:YAG laser increases the surface roughness. these days, we planned the laser energy release to be 150 mj.

Çağlar *et al.*[14] remarked that sandblasting showed higher flexural strength compared to the control group in different surface treatments on zirconia, and Er:YAG laser showed a similar but lower value compared to the control group. He stated that this result was achieved with the application of the laser with the water cooling process and the preservation of the monoclinic phase amount in its structure. They also stated that cracks on the zirconia surfaces in SEM examinations may be one of the reasons for reducing this strength. This result was similar to that of the present study, which reported that the relative amount of the monoclinic phase of Er:YAG laser treatments was close to that of zirconia control groups.

Kurtulmus *et al.*[15] reported that laser and sandblasting before sintering would reduce the flexural strength of zirconia. In study, all surface treatments before sintering illustrated lower flexural strength in zirconia compared to the surface treatments after sintering, and it was statistically significant between the groups. This result was similar to that of the present study.

Within the limitations of this study, it has been evaluated the surface treatments affect the flexural strength of zirconia. However, thermal aging process should be performed and its effect in the oral environment should be evaluated. In addition, it should be determined which one will be more effective by using different parameters in surface treatments. It is necessary to compare different parameters in determining the relationship between surface treatments and phase transforme.

Conclusions

- All sandblasting parameters increased the flexural strength of zirconia.
- All surface treatments before sintering significantly reduced the flexural strength of zirconia compared to after sintering.
- The surface treatment that the most reduced the flexural strength compared to the no surface teratment group was the grinding group.
- The most monoclinic phase transformation was seen with the sandblasting surface treatment.

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Table 1. Test results of biaxial flexural strength of all groups (MPa)

Groups	Before Sintering X ± Sd (MPa)	After Sintering X ± Sd (MPa)	
C Group	1171.72 ± 34.34a	1171.72 ± 34.34k	
S Group	1243.15 ± 29.14b	1287.41 ± 26,59l	t= 5.16 P= 0.001*
E Group	1000.45 ± 46.99c	1115.78 ± 22.91m	t= 7.15 P= 0.001*
N Group	1033.27 ± 53.15c	1101.31 ± 16.21m	t= 3.90 P= 0.004*
ES Group	1102.82 ± 36.38d	1229.43 ± 29.22n	t= 12.82 P= 0.001*
NS Group	1187.39 ± 30.60a	1232.15 ± 23.61n	t= 4.91 P= 0.001*
FG Group	937.11 ± 42.76e	976.23 ± 32.52o	t= 1.70 P= 0.122
CG Group	927.36 ± 27.18e	952.13 ± 32.46o	t= 1.79 P= 0.106
	F= 95.23 P= 0.001 P< 0.05	F= 181.91 P= 0.001 P< 0.05	

*When the mean values of each group before and after sintering are compared, the difference is statistically significant (p<0.05).
** The difference between the means followed with different lowercase letters in the vertical columns is statistically significant according to the Tukey test (P<0.05).

Table 2. Relative amount of monoclinic zirconia (%)

Gruplar	Before sintering	After sintering
C Group	1.46	1.46
S Group	2.02	13.4
E Group	1.94	3.46
N Group	1.82	2.13
ES Group	1.99	11
NS Group	1.71	10.76
FG Group	1.62	6.62
CG Group	1.73	8.86

Figure 1. Positioning of stainless steel balls

Figure 2. The sample was placed on stainless steel balls.

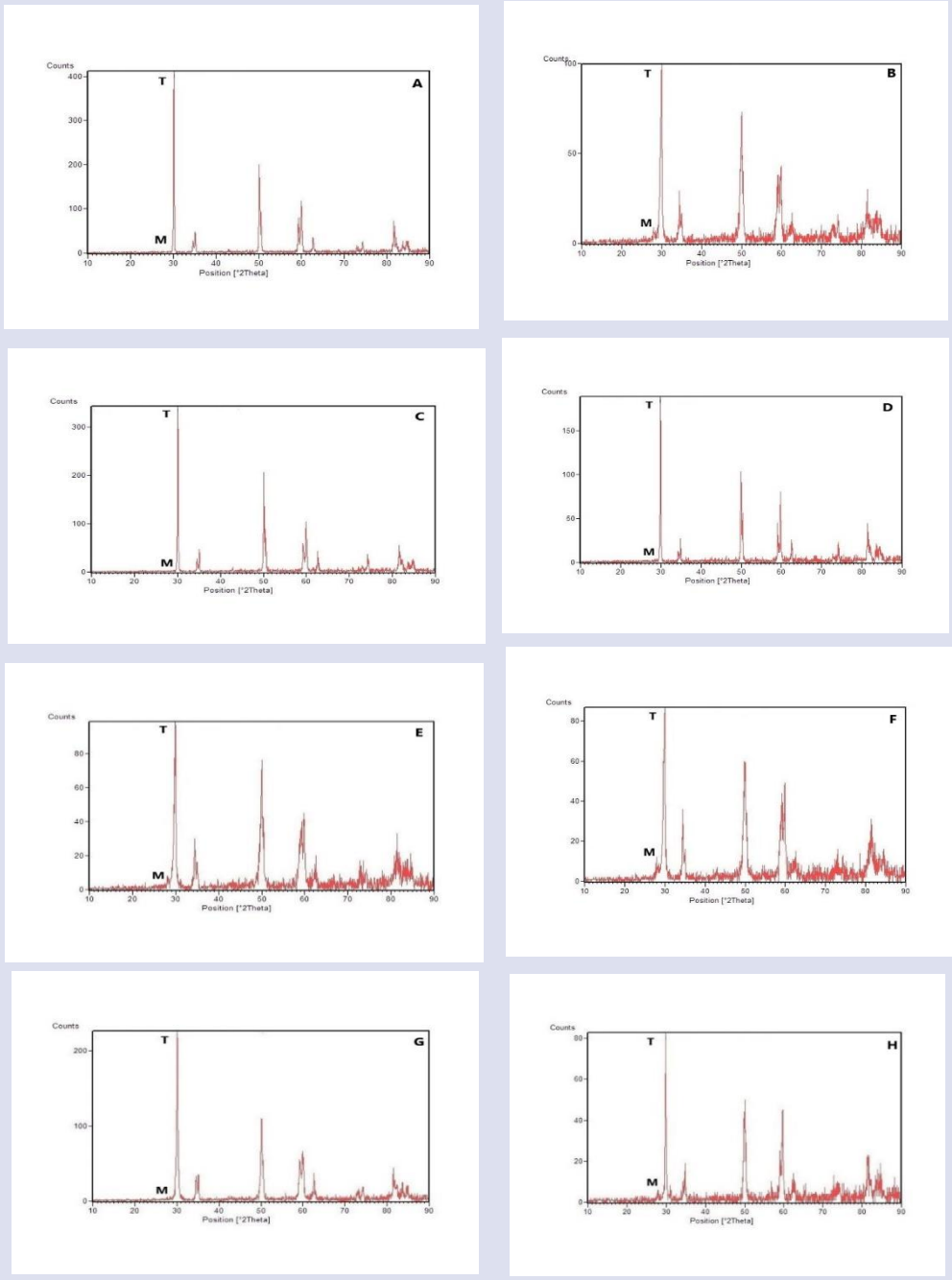

Figure 3. X-ray powder diffraction patterns of all sintered groups: A:Control, B:Sandblasting, C: Er:YAG Laser, D: Nd:YAG laser, E: Er:YAG Laser and Sandblasting, F: Nd:YAG Laser and Sandblasting, G: Fine Grained Bur, H: Coarse Grained Bur.

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Effects of Covid-19 Pandemic on the Career Planning of a Group of Dentistry Students

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ABSTRACT

Objectives: The aim of this study is to examine the effect of the Covid-19 pandemic on the career planning and specialization preference of a group of Turkish dental students and related factors.
Materials and Methods: A total of 305 volunteer students from X University Faculty of Dentistry participated in the study. A questionnaire consist of 44 open-ended and multiple-choice questions was sent to the students. Career plans, specialization preferences and the factors affecting them were questioned in the survey for the periods of before and during Covid-19.
Results: With the Covid-19 pandemic, 23.3% of the students changed their career plan and 24.6% of them changed their field of specialization. Regarding the results of this present study, choice of private practice was preferred for career planning after the pandemic. The specialty of choice before the pandemic was Oral and Maxillofacial Surgery whereas the department with the highest increase after the pandemic was Endodontics.
Conclusions: The Covid-19 pandemic affected the career and specialty preferences of dental students. Factors such as working conditions, financial return, and employment opportunities, rather than aerosol and increased risk of contamination, were effective in this change.

Key Words: COVID-19, Dental Specialties, Dental Students, Career Choice.

Bir Grup Diş Hekimliği Öğrencisinin Kariyer Planlamasına Covid-19 Pandemisinin Etkileri

Süreç

Geliş: 17/11/2023
Kabul: 14/12/2023

ÖZ

Amaç: Bu çalışmanın amacı, Covid-19 pandemisinin bir grup Türk diş hekimliği öğrencisinin kariyer planlaması ve uzmanlık alanı tercihine etkisini ve buna etki eden faktörleri irdelemektir.
Gereç ve Yöntemler: Çalışmaya X Üniversitesi Diş Hekimliği Fakültesi'nden 305 gönüllü öğrenci katıldı. Öğrencilere açık uçlu ve çoktan seçmeli toplam 44 soruluk bir anket formu gönderildi. Ankette Covid-19 öncesi ve sonrası kariyer planları, uzmanlık alanı tercihleri ve bunlara etki eden faktörler sorgulandı.
Bulgular: Covid-19 salgınıyla öğrencilerin %23,3'ünün kariyer planında, %24,6'sının ise uzmanlık alanı tercihinde değişiklik görüldü. Kariyer planlamasında pandemi sonrası en çok özel sektörde çalışmak tercih edildi. Pandemi öncesi en çok tercih edilen uzmanlık dalı Ağız, Diş ve Çene Cerrahisi iken, pandemiyle birlikte en çok artış görülen bölüm Endodonti oldu.
Sonuç: Covid-19 pandemisi, diş hekimliği öğrencilerinin kariyer ve uzmanlık alanı tercihlerini etkilemiş, aerosol ve bulaş riski artışından ziyade; çalışma koşulları, maddi getiri ve iş bulma olanağı gibi faktörler bu değişimde etkili olmuştur.

Anahtar Kelimeler: COVID-19, Diş Hekimliğinde Uzmanlık, Diş Hekimliği Öğrencileri, Kariyer Seçimi.

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Introduction

Due to the Covid-19 pandemic that started in Wuhan, China, and viral pneumonia caused by the SARS-CoV-2 virus, there were difficulties in many issues such as the countries' health systems to fight the pandemic.[1] Various measures were taken to prevent the pandemic, such as increasing social distance, using masks, closing some workplaces and schools, and a flexible working system in Turkey as well as all over the world.[2] Due to these measures, shrinkage was observed in the economies of the countries. Despite the incentives given, employment decreased in many sectors, so it became difficult to find a job.[3] In dentistry, due to the high probability of contamination in procedures involving aerosol, some elective procedures were stopped in parallel with the increase in cases, and only emergency treatments were performed in some periods.[2]

Career plan is the process of determining the goals of the individual during career choice and the tools to be used on the way to this goal. While the right decisions cause happiness and productivity in the work and social life of the individual, the wrong decisions cause unhappiness, inefficiency and reluctance.[4] Studies have shown that factors such as financial return, interest in the field of specialization or career desired by the individual, ease of finding a job, and social status affect career plans.[5] Graduated dentists can choose the public or private sector, a specialization or doctoral program within their career planning.[6]

Specialization in dentistry is of vital importance in meeting the specific treatment needs of the population in cases where undergraduate education is insufficient.[7] In order to meet this need, DUS (Dentistry Specialization Training Entrance Exam), the first of which was held in 2012, was added as an alternative to the previous doctoral education. With this exam, specialization training started in 8 fields, namely Oral and Maxillofacial Radiology (OMFR), Oral and Maxillofacial Surgery (OMFS), Restorative Dentistry, Prosthetic Dentistry, Orthodontics, Endodontics, Pedodontics and Periodontology.[6,8,9] In 2018, Oral Pathology was included in the specialty training.[10]

Pandemics such as Covid-19, which are rare in the world and greatly affect social life, may cause changes in the career plans of individuals due to changing life and work conditions and risks. The aim of this study is to investigate the effects of Covid-19 on the career plan and specialization of 3rd, 4th, and 5th grade dentistry students whose career plans have been largely shaped and who have reached the level of clinical training as trainees.

Material and Method

This study was carried out with the approval of X University Non-Interventional Clinical Research Ethics Committee (No: 2021-03/49) and the permission of the Republic of Turkey Ministry of Health Covid-19 Scientific Research Evaluation Commission (No:2021-03-08T14_32_03).

A total of 305 students of the 3rd, 4th, and 5th grades studying at X University Faculty of Dentistry were participated in the study. In this study, an open-ended and multiple-choice questionnaire consisting of 44 questions was used. Informed consent form was added to the introduction part of the survey regarding the purpose of the study and confidentiality. In the survey, age, gender, class of students, level of knowledge about dentistry before choosing dentistry, Credit and Dormitories Institution's (KYK) Student Loan status; career, and specialty preferences before Covid-19 and with the pandemic were questioned. The questionnaire form used by Kanmodi et al. [11] was modified and used for the factors affecting the career plan. In addition, new questions were added, inspired by the work of Garcia et al. [5] Volunteers were asked to answer the questions on a scale of 1-3 (1 = disagree, 2 = undecided, 3 = agree). The survey form prepared with Google Forms® was delivered to students via e-mail and WhatsApp® application. Collected data were loaded into the SPSS® 22.0 program for statistical analysis. Descriptive statistics and Chi-square tests were applied to the data. It was considered significant if $p<0.05$.

Results

Of the 305 students who participated in the survey, 61% were female and 39% male. The mean age of the students was 22.5 ± 1.49. Of these students, 105 (34.4%) were in the 3rd grade, 98 (32.1%) were in the 4th grade, and 102 (33.4%) were in the 5th grade. With the pandemic, 23.3% of the students reported that they changed their career plan and 24.6% reported that they changed their field of specialization.

Working conditions (77.5%), job opportunities (69%) and financial return (66.2%) were found to be the most effective factors in this change in 71 (23.3%) students who changed their career plans with the pandemic. Concern about contagion to the family was significantly higher in males, and fear of contracting infectious diseases was significantly higher in females ($p<0.05$) (Table 1).

Among 75 students (24.6%) whose specialization preferences changed with the pandemic, interest in the field of specialization (72%), being able to find a job (64%) and financial return (62.7) were the most effective factors. In addition, interest in the field of specialization, working conditions and duration of specialization training in women, and financial return in men were significantly more effective in this change ($p<0.05$) (Table 2).

58% of all students were getting KYK Student Loans. 27.7% of the students who took credit and 17.3% of the students who did not show a change in their career plan ($p<0.05$). The tendency to the private sector has increased among students who have received loans and whose career plans have changed. No significant difference was observed between the status of student loans and the change in the field of specialization ($p>0.05$).

In the students whose career plans changed, there was a significant difference between the genders in their career plans before Covid-19 ($p<0.05$). Specialization in women and work in the private sector in men was the

most preferred option. However, with the Covid-19 pandemic, interest for the private sector has increased for both genders in career planning (Table 3).

There was no significant difference between genders in the preference of specialization of the students who changed their field of specialization after Covid-19 ($p>0.05$). The biggest increase during Covid-19 in both genders was in Endodontics. During Covid-19, interest in Endodontics, OMFR and Oral Pathology increased in both women and men, and the tendency to Restorative Dentistry and OMFS decreased ($p>0.05$) (Graphic-1).

Discussion

The results of this study, which we planned during the Covid-19 pandemic, wondering about the effect of radically changing living conditions and aerosol environment on the career plans and specialty choices of dental students, showed that approximately 25% of dentistry students were affected by this extraordinary situation.

Due to the Covid-19 pandemic in Turkey, face-to-face education has been terminated and online education has been started in all faculties within the scope of epidemic measures with the decision of the Higher Education Council (YÖK), and this decision was still applied in the form of hybrid education in the 2021-2022 academic year.[12,13]

While students in dentistry faculties received clinical education only online in the first semester, face-to-face education continued with a limited number of students in the following semesters. Studies conducted during this period reported that dental students' anxiety levels and future anxieties increased as a result of disruptions in education, and as a result, some students could change their career plans.[14] In the literature, only one study was found that examined the impact of the Covid-19 pandemic on the career plan of American dental students.[5] However, in this study,[5] the reasons affecting the career choices of the students and their field of specialization were not investigated. As far as we know, this study is the first study to investigate the career planning of Covid-19 in Turkish dentistry students, as well as the first study in the literature to investigate the effect of Covid-19 on specialization preferences.

Like many countries in the world, Turkey's economy has also been adversely affected by the pandemic, and not knowing how long the pandemic will last has had a negative impact on employees and many segments.[15] Özdede and Şahin,[14] in their study investigating the views and anxiety levels of Turkish dentistry students about the Covid-19 pandemic, reported that 24.5% of 249 students were considering changing their profession, and this rate increased in students with high anxiety scores. In this study, it was found that the career plans and specialization preferences of the students changed at similar rates within the field of dentistry. The fact that working conditions, financial return and employment opportunities are more effective factors than the risk of aerosol formation in students who change their career plans may be associated with economic concerns. The fact that career plan changes are higher in students who receive KYK credits also supports this situation. In addition, the fact that the interest in the field of specialization was found to be higher than the financial return in students who changed their field of specialization may have been effective because the number of women was higher. This is the limitation of our study.

Considering that the most influential factor in career planning is working conditions, it is noteworthy that the tendency towards public sector options such as specialization and application for public service has decreased with the pandemic. The reason for this may be the decrease in the economy and purchasing power, the low number of vacancies for general practitioners in public service, and the higher employment opportunities in the private sector compared to the public sector. In addition, the fear of contagion in the family was found to be significantly higher in male students whose career plans changed, and the fear of contracting infectious diseases in female students. As the reason for this result, it may be thought that the risk of transmission because of exposure to Covid-19 increased, as well as the dentists' inability to perform their profession because of the appointment of dentists in the public sector for filiation and taking PCR samples.

In the study conducted by Garcia et al. on 252 American dentistry and dental hygienist students to examine the impact of Covid-19 on their career plan, 11.2% of the students reported that their career plan had changed and the majority of those who changed their career plan had shifted to the private sector.[5] It has been reported that the depression and anxiety scores of the students whose career plans have changed are high, while their desire to work in the private sector has increased, their desire to do specialization has decreased, and that these students have more student loan debt. Similarly, in this study, the tendency to the private sector increased in both genders. Although there is no significant difference between students who have changed their career plans and those who do not receive KYK Loans, the trend towards the private sector after covid was seen in this group of students at the highest rate. However, as a limitation in this study, we think that the higher number of female students than males may affect the results in career planning.

One of the main questions in this study is "Is there a transition from fields that more frequent aerosols to less frequent ones?" was the answer to the question. It was assumed that aerosol generating procedures were less in OMFS, Orthodontics, Oral Pathology and OMFR departments, and higher in Endodontics, Pedodontics, Prosthetic Dentistry, Restorative Dentistry and Periodontology departments. According to the results of this study, while the tendency to Orthodontics, OMFR,

Oral pathology increased, the increase in interest in the Department of Endodontics was an unexpected result. With the pandemic, only emergency procedures were carried out in public institutions from time to time, depending on the density of Covid-19 cases, and elective procedures were postponed.[16] Although it includes aerosol generating processes, the reason for the increasing interest in the endodontic department is, it may be that radical treatments have replaced elective treatments in public hospitals and universities. This will naturally cause patients who do not prefer tooth extraction to prefer private sector services, and an increase in financial gain in these centers will also be possible. Again, the extended appointment dates due to covid measures and density in public institutions may have increased the change to the private sector. Financial gain will also increase in private institutions where the risk of transmission is partially reduced since patients will receive faster service and the density is low.

Conclusions

The Covid-19 pandemic has changed the career plan and specialization preferences of about a quarter of dental students after graduation. The effect of aerosol and contamination risk on career and specialty change was found to be less effective than factors such as working conditions, financial return, and difficulty in finding a job. Since this study was conducted shortly after the onset of the Covid-19 pandemic, multicenter studies are needed to examine the long-term effects of the pandemic.

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None.

Conflict of Interest

The Authors declare that there is no conflict of interest.

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Table 1. Distribution of affecting factors in students whose career plans changed during COVID-19 by gender

	Male	Female	Total	p
Working Conditions	74.2%	80%	77.5%	0.845
Financial Income	71%	62.5%	66.2%	0.348
Job Opportunity	61.3%	75%	69%	0.060
Risk of Infectious Diseases	12.9%	20%	16.9%	0.002*
Aerosol Formation Risk	25.8%	22.5%	23.9%	0.216
Concern of Contagion to the Family	22.6%	10.0%	15.5%	<0.001*
Existing Chronic Disease	19.4%	10%	14.1%	0.116

Chi-square test (p: significance level, significant if *<0.05)

Table 2: Factors influencing the before and during COVID-19 specialization preferences of students whose fields of specialization changed

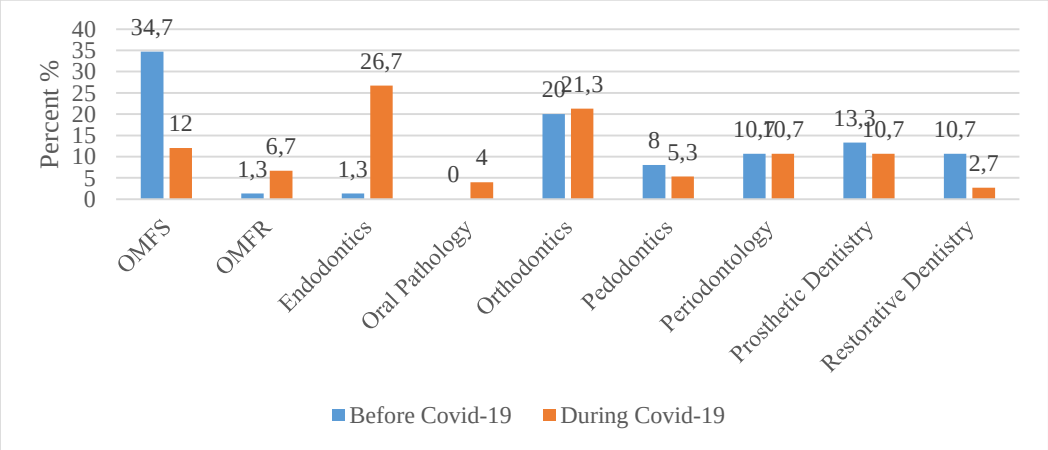
	Male	Female	Total	p
Personal Interest	59.4%	81.4%	72%	0.039*
Job Opportunity	50%	74.4%	64%	0.085
Financial Income	65.6%	60.5%	62.7%	0.044*
Social Status	56.3%	60.5%	58.7%	0.715
Working Conditions	40.6%	65.1%	54.7%	0.009*
Popularity	43.8%	53.5%	49.3%	0.601
Case Diversity	34.4%	46.5%	41.3%	0.55
Ease of Entry	28.1%	46.5%	38.7%	0.069
Complication Risk	34.4%	32.6%	33.3%	0.065
Training Period	15.6%	44.2%	32%	0.026*
Family and Society Impact	31.3%	32.6%	32%	0.158
Training Challenge	15.6%	25.6%	21.3%	0.163
Aerosol Formation	21.9%	20.9%	21.3%	0.571
Risk of Infectious Diseases	9.4%	16.3%	13.3%	0.577
Concern of Contagion to The Family	21.9%	4.7%	12%	0.061

Chi-square test (p: significance level, significant if *<0.05)

Table 3: Distribution of before and during COVID-19 career plans of students whose career plans changed by gender

	Before Covid-19			During Covid-19		
	Male	Female	Total	Male	Female	Total
Specialization Program	29%	57.5%	45.1%	38.7%	30.0%	33.8%
Apply on Public Service	22.6%	32.5%	28.2%	12.9%	15.0%	14.1%
Working in Private Sector	32.3%	5%	16.9%	41.9%	37.5%	39.4%
Doctoral Program	3.2%	0%	1.4%	0%	0%	0%
Working in Abroad	12.9%	5%	8.5%	6.5%	17.5%	12.7%
		χ^2: 14.009 p<0.05*			χ^2: 2.215 p>0.05	

Chi-square test (p: significance level, significant if *<0.05)



Graphic-1: Before and during COVID-19 specialization preferences for students whose fields of specialization changed

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Evaluation of Periodontal Awareness, Attitudes and Behaviors Toward Oral and Dental Health of Patients Presenting to Bursa Oral and Dental Health Training and Research Hospital

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ABSTRACT

Periodontal diseases are inflammatory conditions that concern a large part of society and affect the hard and soft tissues around the teeth. These diseases can be treated easily and successfully when diagnosed at an early stage. The present research aimed to determine whether some sociodemographic factors affect periodontal health, reveal the factors that affect it, if any, and conduct studies to reduce the effects of these factors. To this end, a survey was conducted on 300 patients at Bursa Oral and Dental Health Training and Research Hospital to assess their periodontal health and awareness. This survey included questions about patients' oral and dental health, sociodemographic status, periodontal awareness, and examination frequency. The results obtained from the surveys were evaluated using the IBM SPSS Statistics program for statistical analysis.

As a result of the statistical analysis, a significant relationship was found between gender, age, frequency of going to the dentist, educational status, frequency of tooth brushing, systemic diseases and smoking, and oral and dental health and periodontal awareness.

Keywords: Periodontal Awareness, Periodontal Health, Oral And Dental Health, Examination Frequency

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Introduction

Periodontal disease is a chronic infectious condition that adversely affects oral and systemic health, causes irreversible damage, which may result in the loss of hard and soft tissues of the tooth, and has a high prevalence in society.[1] Periodontal disease may also affect individuals' quality of life by causing gingival bleeding, bad breath, sensitive teeth, tooth mobility, and even the loss of teeth.[2]

Although periodontal diseases that affect 50-90% of the adult population worldwide are not life-threatening, they usually affect the patient's quality of life adversely.[3] Gingival bleeding is the first symptom of periodontal disease. Therefore, it is crucial to increase the awareness of periodontal diseases so that patients are treated at the early stages of symptoms and the necessary periodontal treatment is provided.

Maintaining periodontal health requires an informed and conscious society. Knowing the differences between periodontal health and diseases increases the success of periodontal treatment. Public awareness of periodontal problems and their evaluation by dentists affect periodontal health levels.[4] Many people do not know the symptoms of periodontal diseases or do not associate existing symptoms with the disease. Patients' awareness of symptoms depends on their sociocultural level and the health knowledge they have acquired. When the relevant training programs designed by considering individuals' knowledge and anxiety levels are activated, the level of awareness of these diseases increases further.[5] Knowing the differences between periodontal health and diseases increases the success of periodontal treatments and thus ensures that diseases are detected at an early stage and treatment becomes easier and less costly.[6]

This descriptive research aimed to determine whether some sociodemographic factors affect periodontal health, reveal the factors that affect it, if any, and conduct studies to reduce the effects of these factors.

The present study also aimed to determine the periodontal disease awareness of patients presenting to Bursa Oral and Dental Health Training and Research Center and evaluate their attitudes toward their own oral health and oral health habits.

Materials and Methods

Three hundred patients, consisting of 124 (41.3%) males and 176 (58.7%) females, aged 18 years and above, who presented to Bursa Oral and Dental Health Training and Research Hospital between 01/07/2022 and 31/08/2022 were included in the study. A survey was used as a data collection tool in the study. The study protocol was approved by Bursa Uludağ University Faculty of Medicine Clinical Research Ethics Committee (Decision

numbered 2011-KAEK-26/413, dated May 2022, and numbered 2022-10/46). With the written permission obtained for the study from Bursa Uludağ University Faculty of Medicine Dean's Office, consent was obtained from individuals who agreed to participate in the study on a voluntary basis.

The survey form, including a total of 18 multiple-choice questions, consists of five sections. While 3 questions (age, gender, and educational status of the participants) were asked to determine the participants' sociodemographic characteristics in the first section, 4 questions about the attention the participants paid to their oral and dental health (frequency of tooth brushing, frequency of going to the dentist, last dentist visit, smoking status) were asked in the second section. Eight questions about the participants' awareness of periodontal diseases they had (reason for complaint, how they detected gingival disease, presence of bleeding during brushing, presence of bad breath, presence of gingival recession, mobility, loss of teeth, gingival health) were asked in the third section, 2 questions about the participant's post-treatment condition (implementation of post-treatment routines, whether there was improvement) were asked in the fourth section, and whether the participant had a systemic disease or not was asked in the fifth section.

IBM SPSS Statistics program was used to evaluate the obtained data. The number and percentage distributions were shown in descriptive statistics. The chi-square test was performed to compare categorical variables. The level of statistical significance was determined as $p < 0.05$.

The analyses investigated whether there was an association between gender, age, frequency of going to the dentist, educational status, frequency of tooth brushing, systemic diseases and smoking, and oral and dental health and periodontal awareness.

Results

Three hundred participants filled out these surveys. Of the participants, 41.3% were male (n=124), and 58.7% were female (n=176). While 26.3% (n=79) of the participants were aged between 18-29 years, 41% (n=123) were aged between 30-44 years, and 32.7% (n=98) were aged between 45-64 years.

It was found that while the vast majority of the participants (51.89%) aged 18-29 years brushed their teeth at least twice a day, most participants aged between 30-44 (36.58%) brushed their teeth once a day, and most participants aged between 45-64 (28.57%) brushed their teeth once every 2 days (Table 1).

Of the participants, 27.7% (n=83) gave the answer “gingival complaint” to the question "With what complaint did you present to this hospital?", while 72.3% (n=217) gave the answer “other complaints.” The vast majority of the patients with gingival complaints presented with gingival bleeding.

Most patients (53.3%) gave the answer "bleeding while brushing" to the question "If you have gingival disease, how did you first notice it?". Figure 3 presents those who gave other answers.

When the participants were asked the question, "Do your gums bleed while brushing? If so, is this normal for you?”, while 57 individuals (19%) answered, "Yes, they bleed. I think it's very normal.", 132 individuals (44%) answered, "Yes, they bleed. I feel uncomfortable with it. I think this is a problem", 80 individuals (26.7%) answered, "No, they do not bleed", and 31 individuals (10.3%) answered, "I have never noticed."

Table 3 presents answers to the questions "Do you have bad breath?", “Do you think you have gingival recession?”, "Do you have mobility (loosening) in your teeth?”, and "Have you ever lost a tooth due to spontaneous loosening without any trauma?”.

Whereas 74.68% of the participants aged between 18-29 thought that they had no gingival recession, 58.53% of the participants aged between 30-44 thought that they had no gingival recession, and 53.06%of the participants aged between 45-64 thought that they had no gingival recession (Table 4).

The participants were asked the question, "How do you evaluate your gingival health in general?". Of them, 12.3% (n=37) gave the answer “very good,” 53.7% (n=161) gave the answer “good,” and 34% (n=102) gave the answer “poor.”

To the question "Do you regularly implement the routines (mouthwash, etc.) prescribed by your doctor after your treatment?", 196 individuals (65.3%) answered as "Yes," while 104 individuals (34.7%) answered as "No, I sometimes fail."

The majority (82.7%) answered "Yes, I was satisfied with my treatment process" to the question "Did your complaint improve after the treatment?”.

While 32% of the participants (n=96) answered the question "What is your educational status?" as primary school, 38.3% (n=115) answered it as high school, 25.7% (n=77) answered it as university, and 4% (n=12) answered it as master's degree. It was observed that the participants with primary school education had worse oral and dental health and lower periodontal awareness compared to the participants with higher education levels. Sufficient data could not be obtained to find a significant difference in the participants with a master's or doctorate level of education. Among the study participants, the education level of male individuals was higher than that of female individuals.

Whereas 88 individuals (29.3%) answered the question “How often do you brush your teeth?” as at least twice a day, 103 individuals (34.3%) answered it as once a day, 69 individuals (23%) answered it as once every two days, 28 individuals (9.3%) answered it as once a week, 7 individuals (2.3%) answered it as once a month, and 5 individuals (1.7%) answered it as never. Female participants brushed their teeth more frequently, and the frequency of tooth brushing increased as the age decreased. Furthermore, there was a significant correlation between education level and the frequency of

tooth brushing. The frequency of tooth brushing was found to be higher in female participants (Table 5).

Figures 1 and 2 present answers to the questions “How often do you go to the dentist?” and “When was the last time you had a dental examination?”. The vast majority of the participants (73%) gave the answer "when I have a complaint." These participants did not routinely go to the dentist unless necessary. It was determined that female participants had more frequent dental examinations, and their last dentist visit was more recent (Table 5).

Table 2 contains answers to the questions "Do you have bad breath?", “Do you think you have gingival recession?”, "Do you have mobility (loosening) in your teeth?”, and "Have you ever lost a tooth due to spontaneous loosening without any trauma?”. It was observed that male participants lost their teeth due to trauma more frequently, had more mobility in their teeth, and had a higher incidence of bad breath compared to females. It was revealed that gingival recession was more common in female participants (Table 5).

One hundred twenty-three individuals (41%) and 177 individuals (59%) gave answers "yes" and "no", respectively, to the question "Do you have a systemic disease?”. It was found that male participants had a higher rate of systemic diseases than females (Table 5).

Considering the participants' answers to the question "Do you smoke?", it was seen that while 41.3% were non-smokers, 19% were mild (1-5 cigarettes per day), 20.3% were moderate (5-10 cigarettes per day), and 19.3% were severe (more than 10 cigarettes per day) smokers. It was determined that male participants smoked more than females (Table 5).

Discussion and Conclusion

The main aim of this study was to determine patients' awareness of periodontal diseases, and the other was to identify about which symptoms and signs that may indicate periodontal disease patients complained most, and to investigate the relationship between patients' periodontal awareness and age, gender, educational status, and periodontal status. A total of 300 individuals (176 females, 124 males) were evaluated within the scope of this study. As a result of the study based on the prepared survey questions, it was determined that factors such as sociodemographic factors, frequency of examination, frequency of tooth brushing, systemic diseases, and smoking status affected periodontal awareness and oral and dental health.

It was observed that the hygiene levels of male and female participants differed, and periodontal awareness was higher among female participants. It was found that the participants who visited a dentist regularly had a healthier mouth and higher periodontal awareness.

There was a significant correlation between the participants' education level and their level of self-care and awareness. It was found that the younger population had better oral care. The majority of the patients who presented to the hospital with gingival complaints had gingival bleeding. Patients with poor oral care were observed to have higher rates of mobility, gingival bleeding, and bad breath. It was revealed that systemic diseases also adversely affected the same factors, and periodontal health was inversely proportional to the severity of smoking. Furthermore, it was observed that smoking disturbed the post-treatment recovery.

It was found that especially the sociodemographic factors of the patients who presented to Bursa Oral and Dental Health Training and Research Hospital affected their periodontal awareness. The participants with higher brushing and examination frequency had higher awareness and healthier gums. It was seen that the majority of the patients presenting to the hospital did not have sufficient dental care knowledge. Therefore, periodontal awareness was lower than expected. Advanced periodontal treatment may lead to high expenses for both the patient and society. Insufficient awareness of periodontal diseases and its consequences have been shown to be the most common reasons for periodontal treatment failure in society.[7] The lack of awareness may lead to severe attachment loss in patients until advanced periodontal treatment is required, which reinforces the fact that the loss of teeth is inevitable in patients of advanced ages.[8-10] The early recognition of periodontal disease and the initiation of treatment allow individuals to use their own teeth for a longer time and prevent tooth loss caused by periodontitis.

Among the patients who presented to Bursa Oral and Dental Health Training and Research Hospital, gingival recession was more common among patients in the 30-44 age group.

Of the patients who presented to Bursa Oral and Dental Health Training and Research Hospital, 82.66% indicated that they saw improvement in their periodontal diseases as a result of the treatment recommended by their physicians.

Of the patients who presented to Bursa Oral and Dental Health Training and Research Hospital, 53.33% became aware of their existing periodontal disease due to gingival bleeding.

In their study, Genco *et al.* found that age was an important risk factor for periodontal disease. This may be associated with the increasing severity of periodontal disease with age since it reflects the characteristics of periodontal disease, the duration of exposure of periodontal tissues to bacterial plaque, and the cumulative oral history of the patient.[11]

The relationship between the lack of regular dental checkups and the development of periodontal disease is important. Kocher *et al.* reported that increased education level and regular dental visits protected against periodontal disease. They stated that regular dental checkups affected individuals' ability to recognize their dental condition.[12] Our study also obtained similar results.

Gilbert and Litaker indicated that the self-report of gingival disease increased with increasing severity of periodontitis.[13] Likewise, a study by Başer *et al.*[6] found

that patients' awareness rates increased as the severity of periodontitis increased.

It seems that this view is not very common in underdeveloped societies where there is awareness of periodontal disease symptoms. Poor periodontal health and disease awareness in society also adversely affects daily oral hygiene practices. Studies on old age have revealed that individuals' inadequate knowledge and attitudes regarding oral and dental health prevent effective preventive studies.[14]

There was a significant correlation between the participants' education level and their level of self-care and awareness. It was observed that the younger population had better oral care. The majority of the patients who presented to the hospital with gingival complaints had gingival bleeding. The factors such as educational status, age, and gender that might affect awareness were also compared in this study. Contrary to studies that did not find a correlation between awareness and gender[15], it was determined that females had higher awareness than males in this study. Schneider *et al.*[16] demonstrated that women had more dental checkups compared to men and that the use of dental floss and toothpicks was higher among women. Similar to these results, the researchers found that women had better oral care and benefited more from preventive oral care services in Finland, Greece, and Japan.[17-19] The results of these studies support our results. Considering age, while Luo *et al.*[20] found that periodontal disease awareness rates decreased with age, our study showed that age did not affect awareness. These differences may be due to differences in the sizes and types of the populations studied. According to the results of both our study and the study by Luo *et al.*, it can be said that academic education does not change patients' awareness of periodontal disease and that low awareness of the disease is a problem for the whole society, regardless of educational status. The researchers stated that patients' decisions to consult a physician for any problem and, therefore, their awareness of their illness were closely related to their level of knowledge about the disease.[21] Within the limits of the present study, the following conclusions were reached: 1. More than half of the study population was unaware of periodontal disease. 2. Awareness of periodontal disease was higher in females compared to males. Individuals who presented to ODHCs (oral and dental health centers) for various reasons participated in this study. Since the awareness level of periodontal disease in this study may not fully reflect the awareness level of the general population, this should be considered when interpreting the results of the current study. We believe that research that will be conducted in larger societies and will also include patients' knowledge levels about periodontal disease may guide studies to increase awareness of periodontal disease. It was revealed that systemic diseases also adversely affected the same factors.

It was found that especially the sociodemographic factors of the patients who presented to Bursa Oral and Dental Health Training and Research Hospital affected their periodontal awareness. The participants with higher brushing and examination frequency had higher awareness and healthier gums. It was observed that the majority of the patients presenting to the hospital did not have sufficient dental care knowledge. Hence periodontal awareness was lower than expected.

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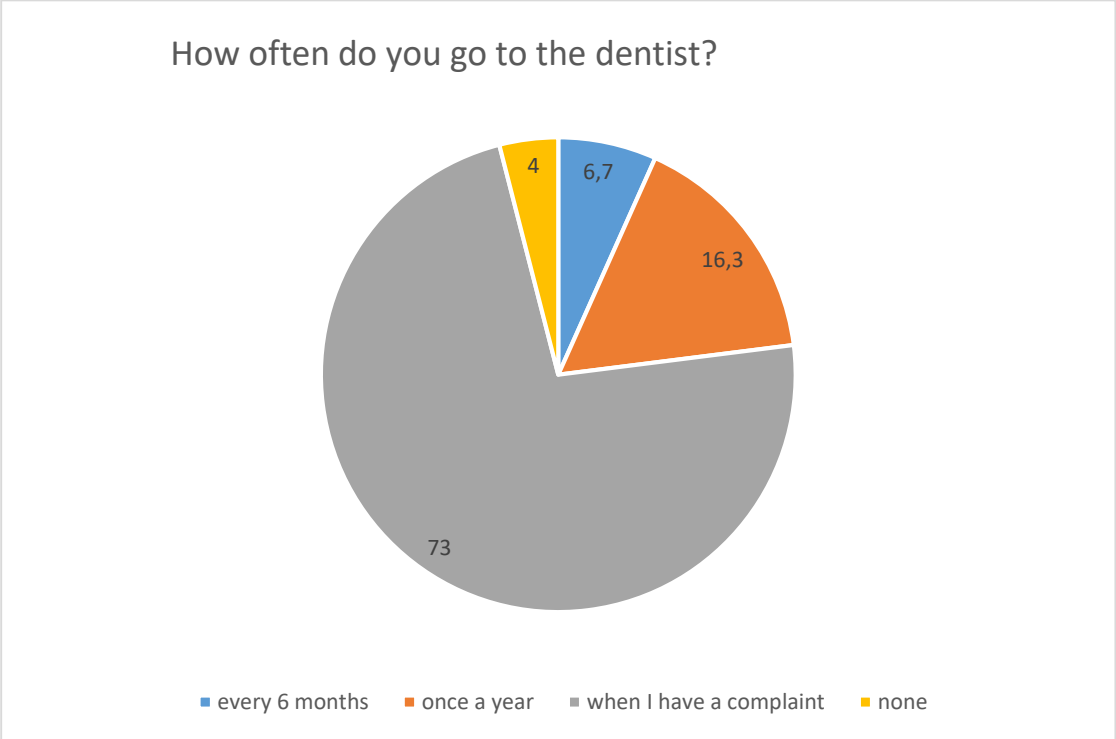

Figure 1. Patients' Frequency of Going to the Dentist

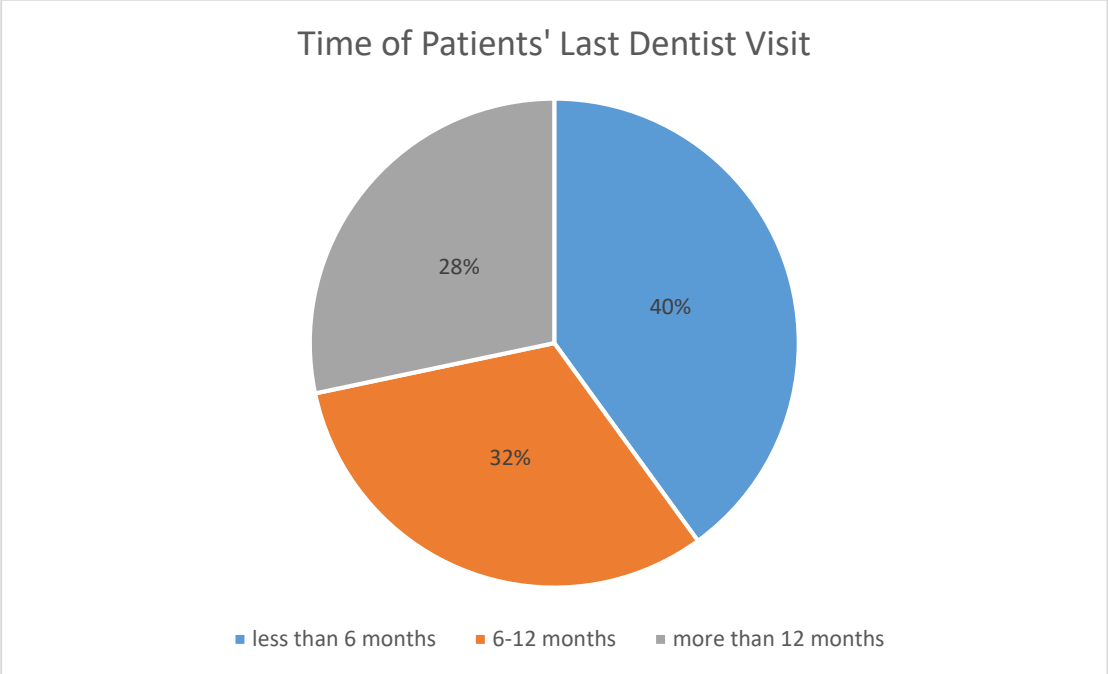

Figure 2. Time of Patients' Last Dentist Visit

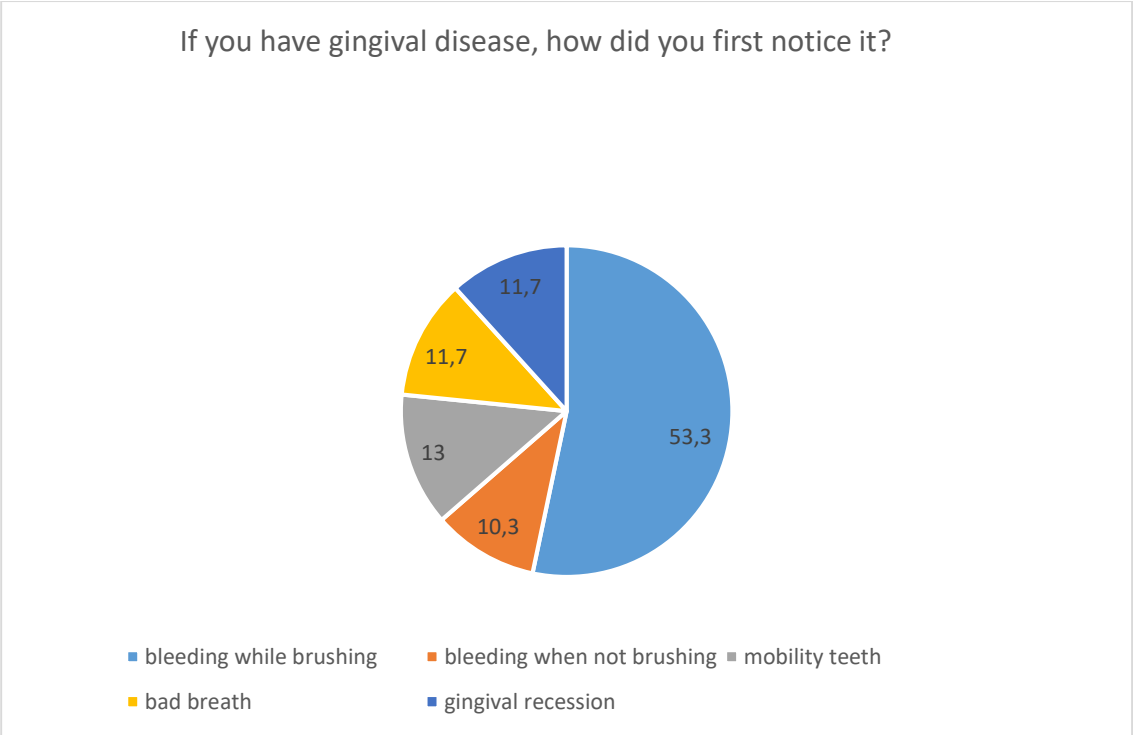

Figure 3. Patients' Reason for Going to the Dentist

Table 1: Comparison of patients' oral hygiene habits by their age

		At least twice a day	Once a day	Every other day	Once a week
How old are you?	18-29	41	31	5	2
	30-44	30	45	36	10
	45-64	17	27	28	16

Table 2: Patients' complaints during dentist visits

Do you have mobility (loosening) in your teeth?	Yes	86	28.7
	No	214	71.3
Have you ever lost a tooth due to spontaneous loosening without any trauma?	Yes	51	17.0
	No	249	83.0

Table 3. Presence of bad breath and gingival recession in patients

		N	%
Do you have bad breath?	Yes	114	38.0
	No	186	62.0
Do you think you have gingival recession?	Yes	117	39.0
	No	183	61.0

Table 4. Patients complain of gingival recession depending on their age

		Yes	No
Age	18-29	20	59
	30-44	51	72
	45-64	46	52

Table 5: Patients' answers to the self-report survey form

		Female	Male	P
What is your educational status?	Primary school	62	34	.001
	High school	64	51	
	Bachelor's degree	44	33	
	Master's degree	6	6	
What is your frequency of tooth brushing?	At least twice a day	62	26	.004
	Once a day	57	46	
	Every other day	44	25	
	Once a week	6	22	
	Once a month	4	3	
	Never	3	2	
How often do you go to the dentist?	Every six months	14	6	.097
	Once a year	32	17	
	When I have a complaint	124	95	
	Never	6	6	
When was the last time you had a dentist examination?	Less than 6 months	80	40	.054
	6-12 months	50	45	
	More than 12 months	46	39	
Do you have bad breath?	Yes	54	60	.001
	No	122	64	
Do you have gingival recession?	Yes	77	40	

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Comparative Investigation of Mechanical Properties of Ball Attachment Manufactured from Different Alloys and Surface Improvement Processes

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ABSTRACT

The retaining system commonly used in overdenture prostheses is the ball attachments, which are deformed over time, which can affect the retention and stability of the prosthesis. The aim of this study is to research the physical properties of the ball attachments which are made of different alloys and used for surface treatment. In our study, ball attachments produced from different alloys (Grade 4, Grade 5, Grade 23, CoCr) and applied various surface treatments (no surface treatment, micro-arc oxidation coating) were used. Samples were prepared in the laboratory environment and exposed to the thermal cycle, which corresponds to a 5-year aging process, by means of chewing simulators. The changes in the surface properties of the ball attachments as a result of the aging process were evaluated with scanning electron microscopy (SEM). Considering that the deformation in the matrix and the patrix would affect the retention resistance, tensile bond strength test was applied in a universal test device to measure this resistance. Values were recorded in Newtons and Megapascals. In order to detect the wear on the patrix, weight measurements were made on precision scales. Values were recorded in milligrams (mg). The data were analyzed using the SPSS program. As a result, loss of retention and wear were observed on all ball attachments and matrix. Retention and weight loss were seen the most in the titanium grade 4 group and the least in the CoCr group. No significant difference was found between the other groups.

Keywords: Ball Attachment; Grade 4 Titanium; Grade 5 Titanium; Grade 23 Titanium; Cocr; SEM, Tensile Strength.

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Introduction

Aesthetic problems can be solved in a short time with complete dentures. However, time is needed to restore the function. In addition, patients must accept that complete dentures cannot be as stable and retentive as natural teeth. The psychology of the patient is another factor that will affect the result as well as the knowledge and skill of the dentist and dental technician.[1]

In developed countries, it has been reported that the frequency of complete edentulism has decreased with the awareness of the society about oral dental health and preventive dentistry practices. However, as a result of epidemiological studies, an increase in the number of edentulous patients has been observed with the increase in the elderly population.[2-4] According to a study conducted in Turkey, the rate of complete edentulism was reported to be 48% in the 65-74 age range.[5] Therefore, prosthetic rehabilitation of edentulous patients remains up-to-date.

The treatment of edentulous patients has various challenges and many treatment options are available. The traditional treatment method of these patients is to make upper and lower conventional complete dentures. The biggest complaint of patients with conventional complete dentures is that their lower dentures are mobile and their chewing ability is reduced. Conventional complete dentures have some disadvantages. These are; lack of stability and retention, ongoing bone destruction, impaired chewing efficiency, social problems, it requires knowledge, experience and detail.[6]

Retention is the resistance of the prosthesis to move away from the tissues in the vertical direction during function. Stability is the ability of the prosthesis to resist movement or displacement under functional forces. The proof that a complete denture is stable is its resistance to horizontal forces. Compared to other treatment alternatives, patients who use complete dentures are less satisfied because of reduced masticatory function. This is due to the lack of retention and stability especially in the lower complete dentures.[7]

There are also different treatment options where implants are used in complete edentulism. These are hybrid prostheses, fixed prostheses on implants and removable prostheses on implants. It is a common conclusion from long-term studies that implant-supported complete dentures are superior to conventional complete dentures in every respect.[8-13]

One of the most frequently preferred and economical treatment methods in edentulous patients is implant-supported removable prostheses supported by two implants in the upper complete denture and two implants

in the lower jaw. In 2002, at a scientific meeting held in Montreal, Canada, a consensus was reached on a common idea based on scientific studies on this subject. This common idea is that lower complete dentures supported by 2 implants should be recommended as the first treatment alternative for edentulous patients. This idea, which was reported to the whole world, is also known as the McGill consensus.[14]

The easiest to use and most popular precision retainer system is the ball attachment (Figure 1-2).

This system consists of an independent ball-shaped patrix of different diameters, usually made of a metal alloy, and a matrix inside the removable prosthesis. The matrix may be all metal or consist of a metal housing with a rubber inside. The metal or rubber part in the base allows rotation between the support and the base against vertical compressive forces. It is a flexible device. When the implants are not placed parallel to each other, situations where the inter-implant angulation is up to 28^{o} can be tolerated by ball attachments. Reduced retention of the ball retainer system can be overcome by changing the tires or activating the clips with special keys.[15,16]

The ball holder system consists of a tire, ball abutment and metal housing. The rubber for the ball attachment can be made of silicone, nitrile fluorocarbon or ethylene propylene. The tire surface is treated with a lubricant to prevent abrasion, rupture and punctures caused by the insertion and removal of the prosthesis. Ball attachments consist of 3 parts: head, neck and body. The metal housing is the part in which the tire is placed. Considering the deformation that may occur, it is not desirable to be made of soft materials such as gold, bronze, aluminum or brass. It is generally preferred to be produced from stainless steel. The circumference of the metal seat should be rounded so that tire deformation does not occur.[17]

In ball attachment systems, tires are generally used for the matrix, but there are also systems that use metal matrices instead of tires. In these systems, the patrix is made of titanium alloy and the matrix is made of gold alloy. It has been reported that better results are obtained with this system in terms of wear among metal matrix systems.[18]

O-ring retainers are matrices made of synthetic polymers in the form of a cyme. O-ring retainers have ability to bend against resistance and then approximately return to their original shape. It consists of a metal housing into which the matrix is inserted and a patrix with a certain anisotropy.

O-ring retainers have ability to move in six different directions. After the abutments are connected to the superstructure, the freedom of movement is restricted. The greater the freedom of movement of a holder, the higher the moment force. Advantages of o-rings; connection change is easy, wide range of movement, the cost is low, it has different retention force values, the time spent for the prosthetic superstructure is less.[19]

In the literature, it is stated that in cases where ball attachments are to be applied, the implants should be placed parallel to each other as much as possible, otherwise their use is not recommended. In such cases, angled abutments, flexible retainers and bar-clip retainers are recommended. When this type of attachment is used on implants that cannot be placed at appropriate angles, serious loss of retention can be seen. Their disadvantage is that they take up too much space in the prosthesis in patients with low inter-arch distance. Their use in the upper jaw is not preferred.[20-23]

Materials and Methods

Our study was carried out in Sivas Cumhuriyet University Faculty of Dentistry Research Laboratory, Sivas Cumhuriyet University Advanced Technology Research and Application Centre, Erciyes University Faculty of Dentistry Research Laboratory, Erciyes University Technology Research and Application Centre with the support of Sivas Cumhuriyet University Scientific Research Project by applying to Sivas Cumhuriyet University Non-Interventional Clinical Research Ethics Committee and obtaining permission with decision number 2019-12/61 and dated 11.12.2019.

Obtaining Blocks to Embed the Specimens and Simulate the Prosthesis

The specimens were prepared in Sivas Cumhuriyet University Faculty of Dentistry Research Laboratory. For our study, 160 implant analogues, 20 ball attachments made of CoCr alloy, 20 ball attachments made of grade 4 titanium, 20 ball attachments made of grade 5 titanium alloy, 20 ball attachments made of grade 23 titanium alloy, 20 ball attachments made of grade 5 titanium alloy with micro arc surface treatment, 20 ball attachments made of grade 5 titanium alloy with anodization surface treatment, 20 ball attachments made of grade 23 titanium alloy with micro arc surface treatment, 20 ball attachments made of grade 23 titanium alloy with anodization surface treatment were used. The diameter of the ball attachments used is 3.5 mm and the step height is 3 mm. (Table 1) (Figure 3)

Draft drawings were made for the preparation of the specimens. It was planned to place the balled attachments on the blocks in pairs with a distance of 22 mm between them to reflect the intraoral situation. PMMA (Polymethylmethacrylate) discs (CAD IVORY Disc, On Dent dental systems, Izmir, Turkey) (Figure 3) with a diameter of 10 cm and a height of 14 mm were used to produce the specimens with CAD-CAM device (Figure 4).

In the CAD CAM device (Redon hybrid, Istanbul, Turkey) available at ESTAŞ EKSANTRİK SANAYİ VE TİCARET A.Ş., PMMA discs with indented edges were obtained from PMMA discs in accordance with the drawn draft in order to fit the chewing simulator with dimensions of 15x35x20 mm to the gods.

A total of 80 blocks were obtained from 20 discs, 4 blocks from each PMMA disc. The slots in these 80 blocks where the implant analogues were to be placed were engraved on a CAD-CAM device (Redon hybrid, Istanbul, Turkey) in a way to be exactly compatible with the analogues.

For the blocks to simulate the prosthesis, 1 master model was produced from PMMA disc. In the block simulating the prosthesis, 2 slots with a distance of 22 mm between them, with a diameter and depth of 6 mm, were opened as a guide for connecting the metal slots of the holders. Measurements were taken from the master model using type A silicone, then cold acrylic was poured into the measurements and rectangular prism shaped blocks were obtained.

Placement of Analogues in Blocks

Two slots in the blocks with a distance of 22 mm between them were prepared by CAD-CAM device in a way to be compatible with the analogues. Implant analogues (Moment, Sivas, Turkey) were placed in the prepared slot and fixed by screwing from the bottom. The analogues were placed at the block level to mimic the crestal placement of the implants.

Connecting the Blocks in which the Ball Attachments are Placed to the Blocks to Simulate the Prosthesis

Ball attachments used in our study were produced from 4 different materials: CoCr, Grade 4 titanium, Grade 5 titanium, Grade 23 titanium. A total of 8 groups were formed by applying micro-arc oxidation and anodization surface treatments to the ball attachments produced from Grade 5 and Grade 23 titanium.

160 ball attachments were placed on the implant analogues and torqued with a torque wrench with a force of 12 N according to the manufacturer's recommendation.

After placing matrices on the abutments to prevent leakage of acrylic resin into the anchor areas, Teflon tapes were placed on the anchor in between. Then, the process of connection to the prosthesis was started. The prosthetic part was tested on the block to which the abutments were connected and contacted with the ball attachments to the acrylic resin. The parts of the prosthetic part where acrylic resin should not come.

Vaseline (Vaseline, Pennsylvania, USA) was applied. Then autopolymerising acrylic resin (Imıcryl, Istanbul, Turkey) was mixed according to the company's recommendations and placed into the prepared cavities and the bonded blocks were placed in a press and kept at 1000 psi pressure to maintain the position until polymerization occurred.

Four different alloys and two different surface treatments were applied to the ball attachments, which were divided into 8 groups in total. After the preparation of the blocks was completed, thermomechanical fatigue, retention measurements, weight measurements, SEM imaging were started to be performed. (Figure 5-11)

Consistency Measurements of Samples

The retention measurements of the specimens were performed by pulling the specimens in a vertical direction at a speed of 5 mm/min using a universal test device (LR 10K Plus, Lloyd Instruments, Farnham, United Kingdom) in the Research Laboratory of Sivas Cumhuriyet University Faculty of Dentistry. With this device, a tension force was applied until the retainers were separated from each other and the maximum retention force required to separate the retainers was recorded. The separation and reattachment of the fully seated patrix and matrix was called 'cycle'. Assuming that the patients wore and removed their prostheses 4 times a day, retention measurements were made in cycles corresponding to 1, 2, 3, 4 and 5 years. Retention measurements were also performed at baseline for the first time without cycle tests. After the 1-year cycles, the tires of the samples were replaced and retention measurements were performed. In this way, the loss of grip on the ball attachments was examined independently of tire wear. A total of 6 grip measurements were performed for each gripper with a universal tester. (Figure 12)

Thermomechanical Fatigue Tests

For this study, thermomechanical fatigue tests were performed using an 8-unit chewing simulator (SD Mechatronic CS-4, Westerham, Germany) (Figure 13) with a thermal cycle in the Research Laboratory of Erciyes University Faculty of Dentistry. The blocks containing the abutments were connected to the godets in the chewing simulator with acrylic, while the blocks containing the metal sockets were connected to the simulator with a connecting apparatus made of brass. After the blocks were connected, the fit of the matrices on the abutments was checked one by one. The device was set to perform 30 cycles per minute. The thermal cycling unit of the device reaches temperatures between 5°C and 55°C degrees, and the aging of the material is carried out during the cycles.

If the patients inserted and removed their prostheses 4 times a day, the insertion, removal and ageing of the specimens corresponding to 1, 2, 3, 4 and 5 years of use were performed by means of a thermal cyclic mastication simulator.

SEM (Scanning Electron Microscopy) Examination of Samples

SEM images of the samples were recorded with the SEM device (TESCAN MIRA3 XMU, Brno-Kohoutovice, Czech Republic) (Figure 15) at Sivas Cumhuriyet University Advanced Technology Research and Application Centre (CUTAM) Laboratory. One ball attachment and one tire holder from each group were randomly imaged from different angles before starting the cycle experiments. After 1, 2, 3, 4 and 5 years of ageing, a randomly selected sample was taken between each year.

SEM imaging of the male and female parts was performed. The ball attachments were imaged without any coating and the tire holders were imaged after 20 nm (nanometer) gold (Au) coating in the Au-Pd (Gold Palladium) coating unit connected to the device.

Statistical Evaluation

The data obtained from our study were analyzed with SPSS 22.0 (Statistical Package for Social Sciences, SPSS for Windows 22.0.0, SPSS Inc, Chicago, USA) and graphs were created with GraphPad Prism V8.0 (GraphPad Software, San Diego, CA). Two-way analysis of variance and Tukey's test were used to compare tensile test data and weight measurements, and the error level was taken as 0.05.

Results

In our study, the first retention force measurements were made before thermomechanical fatigue was applied in the mastication simulator. After the thermomechanical fatigue application started in the chewing simulator, a total of 6 retention force measurements were made at 1440, 2880, 4320, 5760, 7200 cycles.

When the retention measurements of the groups without surface treatment were compared; the least retention force change was observed in the CoCr group during the period corresponding to 5 years of use. The highest retention force loss was observed in the titanium grade 4 group. At the end of the fifth year, the retention values of the CoCr group were statistically significantly higher than the retention values of all other groups ($p<0.05$). While the retention value of the grade 5 group was statistically significantly higher than the retention value of the grade 4 group ($p<0.05$), there was no significant difference between the retention value of the grade 23 group ($p>0.05$). The retention value of the grade 23 group is statistically significantly higher than the retention value of the grade 4 group ($p<0.05$) (Table 2).

When the retention values of titanium samples treated with anodic oxidation and micro arc oxidation surface treatment were compared, at the end of the fifth year, in both grade 5 and grade 23 titanium groups, the retention values of the groups with surface treatment were statistically significantly higher than the retention values of the groups without surface treatment ($p<0.05$). There was no statistically significant difference between the retention values of the micro arc oxidation groups and the retention values of the anodic oxidation groups ($p>0.05$).

Scanning Electron Microscope (SEM) Images Obtained from the Study

When SEM images were analysed, it was observed that while milling marks remaining from the production process of the ball attachments were observed in the control groups, after the thermomechanical fatigue application, as the number of silkus corresponding to the years increased, the amount and depth of abrasion caused by the insertion and removal process increased.

Discussion

In this study, ball attachments manufactured from different alloys and treated with surface improvement processes were subjected to thermomechanical fatigue corresponding to 5 years of use by in vitro experiments.

- To see the changes in the holding force values with the help of tensile test, to investigate which alloy and surface properties of the ball attachment show better mechanical properties against abrasion in the clinic,
- To make qualitative and quantitative analyses at elemental level of the surface treated ball attachments forming the gripper system before and after the experiment.

As a result of the studies, it has been reported that the standard treatment protocol for patients with complete edentulous lower jaw should be 2 implant-supported complete dentures in the lower jaw.[2] In implant-supported complete dentures, mechanisms such as ball attachment, locator attachment, bar or magnet retainer are placed on the implants for retention.[3]

Considering the effect of the type of retention on retention, the ball attachment system, which is frequently used in the clinic, was preferred in our study. The number of samples is very important for obtaining accurate results from the studies. In the literature, it is seen that the number of samples varies between 3-10 in studies examining the retention forces of splinted or non-splinted retainers placed twice on a model.[24-26] In our study, which we started by performing power analysis, the number of samples was determined as 10 (n=10), with 2 grasping attachments in one sample for each group. In studies comparing grasping systems, grasping parts were placed and torqued on implants or analogues in accordance with the recommendations of the companies.

In our study, the retaining parts were torqued to the analogues according to the company's instructions. Implants or analogues were placed in plaster, aluminum bases, acrylic resin or polyvinyl chloride blocks in most of the studies.[27-30] In our study, the analogues were placed in the slots that were opened in PMMA blocks in the CAD-CAM device, which were exactly compatible with the analogues. Overdenture prostheses were simulated using autopolymerising acrylic resin blocks.

When 2 implant-supported removable prostheses were simulated, implants were placed parallel or angled to each other.[25,27,31] For long-term success in overdenture prostheses, the incoming forces should be parallel to the entry path of the implants.[32] This can be achieved by placing the implants parallel to each other. Parallelometers were frequently used to ensure parallelism in studies.[25,33] In our study, the parallelism of the analogues was achieved by opening parallel analogue slots in the CAD-CAM device in accordance with the sketch drawn.

Retention systems used for implant prostheses show wear and loss of retention over time. The amount of wear and loss of retention varies depending on many factors. The complexity of the oral and masticatory system limits the ability to mimic natural conditions by adjusting in-vitro conditions. There are studies reporting that vertical movements caused by the insertion and removal of prostheses are not the main cause of retention loss, and that horizontal forces such as masticatory activity and parafunctional movements are more effective in the wear of abutments.[28,34] Evtimovska et al. reported that in vitro conditions cannot reflect the oral environment. They stated that the absence of saliva and occlusal forces may affect the retention forces due to reasons such as the effect of occlusal forces on the wear of the retaining parts and the ability of soft tissues to transfer more load to the retainers due to their resilience when force is applied on them.[25] Setz *et al.*[35] reported that since the oral environment cannot be fully reflected in in vitro conditions, wear on the retaining parts is seen less and that devices that better reflect the forces in the oral environment are needed to achieve more realistic results.

Ignoring chewing forces in in vitro studies leads to limitations of the studies. This situation can be accepted as a limitation of our study. In in-vitro studies, it is aimed to provide the closest test environment to reality within the framework of the conditions determined.[12,42] Performing the experiments in dry or wet environment affects the friction forces and the amount of wear on the retaining systems. Nagaoka et al. evaluated the retention force in overdenture prostheses and found that the retention force value in wet environment was lower than in dry environment.[36] Different liquids are used for wetting the experimental environment. When the studies in the literature are examined, distilled water, isotonic 0.9% sodium chloride solution and mostly artificial saliva were used.[37,34] In our study, as in the study of Fromentin et al. the denture removal procedure was performed in a wet environment using distilled water. In the study by You et al., the effect of denture cleaning solutions on the retention of locator retainers in a simulated 6-month use was investigated and it was reported that sodium hypochlorite significantly decreased the retention values of locator retainers.[38] It is very difficult to accurately reflect the effect of prosthesis cleaning agents on wear in vitro, and another limitation of our study is the wear caused by prosthesis cleaning agents.

There are many studies assuming that patients remove their implant-retained removable prostheses 3 or 4 times a day.[30,39-41] Kurtulus and Gurbulak[41] applied 720 cycles for 6-month use and 1440 cycles for 1-year use, taking the patients' wearing and removing their implant-retained removable prostheses 4 times a day as a reference. Besimo *et al.*[39], on the other hand, applied 540 cycles corresponding to 6 months of use, assuming that the patients inserted and removed their overdentures 3 times a day. In all of the studies investigating the retention forces of overdenture prostheses, the retention force of the retaining parts was first determined by the pulling force in the axial direction.[42,43] In studies conducted at different times, tensile tests were performed in axial and paraaxial directions and cycles between 540 and 14,600 were performed. Retention force measurements were performed at different time intervals. Retention force measurements were performed by Kobayashi et al.[37] 6 times in total (10, 100, 1000, 5000, 10000 and 14600 cycles), Sultana *et al.*[44] 15 times in total (10.000 cycles, every 500 cycles in the first 4000 cycles and every 1000 cycles in the remaining cycles), Ortegon et al.[45] a total of 36 times (every 100 cycles by applying 3500 cycles), Rodrigues *et al.*[40] a total of 6 times (every 540 cycles by applying 2900 cycles), Pigozzo *et al.*[26] a total of 6 times (0, 1100, 2200, 3300, 4400, 5500 cycles). In our study, as in the studies of Kurtulus and Gurbulak, it was assumed that the implant removable prostheses were inserted and removed 4 times a day (morning, noon, evening and night) and 1 month was accepted as 30 days; 1440 cycles corresponded to 1 year, 2880 cycles to 2 years, 4320 cycles to 3 years, 5760 cycles to 4 years and 7200 cycles to 5 years. Similar to the study of Pigozzo et al.[26], retention force was measured 6 times in total at 0 (before starting the cycles), 1440, 2880, 4320, 5760 and 7200 cycles.

In the studies conducted in the literature, the speeds of the tensile tests performed on the specimens were adjusted at different values. In some studies, the tensile speed of 50 mm/min was considered close to the extraction speed applied in the mouth and the experiments were performed based on this value.[38,42,46] There are studies in which the speed of the tensile test was adjusted as 1 mm/min, 2 mm/min, 3 mm/min.[25,47,43] In a study in which 3 different gripper types were examined, the pulling speed was adjusted as 1 mm/min.[30] Although Rutkunas *et al.* reported that the maximum retention force decreased as the pulling speed increased, there are also studies showing higher retention force despite the higher pulling speed.[39,29] Considering the effect of the pulling speed on the maximum retention force as stated by Rutkunas et al. in their study, the pulling speed was adjusted to 5 mm/min in our study. Since it is easy and reliable to set this speed with the universal tester, tensile tests were performed with this device.

In the studies, locators, ball attachments, bars and their combination retainers were frequently used. In addition to the studies in which un-splinted retainers were placed 1 in the specimens, there were also many studies in which 2 retainers were placed in a specimen with splinted and un-splinted systems in order to mimic the oral environment well.[25,32,37,39,48,49] When the studies in the literature are examined, the distance between implants was adjusted between 20-30 mm when 2 implants were placed in a specimen. In most studies, implants were placed so that the distance between 2 implants was 22 mm.[37,28,50] Taking these studies in the literature as a reference, in our study, the analogues were placed in the models in pairs with a distance of 22 mm between them.

Trakas *et al.*[51] reported that a retention force of 20 N was sufficient for mandibular implant-supported removable prostheses. In studies conducted with retaining attachments of different designs, it was reported that the retention value varied between 10-90 N.[24,32,52,53] However, in terms of patient satisfaction, it is desired that the retention force of overdenture prostheses should be high. Abrasion is the loss of material characterised by the loss of form seen in the abutments under function. Loss of retention caused by abrasion of the abutments is a problem that we observe both in in vitro experiments and in the clinic. The matrix part of the retaining attachment systems is replaced at certain intervals, and in cases where wear is high, the patrix part is also replaced. The wear of the abutments under the function does not occur only as a result of insertion and removal, but many factors affect it. These are; implant angles[45,47], distance between implants[48], abutment and matrix materials[35,39,49], direction of forces separating the prosthesis from the tissue[29], design of the abutments[31,49] and dimensions.[28] Studies directly analysing the abutments are very few. Examination of abrasions on the abutments is performed by SEM imaging, size measurement and weight measurements on a precision

balance. In our study, SEM imaging at cycles corresponding to 0, 1, 2, 3, 4 and 5 years and weight measurements of the gripper attachments on a precision balance were performed to observe the wear on the ball attachments and matrices.

In the literature, the holding forces of the ball attachments have been compared with different gripping attachment systems or by changing the materials from which the matrix parts are produced. There is no study in the literature comparing the holding forces of ball attachments produced from different materials and surface treated.

Chung et al.[24] compared the retention forces of 9 different retention systems (ERA white, ERA grey, Locator white, Locator pink, Ball attachment (Spheroflex), Hader bar-metal clip, Magnets (Shiner SR), Magnets (Magnedisc 800), Magnets (Maxi 2)) and reported that the retention values were between 3.68 N and 35.24 N in the retention force measurement performed with a pulling speed of 50 mm/min in axial direction. Titanium nitride coated ball attachment group ranked 3rd in the holding force ranking with 27.34 N. The holding forces of the ball attachments in the study of Chung *et al.*[24] are higher than the holding forces of the ball attachments in our study. It is thought that this may be due to the different surface treatments and pulling speeds applied. In the study by Ortegon *et al.*[45], the retention force measurements of ball attachments on 2 implants placed parallel and angled to each other with a distance of 20 mm between them were performed. The study consisted of 5 groups. A total of 3500 cycles were applied to the specimens and a total of 36 grip force measurements were made every 100 cycles. It was reported that the retention force values were 21.3 N for implants placed in parallel. It is thought that the reason why the retention force values in the study of Ortegon et al. were higher than the retention force values in our study may be due to the fact that fewer insertion and removal cycles were applied. Gulizio *et al.*[47] applied ball attachments on implants placed at 0°, 10°, 20°, 30° angles and titanium and gold matrices were used. They reported a retention force value of 23.8 N for ball attachments using gold matrix placed without angle.[47] It is thought that the difference between the holding force value of the ball attachments in our study and the holding force value in the study of Gulizio et al. may be due to the different matrix materials used. Wolf et al. investigated the retention force values of 6 different ball attachment systems commercially and applied 50.000 cycles under an eccentric force of 100N in a mastication simulator. They reported that the holding force values were between 1 N and 10.4 N at the end of the study.[54] It is thought that the reason why the retention force values in our study are higher than the retention values in the study of Wolf et al. may be since Wolf et al. applied 50,000 cycles to the specimens. The retention values of the ball attachment systems used in our study decreased over time. This may have been caused by the deformation of the matrices and the wear of the patrixes. Although the same matrix system was used in all groups in our study, different degrees of retention loss were observed. This is thought to be since the ball attachments were produced from different alloys and different surface treatments were applied. Our study is not compatible with the studies that reported that the retention force values increased or did not change despite repeated insertion and removal of prostheses under repetitive force. The decrease in retention force values in retention systems over time is a clinical situation that is seen. Matrices need to be replaced when they are broken, damaged and worn. Many factors such as occlusal forces and parafunctional habits cause a decrease in retention force.

SEM images were taken before and after thermomechanical fatigue to observe the wear of 8 different ball attachment systems used in our study. After thermomechanical fatigue application, it was observed that the amount and depth of wear caused by the attachment and removal process increased as the number of cycles corresponding to years increased. In their study, Abi Nader *et al.*[29] examined the SEM images of both patrix and matrix parts of the ball attachment and locator holder system to which they applied 400,000 cycles of fatigue, as well as the holding force values. In the SEM examination, they determined that there was wear on the patrix and matrix in both gripper systems. In the holding force measurements, they reported the holding force values of the ball attachment group as 10.6 N at the beginning and 7.9 N at the end of the experiments. In our study, in parallel with these studies, abrasions were detected in SEM examination in both the ball attachments and matrix parts (Figure 15-26).

In their study, Saito *et al.* used clips produced from the same material on bar holders produced from different materials (CoCr, titanium grade 4, gold alloy with platinum added) and different shapes (round and dolder). After 7200 cycles in the vertical direction, the retention force was measured and SEM images were analyzed to detect surface wear. The Dolder bar made of CoCr alloy and the clips placed on it showed less wear and debris accumulation. It is stated that this result is obtained because the elastic modulus of CoCr alloy is higher than other materials.[55] In a study examining the amount of wear in SEM images, the weights of the matrix parts before and after the experiment were measured on a precision electronic balance. However, no significant change was found.[39] There is no study in the literature in which weight measurement was performed on a precision balance to determine the wear of the abutments. In our study, the weight of the ball attachments was measured with a precision balance before the experiment and after the thermomechanical fatigue application corresponding to each year. The highest weight loss was observed in titanium grade 4 group. The least weight loss was observed in the CoCr group.

It is very important to ensure retention in removable prostheses. The patient's expectation of retention and stabilization may affect their satisfaction, psychological profile and emotional state.[56] Clinical status, performance and initial retention of the retention systems are important indicators for patient acceptance.[52] In clinical practice, the value required for retention strength is the value that the patient is satisfied with. For this reason, the

retention force should be at a value that will prevent movement of the prosthesis.[35] At the same time, the retention force should be at certain force levels that will not have a destructive effect on periodontal tissues during insertion and removal of the prosthesis.[57] Therefore, the choice of retention system is very important. Physicians choose the retention system to be used in implant-supported removable prostheses according to the retention values specified by the company and their clinical experience. As stated in the literature, adequate retention for implant-supported removable prostheses is related with the patient's satisfaction level.[58]

Conclusions

- The insertion and removal process caused abrasion in all groups.

- The average holding force was highest in the CoCr group and lowest in the titanium grade 4 group.

- The material with the best wear resistance among the experimental groups is CoC.

- If titanium grade 5 and titanium grade 23 are to be used in the production of ball attachments, it should be preferred that they have anodic oxidation or micro arc oxidation surface treatment.

- It is recommended that the tires should be replaced before 1 year of use, taking into account the deformation of the SEM images.

- The lowest average holding force obtained from the study is within clinically acceptable limits.

Acknowledgment

None

Conflicts of Interest Statement

The authors declare that they have no competing interests.

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Table 1. Study Groups

Study Groups
1. Ball attachment made of CoCr alloy
2. Ball attachment made of Grade 4 titanium
3. Ball attachment made of Grade 5 titanium alloy
4. Ball attachment made of Grade 23 titanium alloy
5. Ball attachment made of Grade 5 titanium alloy with anodized surface treatment
6. Ball attachment made of Grade 23 titanium alloy with micro arc oxidation surface treatment
7. Ball attachment made of Grade 5 titanium alloy with anodized surface treatment
8. Ball attachment made of Grade 23 titanium alloy with micro arc oxidation surface treatment

Table 2 Average Retention of Study Groups in Newton (N) Values. Respectively; Control- 1st year- 2nd year- 3rd year- 4th year- 5th year

CoCr	Mean	17.688	17.601	17.522	17.484	17.402	17.363
	SD	0.842	0.932	1.161	1.030	0.729	1.390
Ti Gr4	Mean	17.687	16.616	15.666	14.652	12.670	10.215
	SD	0.733	1.425	1.246	0.997	0.892	0.927
Ti Gr5	Mean	17.592	15.834	15.638	15.289	14.487	13.336
	SD	0.571	0.781	1.265	1.610	0.744	1.049
Ti Gr23	Mean	17.978	15.876	15.731	15.016	14.484	13.306
	SD	1.121	1.018	0.937	1.028	1.719	1.018
Ti Gr5 AO	Mean	17.894	16.636	15.931	15.486	15.086	14.886
	SD	1.047	1.276	0.965	0.971	1.045	1.014
Ti Gr5 MAO	Mean	17.916	16.711	16.054	15.876	15.101	14.996
	SD	1.264	0.924	1.705	0.993	0.938	1.115
Ti Gr23 AO	Mean	17.783	16.616	15.876	15.183	14.916	14.816
	SD	1.135	1.028	0.993	1.135	1.028	1.028
Ti Gr23 MAO	Mean	17.636	16.691	15.881	15.344	15.074	14.911
	SD	0.874	0.925	0.934	1.777	1.778	0.947

Figure 1. Ball Gripper System

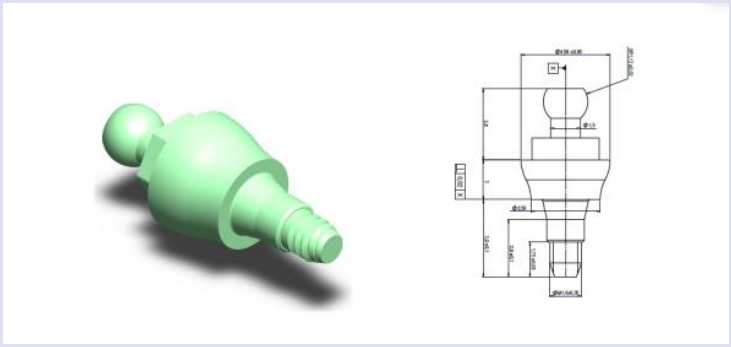

Figure 2. **A**) Three Dimensional View of the Ball Attachment **B)** Draft Drawing of the Ball Attachment

Figure 3. PMMA Disc for Obtaining Rectangular Prism Shaped Blocks

Figure 4. CAD-CAM Device A and B

Figure 5. Sketch of the Rectangular Prism Shaped Block in which implants A and B will be placed

Figure 6. Blocks Prepared in CAD-CAM Device with Implant Analogues A and B

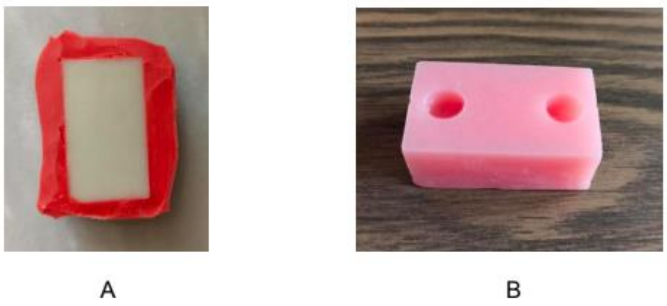

Figure 7. A) Taking Measurements from the Main Model to Simulate the Prosthesis by Using Type A Measuring Item B) Rectangular Prism Shaped Blocks in which the Matrix Simulating the Prosthesis will be Placed

Figure 8. Image Representing the Blocks Where the Ball Attachments are Placed

Figure 9. Pressing of the Ball Attachment System after Fastening

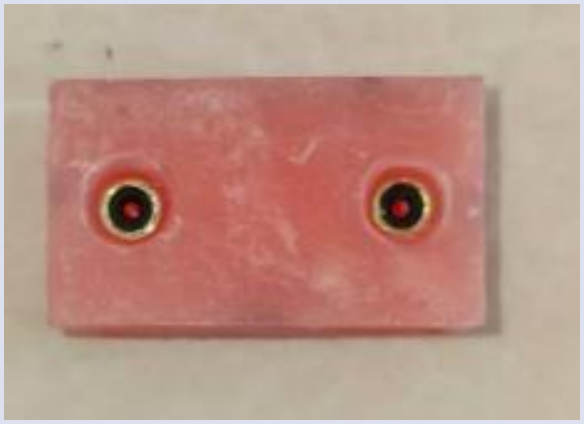

Figure 10. View of the Prosthetic Block after the Pressed Blocks are Separated

Figure 11. Images of Classified and Numbered Blocks

Figure 12. Universal Test Device

Figure 13. Chewing Simulator with Thermomechanical Fatigue

Figure 14. Scanning Electron Microscope (SEM) and Gold Plating Unit Connected to the Device

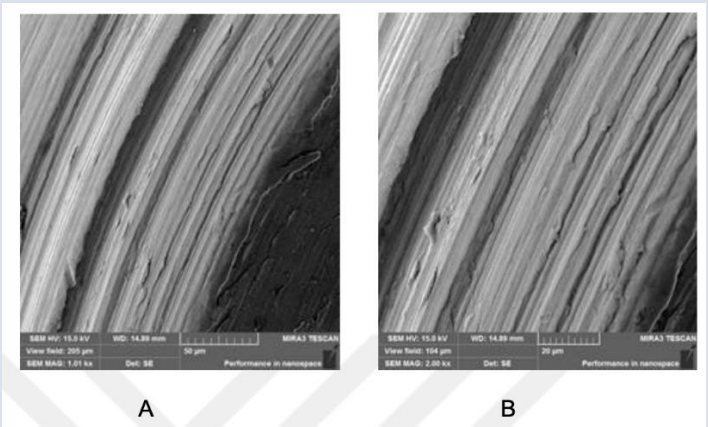

Figure 15. Initial Surface Image of CoCr Ball Attachments at (A) 1000x and (B) 2000x Magnification

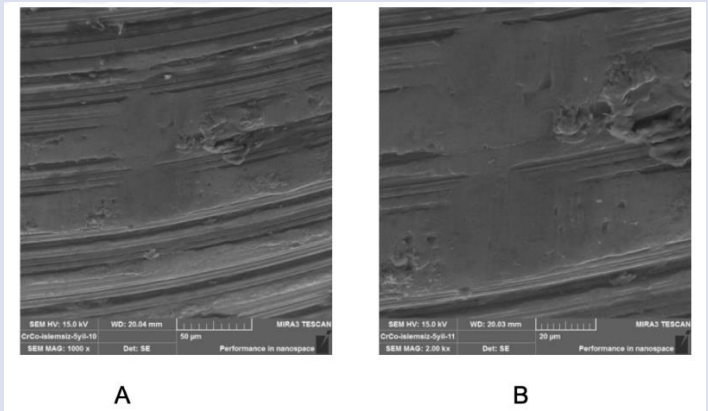

Figure 16. 5-Year Thermomechanical Fatigue of CoCr Ball Attachments at (A) 1000x (B) 2000x Magnification

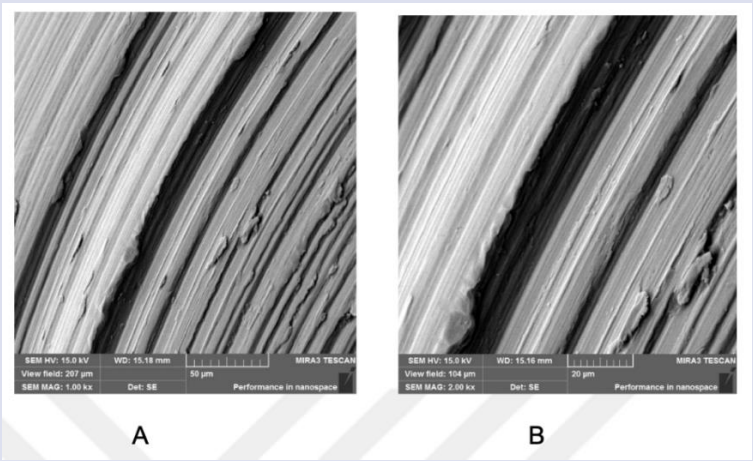

Figure 17. Initial Surface Image of Titanium Grade 4 Ball Attachments at (A) 1000x and (B) 2000x Magnification

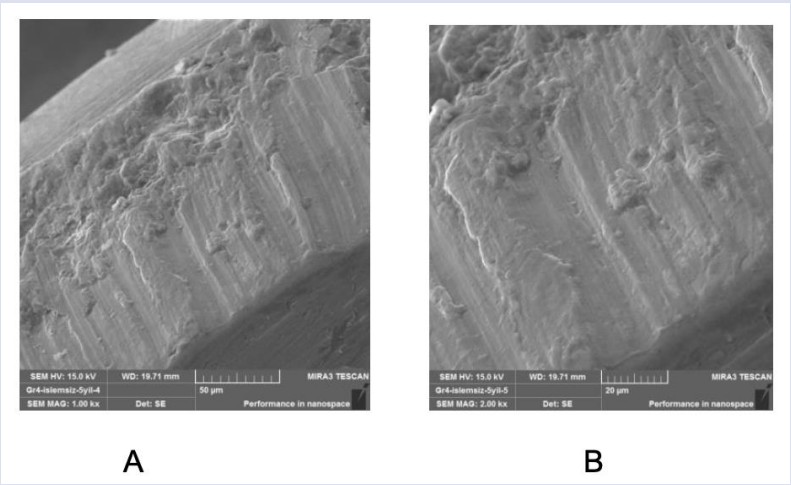

Figure 18. 5-Year Thermomechanical Fatigue of Titanium Grade 4 Ball Attachments at (A) 1000x (B) 2000x Magnification

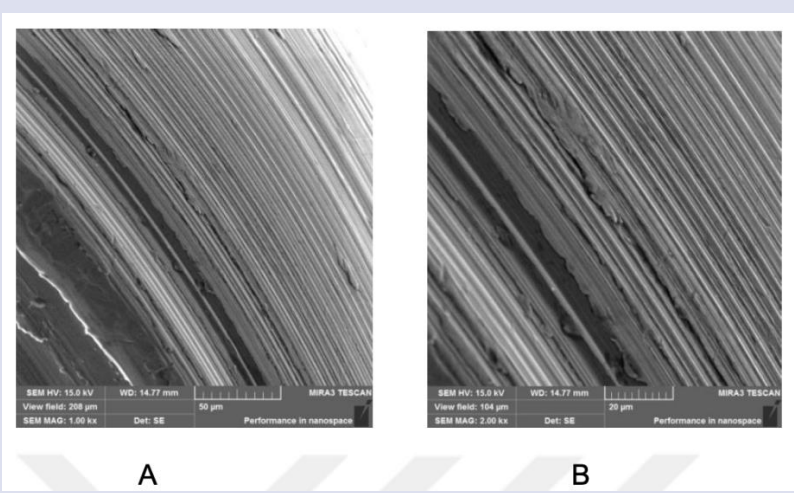

Figure 19. Initial Surface Image of Titanium Grade 5 Ball Attachments at (A) 1000x and (B) 2000x Magnification

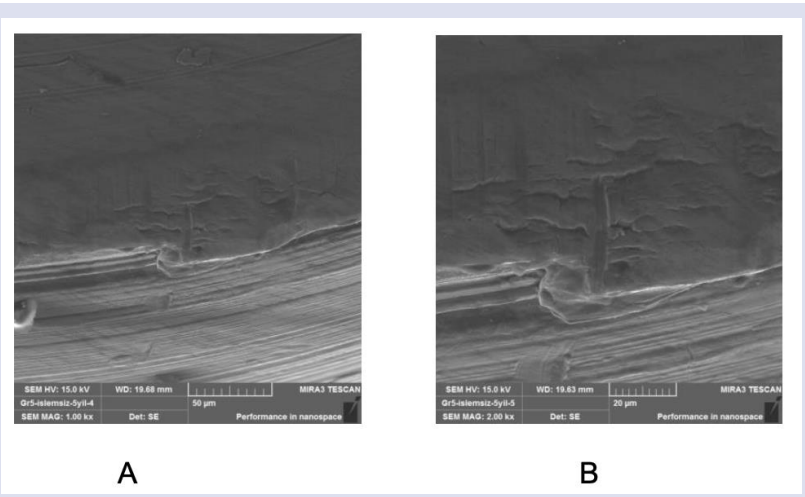

Figure 20. 5-Year Thermomechanical Fatigue of Titanium Grade 5 Ball Attachments at (A) 1000x (B) 2000x Magnification

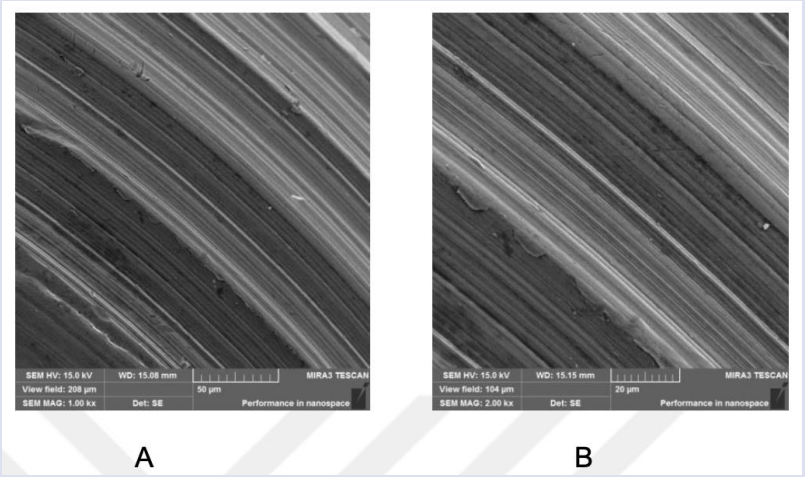

Figure 21. Initial Surface Image of Titanium Grade 23 Ball Attachments at (A) 1000x and (B) 2000x Magnification

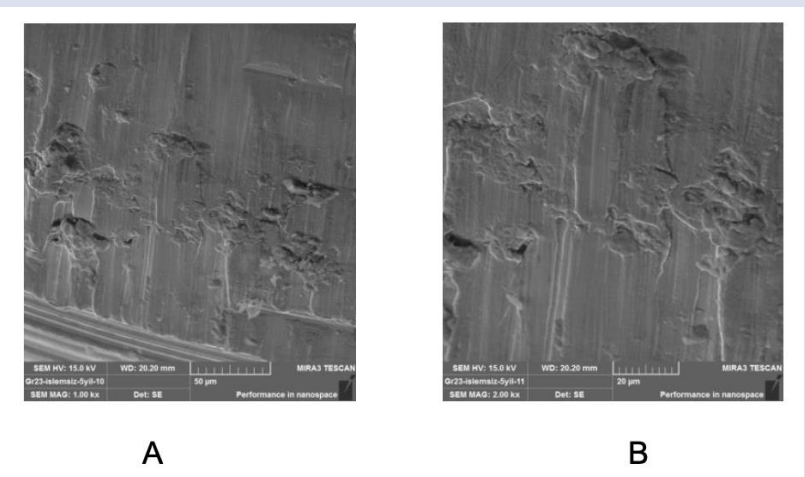

Figure 22. 5-Year Thermomechanical Fatigue of Titanium Grade 23 Ball Attachments at (A) 1000x (B) 2000x Magnification

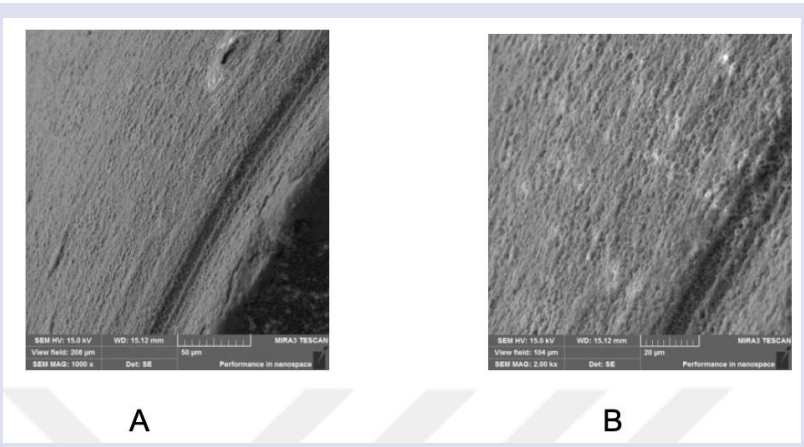

Figure 23. Initial Surface Image of Titanium Grade 5 Ball Attachments with Micro Arc Oxidation Surface Treatment at (A) 1000x and (B) 2000x Magnification

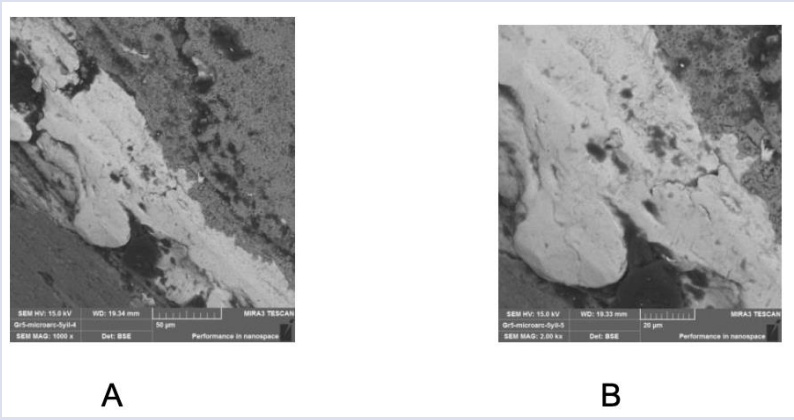

Figure 24. (A) 1000x (B) 2000x Magnification Surface Image of Titanium Grade 5 Ball Attachments with Micro Arc Oxidation Surface Treatment after 5 Years of Thermomechanical Fatigue

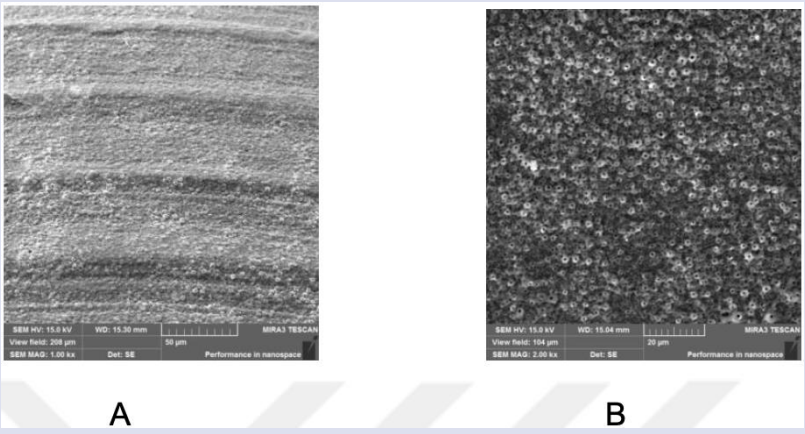

Figure 25. Initial Surface Image of Titanium Grade 5 Ball Attachments with Micro Arc Oxidation Surface Treatment at (A) 1000x and (B) 2000x Magnification

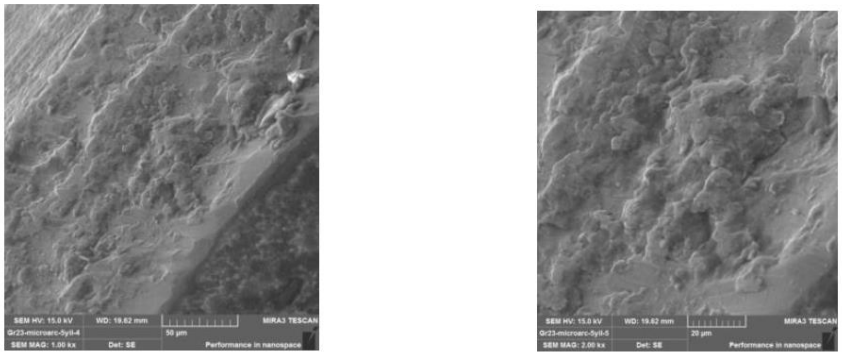

Figure 26. (A) 1000x (B) 2000x Magnification Surface Image of Titanium Grade 5 Ball Attachments with Micro Arc Oxidation Surface Treatment after 5 Years of Thermomechanical Fatigue

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Efficacy of Different Finishing and Polishing Systems on Surface Roughness and Microhardness of Highly Aesthetic Composites

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Research Article

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ABSTRACT

Objectives: The aim of this study is to examine the effect of three different types of highly esthetic composite resins, which will be used for aesthetic purposes in the anterior region, on the surface roughness and microhardness by the application of three different finishing and polishing systems, with three-dimensional Optical Profilometer, Vickers microhardness device and SEM analysis.

Materials and methods: Three different composite resins were used in the study; supra-nanophile (Tokuyama Estelite Asteria), supra-nano spherical (Tokuyama Omnichroma), nanohybrid (Kuraray Clearfil Majesty Esthetic) were used. 40 samples of each composite resin were prepared, 120 in total. After the polymerization and correction processes, ten samples from each group that did not undergo any polishing process were separated as the control group. Then, they were randomly divided into three groups for the polishing process: 4-stage aluminum oxide coated disc (3M Sof-lex disc), beige and pink 2-step spiral rubber consisting of aluminum oxide-containing diamond particles (3M Sof-lex spiral), polyurethane, diamond granules. containing light blue rubber and spiral rubber (Ivoclar Vivadent OptraGloss). Surface roughness (Ra) was measured on all samples with a conventional profilometer device. Then, one sample surface from each group was examined with the Optical Profilometer device and the Scanning Electron Microscope, and all samples were subjected to microhardness testing with the Vickers Microhardness Tester.

Results: As a result of our study, the lowest roughness values were observed in the control group, while the highest roughness values were observed in the Ivoclar Optragloss group. The groups studied with Kuraray Clearfil Majesty Esthetic composite showed higher roughness values compared to other composite groups, but no statistically significant difference was found with other composite groups ($p>0.05$). In our study, the lowest microhardness values were observed in the control group, while the highest microhardness values were observed in the Sof-Lex Disk group. The difference between the groups treated with Kuraray Clearfil Majesty Esthetic composite and the other composite groups was found to be statistically significant ($p<0.05$). The lowest microhardness values were observed in the groups treated with Kuraray Clearfil Majesty Esthetic composite.

Conclusions: It was observed that the effectiveness of the polishing systems used on different restorative materials was different, and when the polishing systems were compared, the Soflex multi-stage disc system and the Soflex two-stage spiral tire system were found to be more successful.

Keywords: Aesthetic Composite, Surface Roughness, Microhardness.

Farklı Bitirme ve Polisaj Sistemlerinin Yüksek Estetiğe Sahip Kompozitlerin Yüzey Pürüzlülüğü ve Mikrosertliği Üzerine Etkinliği

ÖZ

Amaç: Çalışmamızda amaç; anterior bölgede estetik amaçla kullanılacak üç farklı tipteki yüksek estetiğe sahip kompozit rezine, üç farklı bitirme ve polisaj sistemlerinin uygulanmasıyla, yüzey pürüzlülüğüne ve mikrosertliğine etkisini üç boyutlu Optik Profilometre, Vickers mikrosertlik cihazı ve SEM analizleri ile incelemektir.

Gereç ve Yöntemler: Çalışmada 3 farklı kompozit rezin; supra-nanofil (Tokuyama Estelite Asteria), supra-nano sferikal (Tokuyama Omnichroma), nanohibrit (Kuraray Clearfil Majesty Esthetic) kullanıldı. Toplam 120 adet olmak üzere her bir kompozit rezinden 40'ar adet örnek hazırlandı. Polimerizasyon ve düzeltme işlemlerinden sonra, her gruptan herhangi bir polisaj işlemi uygulanmamış on örnek, kontrol grubu olarak ayrıldı. Daha sonra polisaj işlemi için rastgele üç gruba ayrıldı: 4 aşamalı alüminyum oksit kaplı disk (3M Sof-lex disk), alüminyum oksit içerikli elmas parçacıklardan oluşan bej ve pembe renkli 2 adımlı spiral lastik (3M Sof-lex spiral), poliüretan, elmas granüller içeren açık mavi lastik ve spiral lastik (İvoclar Vivadent OptraGloss).Yüzey pürüzlülüğü (Ra) konvansiyonel profilometre cihazı ile tüm numuneler üzerinde ölçüm yapıldı. Daha sonra Optik Profilometre cihazıyla ve Taramalı Elektron Mikroskobuyla tüm gruplardan birer adet örnek yüzeyi incelendi ve tüm örnekler Vickers Mikrosertlik Test Cihazıyla mikrosertlik testine tabi tutuldu.

Bulgular: Çalışmamızın sonucunda en düşük pürüzlülük değerleri kontrol grubunda gözlenirken, en yüksek pürüzlülük değerleri ise İvoclar Optragloss grubunda gözlenmiştir. Kuraray Clearfil Majesty Esthetic kompozit ile çalışılan gruplar, diğer kompozit gruplarına göre yüksek pürüzlülük değerleri göstermiş ancak diğer kompozit gruplarıyla istatistiksel olarak anlamlı bir fark bulunamamıştır ($p>0,05$). Çalışmamızda en düşük mikrosertlik değerleri ise kontrol grubunda gözlenirken, en yüksek mikrosertlik değerleri ise Sof-Lex Disk grubunda gözlenmiştir. En düşük mikrosertlik değerleri Kuraray Clearfil Majesty Esthetic kompozitle çalışılan gruplarda gözlenmiştir.

Sonuçlar: Kullanılan polisaj sistemlerinin, farklı içerikli restoratif matertaller üzerinde etkinliğinin farklı olduğu, Sof-Lex çok aşamalı disk ile Sof-Lex iki aşamalı spiral lastik sistemlerinin, İvoclar Optragloss sistemine göre daha başarılı olduğu söylenebilir.

Anahtar Kelimeler: Estetik Kompozit, Yüzey Pürüzlülüğü, Mikrosertlik.

Süreç

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Introduction

Dentists and patients attach great importance to both the function and aesthetic appearance of teeth. With the increasing interest of patients in aesthetics, the use of resin-based composites is increasing with the developments in bonding procedures and materials.[1]

Over time, with the increasing interest in aesthetics, composite resins have been widely used in the anterior and posterior regions.[2,3]

In composite resins, nanocomposites started to be produced with the development of nanotechnology. The term 'nanotechnology' was developed to describe smaller dimensions that cannot be scaled with micro-technology.[4] When the inorganic phases in the composite content become nano-sized, they are called nanocomposites. Due to the fact that nanocomposites contain very small inorganic filler particles, more successful polishing process and ultimately smoother surfaces can be obtained.[5]

In obtaining composite resins with smooth surfaces, the type and content of the material is important as well as the finishing and polishing systems. There are studies indicating that when appropriate finishing and polishing processes are performed, plaque retention will be reduced, discolouration and recurrent caries can be prevented in this way.[6]

The finishing process provides shaping of the restoration by removing the excesses on the restoration surface and the polishing process provides an aesthetic appearance and shine to the restoration and eliminates the retention areas that cause discolouration.[7]

The presence of rough areas in composite restorations may cause deterioration of the aesthetic appearance, plaque retention and therefore surface discolouration and secondary caries formation.[7]

Many different methods can be used to measure surface roughness. The main ones are mechanical and optical profilometers, transmission electron microscopy (TEM), atomic force microscopy (AFM) and scanning electron microscopy (SEM).[8]

Quantitative methods such as contact profilometer and optical profilometer and qualitative methods such as SEM can be used in surface roughness measurement.[9] Both quantitative and qualitative measurements of the surface can be performed successfully with optical profilometer, also called laser profilometer. Optical profilometers have higher measurement accuracy, can give more detailed and faster results than mechanical profilometers, and can also provide 3D images of the measured surfaces.[10]

Another important property of composite resins is microhardness. This structural property plays an important role in terms of the mechanical life of the restoration.[11] The microhardness of composite resins can be defined as the resistance of the composite against the pressures created by rigid materials.[12]

The aim of this study was to investigate the effect of three different finishing and polishing systems on the surface roughness and microhardness of three different types of highly aesthetic composites to be used for aesthetic purposes in the anterior region with three-dimensional Optical Profilometer and SEM analyses.

Material and Methods

Preparation of Composite Samples

Ethics Committee approval dated 10.02.2021 and numbered 2021-02/42 was obtained by Sivas Cumhuriyet University Non-Interventional Clinical Research Ethics Committee to start the study. A total of 120 composite resin samples were prepared using cylindrical metal molds made of stainless steel with a diameter of 8 mm and a thickness of 2 mm. After the composite resins were placed in metal molds, they were compressed with a transparent tape on the upper and lower surfaces. Then samples were obtained by polymerized using a 10 s with LED light device (VALO Cordless, Ultradent, USA). Then, 600, 800 and 1000 grit silicon carbide papers were applied to the surfaces, respectively, to obtain a standard smear layer.

Experimental Groups

The composite resins used were divided into 3 main groups according to their content. For each main group, 40 samples were used. This study, the composites tested and their composition information are given in Table 1.

***Asteria Composite Group*:** Tokuyama Asteria composite (Tokuyama Dental Tokyo, JAPAN) specimens were prepared using cylindrical metal molds and subjected to processes as described above (n=40).

***Omnichroma Composite* Group:** Tokuyama Omnichroma Single-shade composite (Tokuyama Dental Tokyo, JAPAN) specimens were prepared using cylindrical metal molds and subjected to processes as described above (n=40).

***Kuraray Clearfil Majesty Esthetic Composite Group*:** Kuraray Clearfil Majesty Esthetic Composite (Kuraray Noritake Dental, Okayama, JAPAN) specimens were prepared using cylindrical metal molds and subjected to processes as described above (n=40).

Each composite group was divided into 4 subgroups, as 3 experimental groups and 1 control group, according to the polishing systems to be tested (n=10). The material properties and manufacturers of the polishing systems used in the study are given in Table 2.

Sub-group 1: Control group:

No polishing system was applied to the samples in this group.

Sub-group 2: 3M Sof-lex Polishing Discs:

2nd Group is the Soflex disc system (3M ESPE, St Paul, Mn, USA), which is a multi-stage polishing system, using coarse, medium, fine and super fine grained aluminum oxide coated discs, respectively (15-20 seconds) with water cooling. It was used at a speed of 15.000 rpm under.

Sub-group 3: 3M Sof-lex Diamond Spiral Tire:

With 2-stage Sof-lex spiral rubber system (3M ESPE, St Paul, Mn, USA), beige colored spiral rubber for pre-polishing and pink colored spiral tire with diamond structure for high gloss, 15-20 seconds under water cooling at 15.000 rpm applied throughout.

Sub-group 4: Ivoclar Optragloss Polishing Systems:

Ivoclar Optragloss (Schaan, Leichtenstein), a polishing system consisting of rubber and spiral rubber was used, and light blue lens and flame-shaped tires and spiral rubber were used. The polishing process was carried out under water cooling at a speed of 15.000 rpm for 15-20 seconds.

Measurement of Surface Roughness

The surface roughness of the samples was measured using a profilometer device (Mitutoyo Surftest/ SJ-301, Tokyo, Japan). The average surface roughness value was calculated by taking the arithmetic average of the obtained data by measuring from three different regions of each sample.

Examination of Samples with Optical Profilometer Device

Using an optical profilometer device (Phase View, Zee Scope Compact 3D Digital Microscope, Verrieres Le Buisson, France), one sample from each group was randomly selected and a 3D non-contact image of a total of twelve samples were obtained.

Measuring Vickers Microhardness Values of Samples

The microhardness of each prepared restorative material was evaluated using the vickers microhardness tester (Shimadzu hmv-2/ hmv-2t vickers, Kyoto, Japan).

Analysis of the Surfaces of the Samples by Scanning Electron Microscopy

SEM analyzes of a randomly selected sample from each group were performed using the SEM device (Tescan MIRA 3, Czech Republic).

Statistical Analysis

The data obtained from this study were evaluated with SPSS (Statistical Package for the Social Sciences) 22.0 program one-way ANOVA and Tukey tests.

Results

Surface Roughness Results:

The average roughness values and standard deviation values obtained as a result of statistical evaluations of surface roughness tests are shown in Table 3.

As a result of the statistical evaluations, among the polishing materials; the lowest average roughness values were observed in the control group, while the highest average roughness values were observed in the Ivoclar Optragloss group. There was no statistically significant difference between the groups worked with Sof-lex disc and the groups worked with Sof-Lex Spiral in terms of roughness values ($p>0.05$). Sof-lex disc gave rougher surfaces in Tokuyama Omnichroma composite resin and Sof-Lex spiral gave rougher surfaces in Kuraray Clearfil Majesty Esthetic composite resin. When the composite groups were evaluated, the groups worked with Kuraray Clearfil Majesty Esthetic composite showed the highest roughness values in all groups except Ivoclar Optragloss group. The groups worked with Tokuyama Omnichroma composite resin gave the lowest surface roughness values compared to other composite resin groups.

When the Optical Profilometer Images were evaluated, it was seen that there are superficial fluctuations in the Tokuyama Estelite Asteria composite Control group (Figure 1.a), and the surface roughness in the sof-lex disc group (Figure 1.b) is less than the other groups.

When Optical Profilometer Images of Tokuyama Omnichroma composite are evaluated; While the distance between elevation and depth increases in the control group (Figure 2.a), it is seen that the roughness on the surface is less compared to the other groups, elevations and depths are seen in other polishing groups, but the frequency of roughness increases in the Ivoclar Optragloss group (Figure 2d.).

When the Optical Profilometer Images of the Kuraray Clearfil Majesty Esthetic Composite are evaluated, the elevations and depths are seen in the Control group (Figure 3.a). However, the distance between elevation and depth is less than Soflex disc and Ivoclar Optragloss groups. It is seen that the frequency of elevations and depths in the Ivoclar Optragloss group (Figure 3.d) is higher than the other groups.

Microhardness Values:

The mean microhardness and standard deviation values we obtained in Vickers microhardness tests and statistical evaluations between groups are shown in Table 4.

The difference between Tokuyama Estelite Asteria and Tokuyama Omnichroma composite groups (except the control group) is statistically significant ($p<0.05$). When working with Sof-lex disc and Sof-lex spiral polishing systems, Tokuyama Estelite Asteria composite gave higher microhardness values. When worked with Ivoclar Optragloss polishing system, Tokuyama Omnichroma composite gave higher microhardness values. The difference between the groups worked with Kuraray Clearfil Majesty Esthetic composite and other composite groups was found statistically significant ($p<0.05$). The lowest microhardness values were observed in the groups treated with Kuraray Clearfil Majesty Esthetic composite. In all composite groups, the difference between control and Sof-Lex disc polishing groups was statistically significant ($p<0.05$). The highest microhardness values were observed in the Sof-Lex Disc group and the lowest microhardness values were observed in the control group.

When the SEM analysis images are examined, it is seen that the smoothest surface in all composite groups is in the control group (Figures 4, 5, 6a). The SEM images of the Tokuyama Asteria composite groups polished with Sof-lex disk and Soflex spiral were very similar to each other. In the SEM analysis of the composite groups polished with Ivoclar optragloss, inorganic fillers were separated from the surface and many tiny pits and irregular block clusters were found on the surface (Figure 4.d).

In the SEM analysis of Tokuyama Omnichroma composite groups polished with Ivoclar optragloss, it was determined that a large number of inorganic fillers had broken off from the surface, many pits and a heterogeneous surface were seen on the surface (Figure 5.d). The composite polished with sof-lex disc and sof-lex spiral. Although the

SEM images of the groups were very similar to each other, the surface of the samples polished with the Sof-Lex spiral (Figure 5.c) was observed to be more homogeneous and smooth.

In the SEM analysis of the Kuraray Majesty Esthetic composite groups polished with Ivoclar optragloss, it is seen that the surface is very rough, the inorganic fillers are clustered in places or are broken off from the surface in the form of cracks in places (Figure 6.d). SEM images of the composite groups polished with Sof-Lex disc (When Figure 6.b) was examined, it was seen that the inorganic fillers followed a homogeneous distribution on the surface, and in the composite groups polished with the Sof-Lex spiral (Figure 6.c), although the surface was seen to be smoother, tiny cracks were found homogeneously on the entire surface.

Discussion

The aesthetics of composite restorations are affected by properties such as colour stability, surface roughness and gloss.[13-15] In addition, with the use of composite restorations in the posterior region, their mechanical properties have gained importance for the long-term success of restorations.[16] The microhardness values, which show the structural durability of the materials, affect the mechanical properties of the materials. It is known that as the microhardness of the material increases, wear resistance and mechanical durability increase.[17,18]

In this study, considering the developments in composite resin technology, the effect of supra-nanophile (Tokuyama Estelite Asteria), supra-nano spherical (Tokuyama Omnichroma), nanohybrid (Kuraray Clearfil Majesty Esthetic) anterior composite resins with high aesthetics on roughness and microhardness as a result of the application of different polishing systems were investigated by three-dimensional optical profilometer, Vickers microhardness tester and SEM analyses.

Finishing and polishing processes ensure that the residues that may be seen as a result of the restoration are removed and the desired surface smoothness is obtained in the restoration. Thus, by reducing plaque formation on the surface, it also prevents surface discolouration, gingival inflammation and secondary caries formation.[19-21]

Determining the finishing and polishing technique to obtain an ideal aesthetic appearance and a smooth surface in composite resin restorations is of great clinical importance.[22] In our study, we investigated the effects on surface roughness and microhardness of aluminium oxide coated multi-stage disc system (Sof-Lex disc), two-stage spiral rubber system (Sof-Lex Spiral) consisting of aluminium oxide and thermoplastic elostomer containing beige and pink coloured spiral rubber containing diamond particles, and single-stage polyurethane, light blue rubber containing diamond granules and spiral rubber (Ivoclar Optragloss) polishing systems.

Quantitative methods such as contact profilometer and optical profilometer and qualitative methods such as SEM can be used in surface roughness measurement.[9] Both quantitative and qualitative measurements of the surface can be performed successfully with the optical profilometer, also called laser profilometer. Optical profilometers have higher measurement accuracy, can give more detailed and faster results than mechanical profilometers, and can also provide 3D images of the measured surfaces.[10] Yamanel[23] used optical profilometer device in his study in which the effect of different prophylactic polishing processes on the surface roughness of microhybrid and nanohybrid composite resins were investigated. The reason for this is that optical profilometer devices have advantages such as fast measurement, not damaging the sample surface during measurement, micrometer and nanometer size measurements, and the ability to take two and three dimensional surface images. Davud *et al.*[24] also studied the effects of tooth brushing on the surface properties of micro-hybrid and nano-filled resin composites after different finishing and polishing processes using optical profilometer and SEM devices.

In our study, all samples were measured with a two-dimensional (mechanical) profilometer. In addition, one sample randomly selected from each group was analysed with a three-dimensional optical profilometer and SEM analysis was performed on one sample from each group to examine the composite resin surfaces.

Although composite resins have many physical and mechanical properties, one of the most important of these is microhardness.[25] It has been reported that finishing processes should be used in order to increase the surface hardness value of composite resin and in this way, a mechanically robust surface that is more resistant to abrasion will be formed.[26,27] Erdemir et al[28] applied different polishing systems (Sof-Lex disc, Pogo polishing system) on composite resins and compared their microhardness values. In their study, they argued that polishing systems increased the microhardness values, but they concluded that there was no statistically significant difference between polishing systems ($p>0.05$). Venturini *et al.*[29] reported that different polishing systems resulted in different microhardness values. In our study, multi-stage polishing with Sof-Lex disc resulted in the highest microhardness values. In Tokuyama Estelite Asteria composite group, Sof-Lex spiral polishing system gave statistically significantly higher microhardness values than Ivoclar Optragloss system ($p<0.05$). The results of our study are consistent with the results of Venturini *et al.* in terms of different polishing systems giving different results in terms of microhardness values.

Many studies have shown that the smoothest surfaces can be obtained with multi-stage aluminium oxide coated discs.[30-32] Bilgili et al [32] found that the smoothest composite surfaces were obtained with the sof-lex disc system. They argued that the reason for this is that since the composite surface is sanded gradually up to the fine particle discs, the polishing process is provided with the

super fine disc, which is the last stage. Korkmaz et al [33], in their study; applied three different polishing systems (Pogo, Sof-lex disc, Optrapol) on six different composite materials, two nanofillers (Filtek Supreme XT, Aelite Aesthetic Enamel), two nanohybrids (Tetric EvoCeram, Grandio), one nanoceramic (CeramX) and one microhybrid (Filtek Z250) and examined the roughness values with surface profilometer and surface hardness with Vickers microhardness device. They reported that in the nanohybrid composite (Tetric EvoCeram) group, Sof-Lex polishing system showed higher roughness values than other polishing systems and in the microhybrid composite (Filtek Z250) group, PoGo polishing system showed higher roughness values. At the same time, the nanohybrid composite (Grandio), which had the highest filler content (87 wt%) in this study, showed higher microhardness values than the other composites. When all polishing systems were used, they stated that the lowest microhardness values were obtained in all of the groups finished with mylar strip tape (control).

In our study, the roughest surfaces were obtained with the single-stage Ivoclar Optragloss polishing system in all composites. Although multi-stage Sof-Lex disc polishing system in Tokuyama Omnichroma composite group and two-stage Sof-Lex spiral polishing system in Kuraray Clearfil Majesty Esthetic composite group gave rougher results, the differences between them were statistically insignificant. When our study was evaluated in terms of microhardness; among the different polishing systems, the lowest microhardness values were obtained in the control group finished with mylar strip tape without any polishing process.

It has been reported by many researchers that the use of transparent tape during the construction of composite resin restorations reduces surface roughness values.[34-36] When our study was evaluated in terms of surface roughness; similar to these studies[34-36], the group finished with Mylar strip and used as control group showed the lowest surface roughness values. Since composite resins contain inorganic fillers of different sizes and the filler particles have different degrees of hardness, they produce different surface roughness and different microhardness values after finishing and polishing processes.[37]

Göztaş *et al.*[38] compared surface roughness and microhardness values after polishing using one nanofilament (3M Filtek Supreme XT) and four nanohybrid (Ivoclar Tetric EvoCeram, Dentsply Ceram X, Voco Grandio, Bisco Ælite Enamel) composite resins. They stated that the surface of nanofil composite resin was smoother than nanohybrid composites. And the microhardness values measured in their study were in parallel with the filler ratio; the composite resin material with the highest filler content showed the highest hardness values.

Similar to this study, we used composites with different filler ratios in our study. Tokuyama Estelite Asteria (82% by weight), Tokuyama Omnichroma (79% by weight), Kuraray Clearfil Majesty Esthetic (78% by weight); We obtained the lowest microhardness values in Kuraray Clearfil Majesty Esthetic composite, which is in line with the filler ratio. These results are parallel to the results of the study conducted by Göztaş *et al.*[38] In our study, among supra-nanophile, supra-nano spherical and nano-hybrid composite resin groups; While the smoothest surfaces were seen in the supra-nano spherical composite groups, the roughest surfaces were seen in the nano-hybrid composite groups.

Conclusions

As a result of our study, it was concluded that finishing and polishing processes are effective on surface roughness and microhardness. It can be said that the polishing systems used have different effectiveness on restorative materials with different contents, and Sof-Lex multi-stage disc and Sof-Lex two-stage spiral rubber systems are more successful than the Ivoclar Optragloss system.

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Conflicts of Interest Statement

None.

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Table 1. Composites tested and their composition

Composite	Type	Color	Content	Manufacturer	Ratio W-V
Tokuyama Estelite Asteria	Supra- nanophile composite resin	A2	Bis-GMA Bis-MPEPP TEGDMA UDMA	Tokuyama Tokyo, Japan	82/71
Tokuyama Omnichroma	Supra-nano Sferical composite resin	-	UDMA, TEGDMA, mequinol, Dibutyl hydroxyl toluene, UV absorber	Tokuyama Tokyo, Japan	79/68
Clearfil Majesty Esthetic	Nano hybrid composite resin	A2	Bis-GMA, hydrophobic aromatic dimethacrylate	Kuraray Noritake Dental, Okayama Japan	78/66

Table 2. Material properties and manufacturers of the polishing systems used in the study

Polishing Material	Material properties	Manufacturer
Sof-Lex Polishing Discs	Aluminum oxide coated discs (coarse, medium, fine, super fine)	3M/ESPE, St Paul, Mn, ABD
Sof-Lex Diamond Spiral Tire	Beige colored 2-step spiral tire with aluminum oxide and thermoplastic elastomer content and pink colored diamond particle content	3M/ESPE, St Paul, Mn, ABD
Ivoclar Optragloss	Light blue rubber and spiral rubber with polyurethane, diamond granules	Ivoclar Vivadent, Schaan, Leichtenstein

Table 3. Mean and standard deviation of roughness values of experimental groups (Ra)(SD)

Polisaj Materials	Tokuyama Asteria *Mean (Ra) (SD)*	Tokuyama Omnichroma *Mean (Ra) (SD)*	Kuraray Clearfil Majesty Esthetic *Mean (Ra) (SD)*
Control	0.20 (0.04) ^{a}	0.17 (0.05) ^{d}	0.25 (0.10) ^{e}
Sof-Lex Discs	0.49 (0.14) ^{b}	0.34 (0.08)	0.54 (0.20) ^{f}
Sof-Lex Spiral Tire	0.49 (0.20) ^{c}	0.31 (0.09)	0.57 (0.22) ^{g}
Ivoclar Optragloss	1.02 (0.49) ^{A,a,b,c}	0.60 (0.11) ^{A,B,d}	0.95 (0.48) ^{B,e,f,g}

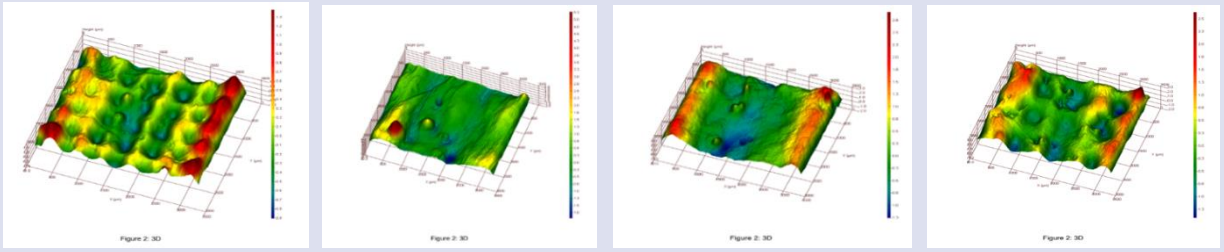
F= 13.464, P=0.000 (p<0.05)
^{A,B} In the same line; The same superscript symbolizes groups with differences between the groups indicated by capital letters.
^{a,b,c} In the same column; The same superscript symbolizes groups with differences between the groups indicated by lowercase letters.

Table 4. Average microhardness and standard deviation values obtained in Vickers microhardness tests and statistical evaluations between groups

Polishing Systems	Tokuyama Estelite Asteria *Mean (SP)*	Tokuyama Omnichroma *Mean (SP)*	Kuraray Clearfil Majesty Esthetic *Mean (SP)*
Control	83.74 (4.39) ^{A,a,}	88.04 (1.95) ^{A,c}	63.81 (1.88) ^{e,f}
Sof-Lex Discs	108.7 (8.04) ^{b,}	101.1 (7.42) ^{d}	83.05 (5.06)
Sof-Lex Spiral Tire	101.5 (6.9) ^{b,}	92.73 (3.09) ^{c}	67.03 (2.05) ^{e,g}
Ivoclar Optragloss	89.80 (5.91) ^{a,}	100.8 (2.15) ^{d}	68.92 (4.7) ^{f,g}

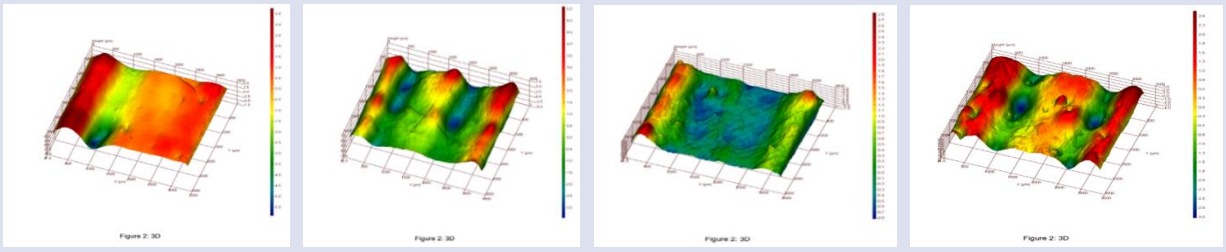
F= 88.728 P=0.000 (p>0.05)
^{A} In the same line; The same superscript symbolizes groups where there is no difference between the composite groups shown in capital letters.
^{a,b,c,d,e,f,g} In the same column; The same superscript symbolizes groups where there is no difference between the polishing groups shown in lowercase letters.

Optical Profilometer Images:



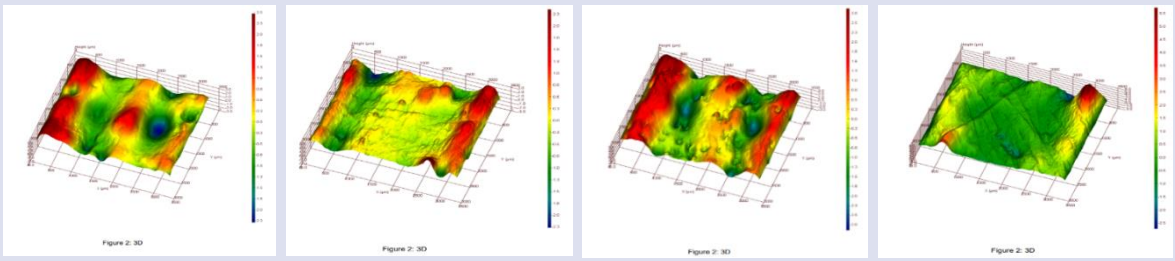
a) Control b) Sof-lex disc c) Sof-lex Spiral d) Ivoclar Optragloss

Figure 1(a.b.c.d.) Optical Profilometer Images of Tokuyama Estelite Asteria Composite



a) Control b) Sof-lex disc c) Sof-lex Spiral d) Ivoclar Optragloss

Figure 2(a.b.c.d.) Optical profilometer images of Tokuyama Omnichroma Composite



a) Control b) Sof-lex disc c) Sof-lex Spiral d) Ivoclar Optragloss

Figure 3(a.b.c.d.) Optical Profilometer Images of Kuraray Clearfil Majesty Esthetic Composite

SEM Images of Tokuyama Estelite Asteria Composite Groups

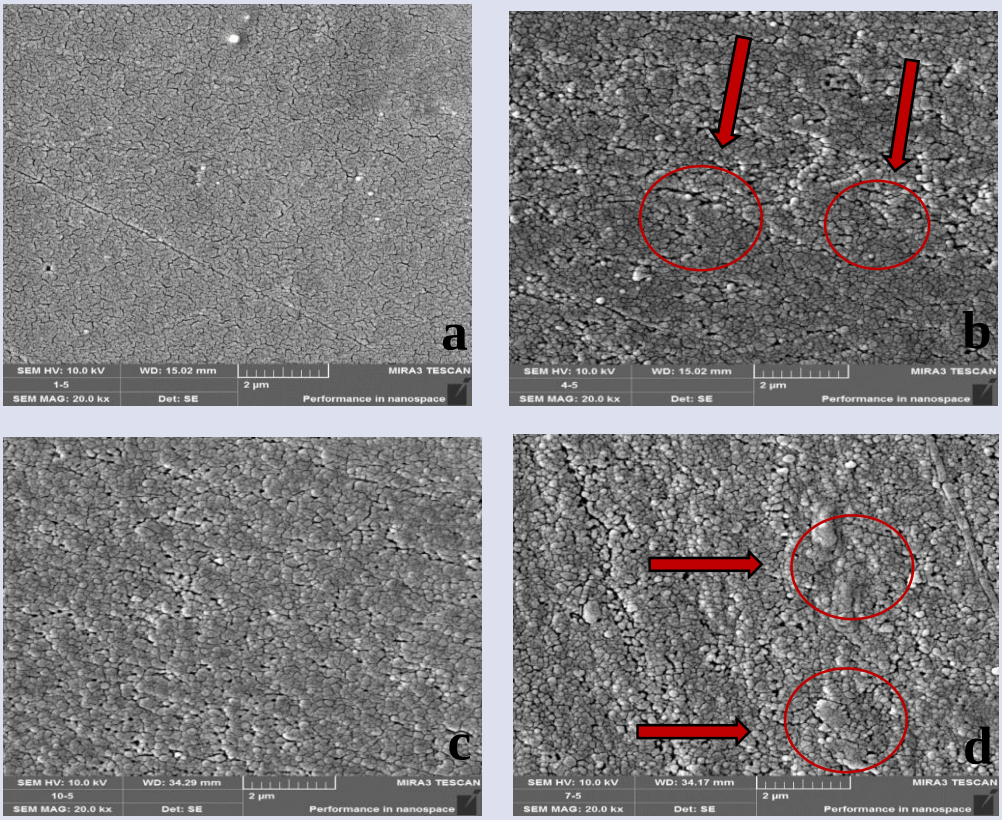


Figure 4. Tokuyama Estelite Asteria SEM images of groups a. control, b. Sof-lex disc, c. Sof-lex Spiral, d. Ivoclar Optragloss.

SEM Images of Tokuyama Omnichroma Composite Groups

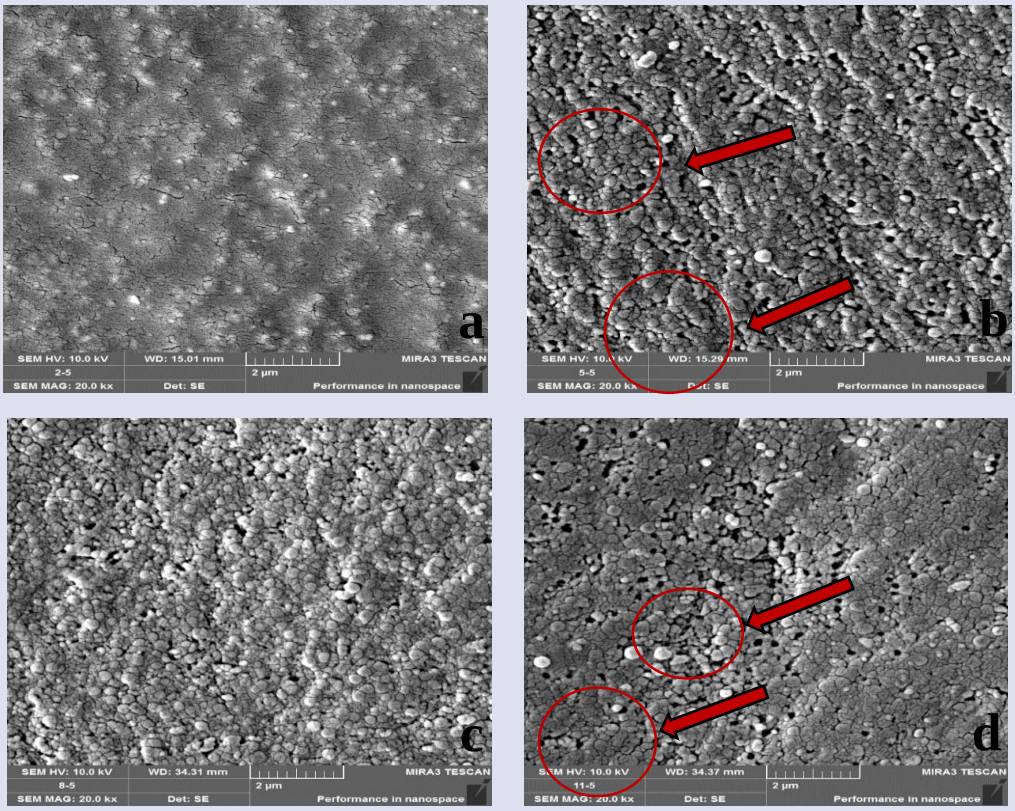


Figure 5. Tokuyama Omnichroma SEM images of groups a. control, b Sof-lex disc, c. Sof-lex Spiral, d. Ivoclar Optragloss.

SEM Images of Kuraray Clearfil Majesty Esthetic Composite Groups

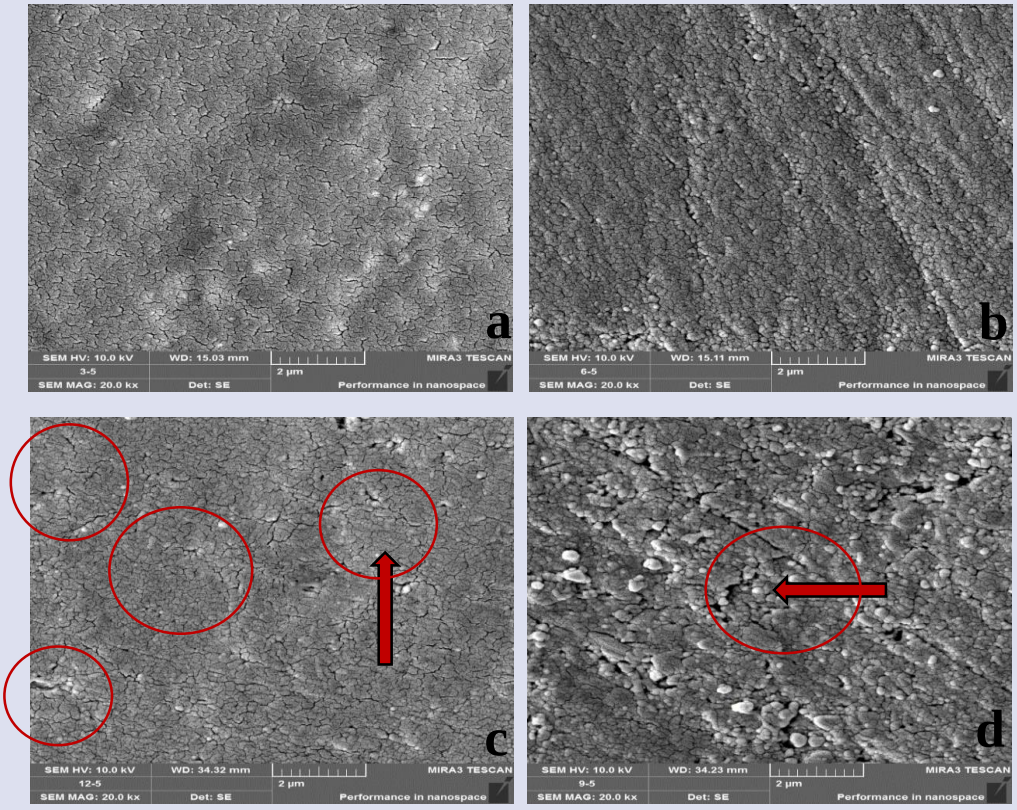


Figure 6. Kuraray Clearfil Majesty Esthetic SEM images of a. control, b. Sof-lex disc, c. Sof-lex Spiral, d. Ivoclar Optragloss groups.

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Evaluation of Dentistry Students' Perspectives of Specialization in Restorative Dentistry

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ABSTRACT

Aim: The aim of this study was to evaluate the perspectives of the students studying at the faculty of dentistry on the specialization in the field of restorative treatment.

Materials and Methods: A total of 139 students, comprising 4th and 5th graders enrolled at the Gaziantep University Faculty of Dentistry, participated in the study. Of these, 71 students were in the 4th grade, while 68 were in the 5th grade. Students were administered a 10-question questionnaire about their evaluation of specialization in dentistry. The data collected was subjected to statistical analysis using the chi-square test. The statistical significance of the findings is at a level of $p<0.05$.

Results: The most popular specialty in dentistry is Oral and Maxillofacial Surgery, with 45.3% of respondents selecting it as their first choice. The majority of respondents, at 66.9%, reported that they first became aware of the Restorative Dentistry department within the preclinical department. According to the survey, 47.5% of the students stated that the Restorative Dentistry department was primarily influenced by their clinical experience.

Conclusion: It is widely acknowledged that the preclinical period is a critical juncture in shaping dental students' initial impressions of various specialties. Furthermore, a range of factors, including clinical exposure, income expectations, and personal interests, play a significant role in determining the specialty that a student may choose to pursue.

Key Words: Dentistry, restorative dentistry, specialization.

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Introduction

All dentists who have earned their degree from the faculty of dentistry are equipped with the necessary authority and expertise to provide general dentistry treatments. However, there may be instances where more specialized information and techniques are required, in which case post-graduate education becomes crucial.

The "Omnibus Law" numbered 6225, published in the Official Gazette on April 26, 2011 and identified as numbered 27916, designated 8 specialties as Oral and Maxillofacial Radiology, Oral and Maxillofacial Surgery, Prosthodontics, Endodontics, Restorative Dentistry, Pediatric Dentistry, Periodontology, and Orthodontics.[1] It is important to note that the Orthodontics and Oral and Maxillofacial Surgery departments provide a 4-year program of detailed theoretical and practical training, while the other departments offer a 3-year program of the same nature. Upon completion of these programs and the submission of a thesis that has been successfully evaluated, physicians may be granted the title of "Specialist Dentist" or "Restorative Dentistry Specialist" in the Restorative Dentistry department.[2,3]

Restorative Dentistry is a branch of dentistry that focuses on enhancing the aesthetic, functional, and phonetic qualities of teeth that are unacceptable due to various factors such as disease, trauma, wear, or developmental defects.[4] This field utilizes both indirect and direct methods, including procedures such as inlay, onlay, and overlay restorations, closure of interdental diastemas, laminate-composite veneers, in-office and at-home bleaching procedures, and devital bleaching procedures. These techniques can be performed in a Restorative Dentistry treatment clinic.

The advancement of technology and the more active role of social media in our lives have brought along aesthetic concerns that are becoming increasingly widespread in society. Especially smile design and whitening treatments, which are common applications in restorative treatment clinical operation, increase the interest in restorative treatment. However, studies in the literature have shown that many factors such as interest in the field of specialization, the city where the specialization will be carried out, the financial gain to be obtained after the specialization and the duration of the specialization program are effective in preferences.[5-7]

Based on the information provided, our study aimed to examine the perspectives and motivations of students from the Gaziantep University Faculty of Dentistry in the 4th and 5th grades regarding their interest in specializing in Restorative Dentistry after graduation.

Materials and Methods

Given the importance of knowledge and experience in selecting a specialty in dentistry, the survey was designed to be administered solely to 4th and 5th grade students. Prior to its implementation, the necessary approval was obtained from the Gaziantep University Clinical Research Ethics Committee, which granted authorization with the decision number 2023/173.

During the academic year 2022-2023, a total of 139 students enrolled in the 4th and 5th grades at the Faculty of Dentistry of Gaziantep University were involved in the study. All participants provided their consent by signing the consent forms and were informed of their right to withdraw from the study at any time without consequences. The questionnaires were administered on a voluntary basis at the end of the class hour, and no personal identifying information was collected from the participants. The enquiries posed to the students were akin to those employed in the research conducted by Aksoy *et al.*[8] and the survey questions are presented in Table 1. The inquiries encompassed both preferences for specialization in dentistry and perspectives on the Restorative Dentistry specialization.

IBM SPSS Statistics 22 (IBM SPSS, USA) program was preferred for statistical analysis of the findings obtained in the study. Chi-square test was used to evaluate the data obtained. Statistically, a significance level of 0.05 was accepted.

Results

A total of 139 students, comprising 70 from the 4th grade and 69 from the 5th grade, were enrolled in the Faculty of Dentistry at Gaziantep University during the 2022-2023 academic year and were selected for this study. The answers to the survey questions were examined. The distribution of the answers to the questions is shown in Table 1.

A statistically significant proportion of respondents, namely 66.9%, indicated that they were initially introduced to the Restorative Dentistry department during their preclinic experience, while 14.4% reported that they were first made aware of it during the pre-school and university preference periods. No significant difference was observed between the responses of male and female participants in this regard (p= 0.885).

With regards to the most influential introductory experience regarding the Department of Restorative Dentistry, 47.5% (n=66) of respondents indicated that it was their clinical experience, while 20.9% (n=29) attributed it to their preclinical course. Furthermore, 17.3% (n=24) believed that it was their faculty member teaching the Restorative Dentistry lecture. No significant difference was observed between the responses given by male and female participants (p= 0.0887).

With regards to their experience with the Restorative Dentistry department, 60.4% (n=84) of the respondents expressed mostly positive sentiments. Similarly, when asked about their general perception of the future need for the Restorative Dentistry department, 51.1% (n=71) of the participants held a mostly positive outlook. No significant discrepancies were observed between genders in either question (p= 0.275, p= 0.896).

The selection of a specialty was primarily based on the level of interest in the field, with 59.7% (n=83) of respondents indicating that this was the most crucial factor. This was followed by the faculty of specialty training with 27.3% (n=38). The city of specialty training was marked by 5.8% (n=8). While 'financial gain' received the highest number of responses from both male and female participants, no significant difference was observed in gender comparison (p= 0.085).

When the participants were inquired about their preferred specializations within the first three departments, the results indicated that 45.3% (n=63) of the respondents expressed a strong inclination towards Oral and Maxillofacial Surgery. Furthermore, 17.3% (n=26) of the participants opted for Pedodontics, while 12.9% (n=18) showed a keen interest in Periodontology. In terms of second choices, 31.7% (n=44) of the participants preferred Periodontology, 24.5% (n=34) opted for Prosthodontics, and 21.6% (n=30) showed a strong inclination towards Pedodontics. Orthodontics was the third choice with 53.2% (n=74), followed by Restorative Dentistry with 31.7% and Prosthodontics with 8.6%. When the effect of gender on preferences was analyzed, it was seen that the first three preferences of both male and female participants were the same departments and there was no statistically significant difference in these rates, respectively (p= 0.669, p=0.785, p=0.369).

The results of the study indicate that the majority of participants, 34.5%, believed that they would obtain the greatest financial gain in the field of Orthodontics. Additionally, 27.3% of participants believed that they would gain the most financial benefit in Prosthodontics, while 15.1% believed that Oral and Maxillofacial Surgery was the best option. Restorative Dentistry was ranked sixth with only 2.9% of participants selecting it. It is worth noting that Orthodontics was the most popular choice among both male and female participants, with no significant difference between them (p= 0.838).

When queried concerning the most notable department in terms of both patient care and dentistry, Oral and Maxillofacial Surgery emerged as the top choice, with 29.5% of participants citing its effectiveness in patient care and 33.8% in dentistry. Restorative Dentistry was found to be the third most effective department, with 11.5% of participants recognizing its excellence in patient care and 12.9% in dentistry. When analyzed in terms of gender, it was observed that preferences were always parallel and there was no statistically significant difference between them (p= 0.182, p= 0.279).

The primary motivation for wishing to specialize in Restorative Dentistry was a strong sense of personal skills, which was reported by 43.2% of respondents (n=60). The decision to specialize is influenced by several factors, including the contribution to professional life (22.3%), patient need (15.8%), and financial gain (11.5%). While 60.52% of men and 36.63% of women answered 'personal skills' to this question, a significant difference was found between genders (p= 0.043).

Discussion

In this study, the perspectives of students studying in different years of education on specialization in Restorative Dentistry were evaluated. In addition, a comparison was made with other specialty departments of dentistry through survey questions.

The importance given to specialization in dentistry is increasing. This is clearly seen in the studies evaluating the perspectives and motivations of dental students towards specialization after graduation. It was stated that the majority of dental students want to specialize and will prepare for the Dental Specialization Examination (DSE).[9,10]

Studies have shown that Oral and Maxillofacial Surgery is the most preferred department for dentistry students [9-11]. In our study, the department of Oral and Maxillofacial Surgery was the most preferred department with 45.3%. We think that Oral and Maxillofacial Surgery department is preferred first because of the high financial gain and the fact that much more complicated and advanced procedures are learned only during the specialization period compared to the undergraduate period.

The first preference of female students was Oral and Maxillofacial Surgery with 46.53%, while this rate was 42.10% for male students. Although there is no significant difference between them, the rate of girls' preference for the department of Oral and Maxillofacial Surgery is higher. This is consistent with other studies in the literature. [8,12]

Participants expressed their general experience with the Restorative Dentistry department as ‘mostly positive’ with 60.4%, ‘sometimes positive’ with 33.8% and indifferent with 5.8%. Although it is pleasing to see that 'mostly negative' and 'sometimes negative' statements in the options are not marked, it is seen that this does not have much effect on the order of preference. In the ranking of the first three departments to be preferred, Restorative Dentistry was not marked at all in the first place in the order of preference, but only in the second and third preferences. We maintain that the root cause of this situation lies in the response provided to question 7 (In which specialty do you think you can earn more money?), specifically the answer "Restorative Dentistry department" which accounted for 2.9% of the votes. It is possible that the relatively low preference ranking for the Restorative Dentistry department is also influenced by the belief among students that they will improve their manual skills in this area through the courses they will take after completing their undergraduate studies.

It is expected that the participants will opt for the Orthodontics department as the one that will bring them the most financial benefits, yet the Oral and Maxillofacial Surgery department is considered to be the first choice among the top three departments, due to a keen interest in the field of specialization rather than financial prospects during preferences. Our research shares similarities with the investigation conducted by Erhamza *et al.*[13], in that the participants expressed the belief that they would attain the greatest financial benefits in the field of Orthodontics.

In 4th and 5th graders' first three department preferences, although the first and third preferences were the same, there was a concentration in different departments in the second preferences. 4th graders were assigned to Periodontology and 5th graders were assigned to Prosthodontics as their second choice. In response to the inquiry regarding the most impactful introductory experience in their field of expertise, 47.5% of the participants indicated that it was their “clinical experience”. Given the challenging nature of certain procedures, such as taking impressions and preparing teeth, for 4th grade students to not choosing the Prosthodontics Department comparing 5th grade, it is possible that the increased clinical exposure and communication opportunities available to 5th grade students may have influenced these results.

It has been observed in our study that personal interest in a particular specialty was deemed to be the most critical factor in specialty choice, regardless of gender and period of study. This finding is consistent with other studies in the relevant literature.[14,15] In a related study, it was disclosed that the economic prosperity and development of a nation have a profound impact on the specialization choices of individuals.[16]

While an undergraduate dental student receives clinical training on the basics of a wide range of specialties, when he/she starts a specialty training program, he/she learns the knowledge and practice of a specific area in more detail.[17] A plethora of professional, personal, and economic factors, regardless of gender or period of education, impact a person's selection of specialization.

Conclusions

The decision of students to specialize in a particular field is influenced by a variety of factors, including observing the preclinical and clinical operations of eight different specialty departments, attending theoretical lectures, applying theoretical knowledge in clinical practice, individual abilities and aptitudes, financial considerations, and the city in which they are studying.

Although both the experience and the general perception about the future needs of the department are mostly positive, Restorative Dentistry does not find a place at the top of the preference list.

Acknowledgment

None

Conflicts of Interest Statement

None

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Table 1. Distribution of participants' answers to questions by gender and grades

	Grade 4	Grade 5	p	Female	Male	p
1. When were the students first introduced to Restorative Dentistry?						
Pre-school	10 (14.08%)	10 (14.71%)		16 (15.84%)	4 (10.53%)	
University preference period	10 (14.08%)	10 (14.71%)		14 (13.86%)	6 (15.79%)	
Preclinical course	49 (69.01%)	44 (64.71%)	0.698	67 (66.34%)	26 (68.42%)	0.885
Clinical practice	2 (2.82%)	2 (2.94%)		3 (2.97%)	1 (2.63%)	
Other	0 (0%)	2 (2.94%)		1 (0.99%)	1 (2.63%)	
2. Which introductory experience to Restorative Dentistry influenced students most?						
Preclinical course	21 (29.58%)	8 (11.76%)		21 (20.79%)	8 (21.05%)	
Clinical practice	26 (36.62%)	40 (58.82%)		48 (47.52%)	18 (47.37%)	
Faculty member delivering lecture	10 (14.08%)	14 (20.59%)	0.005	17 (16.83%)	7 (18.42%)	0.887
Dental journal/dental website	10 (14.08%)	2 (2.94%)		10 (9.90%)	2 (5.26%)	
Other	4 (5.88%)	4 (5.88%)		5 (4.95%)	3 (7.89%)	
3. Were these experience about Restorative Dentistry positive or negative?						
Mostly positive	32 (40.07%)	52 (76.47%)		57 (56.44%)	27 (71.05%)	
Sometimes positive	31 (45.59%)	16 (23.53%)		38 (37.62%)	9 (23.68%)	
Indifferent	8 (11.27%)	0 (0%)	0.000	6 (5.94%)	2 (5.26%)	0.275
Sometimes negative	0 (0%)	0 (0%)		0 (0%)	0 (0%)	
Mostly negative	0 (0%)	0 (0%)		0 (0%)	0 (0%)	
4. What is the students' overall perception of the future need of Restorative Dentistry?						
Mostly positive	37 (52.11%)	22 (32.35%)		52 (51.48%)	19 (50%)	
Sometimes positive	34 (47.89%)	26 (38.24%)		35 (34.65%)	13 (34.21%)	
Indifferent	10 (14.08%)	6 (8.82%)	0.249	12 (11.88%)	4 (10.53%)	0.896
Sometimes negative	2 (2.82%)	0 (0%)		1 (0.99%)	1 (2.63%)	
Mostly negative	0 (0%)	2 (2.94%)		1 (0.99%)	1 (2.63%)	
5. What is the most important criterion that students pay attention to choose a specialization?						
Interest in the specialization	41 (57.75%)	42 (71.76%)		57 (56.44%)	26 (68.42%)	
Faculty where you will receive your specialization program	22 (30.99%)	16 (23.53%)		33 (32.67%)	5 (13.16%)	
The location of specialization program	4 (5.88%)	4 (5.88%)	0.730	4 (3.96%)	4 (10.53%)	0.085
Cost of specialization program	0 (0%)	0 (0%)		0 (0%)	0 (0%)	
Length of the specialization program	0 (0%)	0 (0%)		0 (0%)	0 (0%)	

Other	4 (5.88%)	6 (8.82%)		7 (6.93%)	3 (7.89%)	
6. Which top three careers do students want to pursue?						
Oral and Maxillofacial Surgery	33 (46.48%) First choice	30 (44.12%) First choice				
Oral and Maxillofacial Radiology						
Endodontics						
Orthodontics	42 (59.15%) Third choice	32 (47.06%) Third choice				
Pediatric Dentistry						
Periodontology	24 (3.80%) Second choice					
Prosthodontics		26 (38,24) Second choice				
Restorative Dentistry						
7. What specialties do students believe have the highest salaries?						
Oral and Maxillofacial Surgery	15 (21.13%)	6 (8.82%)		16 (15.84)	5 (13.16%)	
Oral and Maxillofacial Radiology	0 (0%)	0 (0%)		0 (0%)	0 (0%)	
Endodontics	0 (0%)	0 (0%)		0 (0%)	0 (0%)	
Orthodontics	28 (39.44%)	20 (49.41%)	0.001	33 (32.67%)	15 (39.47%)	0.838
Pediatric Dentistry	2 (2.82%)	16 (23.53%)		13 (12.87%)	5 (13.16%)	
Periodontology	2 (2.82%)	8 (11.76%)		9 (8.91%)	1 (2.63%)	
Prosthodontics	22 (30.99%)	16 (23.53%)		27 (26.73%)	11 (29.95%)	
Restorative Dentistry	2 (2.82%)	2 (2.94%)		3 (2.97%)	1 (2.63%)	
8. How do students perceive specialties according to their impact on patient care?						
Oral and Maxillofacial Surgery	21 (29.58%)	20 (49.41%)		27 (26.73%)	14 (36.84%)	
Oral and Maxillofacial Radiology	8 (11.27%)	4 (5.88%)		11 (10.89)	1 (2.63%)	
Endodontics	8 (11.27%)	2 (2.94%)		9 (8.11%)	1 (2.63%)	
Orthodontics	4 (5.88%)	6 (8.82%)	0.074	7 (6.93%)	3 (7.89%)	0.182
Pediatric Dentistry	8 (11.27%)	4 (5.88%)		9 (8.91%)	3 (7.89%)	
Periodontology	6 (8.45%)	18 (26.47%)		18 (17.82%)	6 (15.79%)	
Prosthodontics	8 (11.27%)	6 (8.82%)		12 (11.88%)	2 (5.26%)	
Restorative Dentistry	8 (11.27%)	8 (11.76%)		8 (7.92%)	8 (21.05%)	
9. How do students perceive specialties according to their impact on dental field?						
Oral and Maxillofacial Surgery	27 (38.03%)	20 (49.41%)		32 (31.68%)	15 (39.47%)	
Oral and Maxillofacial Radiology	8 (11.27%)	2 (2.94%)		9 (8.91%)	1 (2.63%)	
Endodontics	8 (11.27%)	4 (5.88%)		8 (7.92%)	4 (10.53%)	
Orthodontics	6 (8.45%)	6 (8.82%)	0.034	8 (7.92%)	4 (10.53%)	0.279
Pediatric Dentistry	0 (0%)	4 (5.88%)		3 (2.97%)	1 (2.63%)	
Periodontology	2 (2.82%)	8 (11.76%)		8 (7.92%)	2 (5.26%)	
Prosthodontics	10 (14.08%)	16 (23.53%)		23 (22.77%)	3 (7.89%)	
Restorative Dentistry	10 (14.08%)	8 (11.76%)		10 (9.90%)	8 (21.05%)	
10. What the most important criteria for students to while choosing Restorative Dentistry as a specialization?						
Contribution to professional life	13 (18.31%)	18 (26.47%)		24 (23.76%)	7 (18.42%)	
Patients' needs	16 (22.54%)	6 (8.82%)		21 (20.79)	1 (2.63%)	
Financial salary	6 (8.45%)	10 (14.71%)	0.038	12 (11.88%)	4 (10.53%)	0.043
Personal abilities	28 (39.44%)	32 (47.06%)		37 (36.63%)	23 (60.53%)	
Other	8 (11.27%)	2 (2.94%)		7 (6.93%)	3 (7.89%)	

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Investigation of the Fracture Strength Between Dental Implant and Ti-Base Abutment Produced with Different Heights and Grades of Titanium Material

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ABSTRACT

New prosthetic designs have been developed in order to provide a balanced transmission of the stress caused by the chewing function to other mechanical and anatomical structures and these designs have revealed new research areas. An example of this is screw-retained implant-supported prostheses. With screw-retained prostheses, the residual cement problem is eliminated. However, abutment material and abutment design may adversely affect the mechanical and aesthetic properties of prostheses. Ti-base abutments have been developed to solve these problems. However, studies on clinical success, material content and abutment height of ti-base abutments remain up-to-date. In our study, the effect or abutment heights on the bond strength and stress distribution with monolithic zirconia crowns in ti-base abutments manufactured from different titanium Gr types will be tested. Titanium Gr 4, Gr 5 and Gr 23 ELI materials will be used in our study. A total of 7 groups are planned with ti-base abutments with an abutment length of 3.5 mm, 5.5 mm for Gr 4 and Gr 5, abutment length of 3.5 mm, 5.5 mm and 7 mm for Gr 23. In the in vitro experiment, the fracture strength of the samples will be tested with the universal testing device. total of 77 implants, ti-base abutments and monolithic zirconia crowns will be used by creating 11 samples for each study group. The obtained values will be recorded in Newtons and Megapascals. The data will be analyzed using the SPSS 22.0 program. As a result, while the lowest fracture strength values were observed in Gr 4 Ti material in all ti-base abutment lengths in the samples for which the fracture strength test was performed, similar values were observed in the ti-base abutments produced from Gr 5 and Gr 23 ELI alloys. When the relationship of bonding strengths with Ti alloys was evaluated, it was seen that there was no significant difference between Ti alloys.

Keywords: Grade 4, Grade 5, Grade 23, Fracture Strength.

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Introduction

The planning of implant-supported prostheses may vary as removable or fixed prostheses according to the width of the edentulous area and the condition of hard and soft tissues in the mouth.[1] According to these plans, the number of implants applied, and the type of material changed. This change has brought along new problems. One of the main problems encountered in oral implantology is mechanical complications in prosthesis structures. The stress on the restoration, abutment and implant structures due to the chewing function is the main factor of mechanical complications. Today, many materials and production techniques are being investigated to better meet this stress and ensure it is transmitted to other mechanical and anatomical structures within biological limits.

Today, the most common material type in dental implant production is titanium and titanium alloys.[2] Compared to other implant materials, the modulus of elasticity of titanium is closer to the modulus of elasticity of bone. Thus, the force distribution at the bone-implant interface is more balanced.[3] Its compatibility with biological tissues, exceptionally good corrosion resistance, low cost and high material resistance have made titanium a more preferred material.[4-6]

One of the important components of implant supported prostheses is abutments. Titanium, alumina, and zirconia were used as material types in abutments. Alumina gives a radiolucent appearance with insufficient mechanical resistance.

The design combining the mechanical properties of titanium abutments with the aesthetic properties of zirconia abutments is called 'Hybrid Abutment'.[7,8] Since the mechanical properties of hybrid abutments are higher than those of one-piece zirconia abutments, titanium abutments called 'Ti-base' have started to be produced. However, the mechanical properties of ti-base abutments and their physical interaction with crown materials have not been sufficiently elucidated.

The aim of this study is to investigate the effect of different chimney heights on fracture strength, connection strength and stress distribution in ti-base abutments made of different titanium types.

One of the other aims of the study is to elucidate the mechanical properties of titanium Gr 23 ELI alloy in the implant system with ti-base by comparing it with other titanium types.

Hypotheses of this study;

The fracture strength values of the ti-base abutment-implant system produced from Gr 23 ELI titanium will be lower than the fracture strength values of the ti-base abutment-implant systems produced with other titanium types.

The change in the height of the Ti-base chimney will not affect the bond strength values of monolithic zirconia crowns.

Materials and Methods

This study was carried out under in vitro conditions in Sivas Cumhuriyet University Faculty of Dentistry Research Laboratory, Private Setdent Dental Prosthesis Laboratory and Estaş Medical Inc. Laboratory. It was carried out under in vitro conditions (Table 1).

In this study, it is aimed to investigate the effect of different chimney heights on fracture strength and connection strength of ti-base abutments produced from different titanium types.

For this purpose, implants made of Gr 4, Gr 5, Gr 23 titanium materials, ti-base abutments with 3.5, 5.5, 7 mm chimney length and Ti abutment screws made of the same titanium materials were used in our study. Monolithic zirconia crowns were used for the superstructure of the study specimens planned as implant-supported screw-retained prosthesis design. A total of 7 study groups were organised with 11 specimens in each group. In the in vitro phase of the study, the specimens prepared in the study groups were tested for fracture strength with a universal test device.

Sample Preparation

In the in vitro phase of our study, the right 1st molar tooth was removed from the plastic lower jaw model and the toothless crest appearance was given to this area with wax modelling (Figure 2). A 3.8 mm diameter and 13 mm length titanium implant were fixed to the center of the existing edentulous cavity. Ti-base abutments with 2 mm gingival height, 3.5, 5.5- and 7-mm chimney lengths made of different types of titanium were fixed to these implants (Table 2).

A thin layer of scanning spray (Calidia Scan Spray, Essen, GERMANY) was applied on the jaw model and ti-base abutments and placed in a 3D scanning device (Dental Wings 7 Series, Montreal, CANADA) (Figure 2). A digital model was obtained by scanning the spray-coated specimens on the scanning device.

Using CAD/CAM software (Dental Wings 7 Series, MONTREAL, CANADA), sections were taken on the implant and abutment placement area on the digital model and the natural tooth structures and model parts outside this area were removed. Crown designs with homogeneous cement spacing and anatomical structure were made on Ti-base abutment models (Figure 3-5).

For 3.5, 5.5, 5.5, 7 mm ti-base abutments, crowns were produced from polymethylmethacrylate (Imicryl, Imident, TURKIYE) material in order to ensure crown standardization, and their compatibility with the abutments and their forms were checked. The crown designs, whose control phase was completed, were enlarged by 25% and placed on the digital zirconia disc model.

Pre-sintered zirconia discs (Optima, Shenzhen Upcera Dental Co., Ltd., CHINA) were placed in the milling unit (D30, Yena Dent, Istanbul, TURKIYE) and milling was completed with the help of inserts that can move in various axes.

After milling, the samples were carefully removed from the blocks and placed in the sintering furnace (160/1, Protherm Mos, Ankara, TURKIYE). The sinterization procedure was carried out at 900 C° for 2 hours, 1480 C° for 4.8 hours and 900 C° for 1 hour, respectively, in accordance with the manufacturer's recommendations (Figure 6).

The inner surface of the monolithic zirconia crowns was blasted with 50 µm aluminum oxide particles (Korox Bego Bremen, GERMANY) in a sandblaster (Blasmate II, NEY, Yucapia, Ca, USA) (Figure 7) at a distance of 10 mm for 20 seconds under 2 bar pressure. The samples were rinsed and dried with oil-free compressed air and prepared for cementation (Figure 7).

Adhesive resin cement (Theracem Ca, Bisco, Schaumburg IL, U.S.A.) was applied to the inner surface of the sandblasted crown with a uniform thickness. The crowns were placed on the abutments with finger pressure. After irradiation for 2-3 seconds, the cements overflowing from the marginal edges were cleaned with the help of a sonde. In the next stage, the cementation stage was completed by irradiating for 20-30 seconds in accordance with the manufacturer's recommendations (Figure 8).

Titanium implants were fixed in metal blocks with a height of 22 mm and a diameter of 15 mm with autopolymerising acrylic resin (Meliodent, Heraeus Kulzer, GERMANY) mixed in a ratio of 5 g powder to 3.5 g liquid according to the manufacturer's recommendations. The cemented monolithic zirconia and ti-base abutments were torqued with a force of 12 N/cm in the direction recommended by the manufacturer. After torquing, the screw entry path was sealed with Teflon tape (Figure 9).

Specimens Performing Fracture Strength Test

The fracture strength test was performed using a universal testing machine (LR 10K Plus, Lloyd Instruments, Farnham, UK) (Figure 1). The test specimens were placed on a table designed to remain stationary while the force was applied, and this table was fixed to the lower part of the machine. The loading rate was 1±0.5 mm/min according to ISO standards.

In our study, a continuously increasing force was applied until a fracture occurred, which could be detected by visible rupture or sound, at a tip speed of 1 mm/min with a diameter of 4 mm. The test was terminated as soon as the fracture occurred. The data obtained were recorded in Newton (N) in the instrument's own database.

Performing Statistical Analysis

The data obtained after the in vitro test phase was completed were recorded in Newton to the device's own database. SPSS 22.0 (SPSS Inc. Version 22, Chicago, USA)

programme was used for statistical analysis of the data and graphs were generated with GraphPad Prism V8.0. One-way analysis of variance and Tukey test were used to compare the fracture strength test data. Differences between groups were evaluated at a significance level of $p \leq 0.05$.

Results

Fracture strength of implant-supported monolithic zirconia restorations designed with 3 different titanium materials and 3 different ti-base chimney heights (Figure 10) (Gr=Grade).

1. When all chimney heights were compared, the lowest fracture strength values were found in the ti-base abutment group made of Gr 4 Ti material.

2. The fracture strength values of the ti-base abutment groups produced from Gr 23 ELI and Gr 5 Ti alloys are similar and there is no difference in the preference of these two Ti alloys.

3. When the chimney heights of Gr 4, Gr 5 and Gr 23 ELI Ti materials groups are compared within themselves, it is seen that the change in the chimney height has no significant effect on the fracture strength values.

4. When the fracture strength test data performed in vitro are evaluated, the lowest average fracture force is within clinically acceptable limits.

5. In our in vitro study, thermocyclus aging technique was not used due to our preference for titanium abutment. Since we only examined static loads in our thesis study, it is necessary to investigate the behavior of the materials compared because of dynamic loading.

6. When the fracture types that occurred in the fracture strength tests in the study were examined, it was determined that fractures occurred in the neck area of the ti-base and in the connection area with the implant. When this situation is evaluated, it is thought that the ti-base titanium strength is not sufficient in the mentioned areas. Therefore, it is recommended to change the material or production method to increase the ti-base strength.

7. When the relationship between connection strengths and Ti alloys was evaluated, it was observed that there was no difference between Ti alloys. However, when 3.5, 5 and 7 mm were compared, it was determined that the connection strength of monolithic zirconia crowns to ti-base abutments increased with the increase in chimney length height. This situation may lead to the desimantation of restorations with short ti-base abutments in single tooth deficiencies in the future.

Discussion

When the findings of our study were evaluated;

The hypothesis that the fracture strength values of the ti-base abutment-implant system produced from Gr 23 ELI titanium will be lower than the fracture strength values of the ti-base abutment-implant systems produced from other titanium types is rejected. The study groups using Gr 23 ELI titanium have similar success with the study groups using Gr 5 titanium.

The hypothesis that the change in Ti-base chimney length will not affect the bond strength values of monolithic zirconia crowns is rejected.

Monolithic zirconia restorations are preferred due to their high fracture resistance.[22] In the in vitro phase of our study, it was aimed to evaluate the fracture strength of abutment-implant systems with ti-base abutments of different shaft lengths and manufactured from different types of titanium. In our study, monolithic zirconia restorations were preferred, considering that early fractures of prosthetic restorations with lower fracture strength would make it difficult to evaluate implant-supported prosthetic systems in this respect.[23] To determine the load-bearing capacity of monolithic zirconia crowns and the amount of acceptable occlusal thickness, it was reported that the fracture strength of restorations increased as the occlusal thickness increased from 0.6 mm to 1.5 mm in monolithic zirconia crowns.

In a systematic review by Wittneben *et al.*[24], screw-retained and cement-retained restorations were compared in terms of survival, mechanical/technical complications, and biological complications. It was reported that the 5-year survival rates of cement and screw-retained restorations were similar and there was no significant difference in failure rates.

In the review, technical complications were statistically more common in cement-retained restorations; however, no significant difference was found between the two retainer types in terms of other technical complications such as abutment, substructure, implant, and abutment screw fracture. In the review, it was reported that biological complications such as fistula and suppuration were more common in cement retained restorations. As a result, it is understood that the type of attachment affects prosthetic success and biological complication rate, although it does not affect the implant survival rate. In addition, screw-retained prostheses can be easily removed during repair, surgical and restorative procedures. The delivery phase of screw-retained prostheses is shorter than cement-retained prostheses. After cementation, it is exceedingly difficult to clean the cement residues in areas where the gingival pocket depth is high. This may cause hard and soft tissue infections and consequently implant loss. When the given Ti-base materials are compared within themselves, there is no difference in the preference for the chimney height. Likewise, there is no difference between Gr 23 Ti ti-base abutments in the choice of 3.5, 5.5- and 7-mm chimney height. In line with this information, screw-retained implant-supported prosthetic design was preferred in our study.

Abutment material and design gain importance in implant-supported fixed prostheses made to meet the functional and aesthetic expectations of patients. The use of zirconia abutments is becoming widespread due to the disadvantageous properties of titanium material in areas with a thin gingival phenotype and in achieving restoration color matching. However, in one-piece zirconia abutments, wear occurs in the titanium implant body due to the hardness difference between the titanium implant body and the zirconia abutment.[25] To

solve this problem, a titanium platform called 'ti-base' was produced at the junction of the zirconia abutment with the implant body.[26] With the zirconia core processed on the titanium platform, it is aimed to eliminate the mechanical disadvantages of zirconia and the aesthetic disadvantages of titanium in the implant body. This design is called 'Hybrid Abutment'. In the study of Truninger *et al.*[27], in which they examined the flexural strength of one-piece zirconia and hybrid zirconia abutments, it was stated that titanium platform support contributed positively to the stability of the system[28] reported that the incompatibility of zirconia abutments with the implant body was 3-7 times higher than titanium abutments in their study in which they examined the compatibility of titanium and zirconia abutments in internal surface connections.[29] Reported that hybrid zirconia abutments exhibited higher fracture strength than monolithic zirconia abutments. In a study by Nouh *et al.*[30], it is reported that the fracture strength of hybrid zirconia abutments allows their use in the posterior region. Despite the advantageous features of hybrid abutments, the zirconia core structure prepared on a titanium platform requires an extra laboratory stage. In addition, new zirconia (BruxZir, Glidewell Laboratories, California, U.S.A.) materials with superior light transmittance and aesthetic properties make it possible to use monolithic zirconia crowns on a titanium platform without using a zirconia core structure.[31] In line with the given information, ti-base abutment and monolithic zirconia crown design were preferred in our study.

In the literature, blasting with Al_2O_3 is reported to be the most suitable surface treatment to increase the bond strength between resin cements and the zirconia surface.[43-45] In a systematic review by Gargari *et al.*[46], it was reported that the best procedure for cementation of zirconia restorations in terms of retention was the combination of sandblasting with 50 µm Al_2O_3 and MDP-containing resin cement. In our study, 50 µm Al_2O_3 sandblasting, and MDP-containing resin cement were used in accordance with the given information. It is known that the method of closing the abutment screw entryway before cementation of the restorations to the abutments can affect the retention. There is no clear opinion on whether the abutment screw entryway should be completely or partially closed or left empty. Koka *et al.*[47] reported in their study that complete closure of the screw entry path showed a higher retention value compared to no closure of the entry path. Kent *et al.*[48] examined the effect of partial closure of the screw entry path with autopolymerising resin on retention and reported that this method did not show a significant effect on retention. Analyzed the effect of sealing the screw entryway with 3 different methods on retention in their study. In the first group, the entryway was completely sealed with polyvinylsiloxane, in the second group it was partially sealed with polyvinylsiloxane, and in the third study group, part of the entryway was sealed with polyvinylsiloxane and the remaining part was sealed with composite resin. In the study, it was reported that the removal force was lower in the study group in which the screw entry path was completely closed. In our study, considering that filling the abutment screw entry path may affect the retention values, the abutment screw entry path was closed with Teflon tape. In this way, interaction between the material covering the screw entryway and the cement material was prevented.

After the chewing function, the wear structure in the occlusal region is realized as a surface area, not as a point. For this reason, the size of the fracture tip to be used in the studies gains importance.[50] The sizes of the fracture tips used in the literature vary between 2.65 mm and 6.35 mm. In our study, tests were carried out using a fracture bit with a diameter of 4 mm. In fracture strength tests, the high speed of the fracture bit to be loaded shortens the time required for the progression of microcracks. This situation increases the durability of the material and causes the results obtained to be inaccurate. Therefore, the loading speed should be as low as possible. According to ISO standards, an average loading rate of 1 ± 0.5 mm/min is recommended.[51] In the in vitro phase of this study, a compressive force was applied to the restorations in a direction perpendicular to the ground plane and with a fracture tip speed of 1 mm/min. In the literature, it is recommended to use specimens close to the crown structure instead of bar or disc form in the specimens to be used in fracture strength tests.[52,53] In our study, the restorations were designed in the form of a right first molar crown. To prevent the adverse conditions seen during the milling stage, pre-sintered zirconia blocks, which are preferred instead of fully sintered zirconia blocks.

In another study, it was reported that increasing the thickness of zirconia substructure from 0.5 mm to 2-2.5 mm increased the fracture strength of veneer crowns.[54] It is known that the type of abutment material also affects the fracture strength. In a study by Larsson *et al.*[55] comparing the fracture strength of zirconia and full ceramics, it was reported that the fracture strength values of the specimens cemented on titanium abutments were higher than the specimens cemented on natural teeth. examined the effect of cement types, restoration occlusal thickness, abutment lengths and material types on the fracture strength of implant-supported restorations and reported that the fracture values obtained from the study groups with titanium abutments were higher than those with zirconia abutments. In addition, it was reported that the fracture values obtained from the groups using adhesive cement were higher than the groups using non-adhesive cement.[57] Examined the fracture strengths of monolithic zirconia crowns fixed directly to the implant and monolithic zirconia crowns prepared on a ti-base abutment. In the study, monolithic zirconia crowns were milled from pre-sintered and fully sintered zirconia blocks and crown designs were planned as 2 separate subgroups. In 4 study groups, crowns were prepared in tooth form and fracture strengths analyzed. It was reported that ti-base supported monolithic zirconia crowns (453±25 (PSZ+Ti-base), 439±41 (FSZ+Ti-base)) showed higher fracture values than monolithic zirconia crowns fixed

directly to implants (259±23 (PSZ), 140±13 (FSZ), 290±39 52 (Procera)). In our study, it is thought that the use of titanium-containing ti-base abutments, the choice of monolithic zirconia crown design, the choice of occlusal thickness of 2 mm, the use of 50 µm Al_2O_3 sandblasting for surface treatment, and the use of MDP-containing adhesive resin cement in the cementation of the crowns to the ti-base abutments caused the fractures that occurred as a result of the fracture strength test to occur in the ti-base abutments.

Lower first molars, which are the first permanent teeth to erupt in natural dentition, constitute the basis of occlusion and mastication function. Factors such as early exposure of these teeth to caries attacks and the fact that fissure morphology is a crucial factor for caries cause these teeth to be the molars with the highest incidence of caries and tooth loss.[58]

In the studies conducted in the literature, the structures to which loading forces are applied vary. It has been observed that forces are applied directly to the implant body, on the abutment or on the crown structure.[59-63] Although there are differences in the literature in terms of the structure to which the force is applied, it is reported that applying the force on the crown restoration will yield more realistic results.[64] In accordance with the given information, the forces were applied on the crown structure. In the literature, it has been observed that some studies take the tubercle-marginal ridge relationship as the area where the force will be applied, some studies take the tubercle-fossa relationship as the basis, and some studies define the forces directly on the central fossa.[65-68] In our study, forces were defined on the marginal ridges in analyses with vertical loading. In oblique loading, the forces were defined to be applied on the marginal ridges of the buccal tubercles.

Conclusions

Our study was planned to realize monolithic zirconia fractures in the ti-base abutment-implant system. However, since monolithic zirconia fractures did not occur, it was decided to measure the failures in the ti-base neck region in our plan B. In all specimens, deformation of the neck region of the ti-base abutments occurred, and there were no specimens with monolithic zirconia crown fractures. No implant neck fracture was detected in all three groups. According to the data obtained, when the fracture types of the specimens with 3.5 mm ti-base chimney length were evaluated, 72.7% implant-abutment connection fractures were detected in all groups. When the fracture types of the specimens with 5.5 mm ti-base flue length were evaluated, 81.8% implant-abutment connection fractures were detected in Gr 23 ELI Ti study group, 90.9% in Gr 5 Ti study group and 81.8% in Gr 4 Ti study group. In the Gr 23 ELI Ti study group with 7 mm ti-base chimney length, 81.8% of implant-abutment connection fractures were detected.

The fracture strength values of the ti-base abutment groups produced from Gr 23 ELI and Gr 5 Ti alloys are similar and there is no difference in the preference of these two Ti alloys.

When the fracture strength test data performed in vitro are evaluated, the lowest average fracture force is within clinically acceptable limits.

Acknowledgment

None

Conflicts of Interest Statement

The authors declare that they have no competing interests.

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Table 1. Materials and Equipments

Monolithic Zirconia Block	Optima, Shenzhen Upcera Dental Co., Ltd., CHINA
Resin Cement	Theracem Bisco, Schaumburg, Il, U.S.A.
50 µm AL2O3 Sandblasting Material	Korox Bego Bremen, GERMANY
Sand Blasting Unit	Blasmate II, NEY, Yucapia, Ca, U.S.A.
Temporary crown acrylic	Imicryl, Imident, TURKIYE
Autopolymerizing acrylic	Meliodent, Heraeus Kulzer, GERMANY
Grade 4 implant	Estas Medikal A.S., Sivas, TURKIYE
Grade 5 implant	Estas Medikal A.S., Sivas, TURKIYE
Grade 23 implant	Estas Medikal A.S., Sivas, TURKIYE
CAD/CAM Device	7 Series, Dental Wings, Montreal, CANADA
CAD/CAM Cihazı	D30, Yena Dent, Istanbul, TURKIYE
Sinterization unit	160/1, Protherm Mos, Ankara, TURKIYE
Strength test unit	Lr30 K; Lloyd Istruments Ltd, Farnham, ENGLAND
Strength test analysis program	Nxygen Plus

Table 2. Fracture Locations According to Ti-base Chimney Length and Titanium Type for the Study Groups

Titanium Type	Ti-base Chimney Length	Ti-base Neck Fracture	Implant-Abutment Connection Fracture
Grade 5	3.5	3	8
Grade 5	5.5	1	10
Grade 4	3.5	3	8
Grade 4	5.5	2	9
Grade 23 ELI	3.5	3	8
Grade 23 ELI	5.5	2	9
Grade 23 ELI	7	2	9

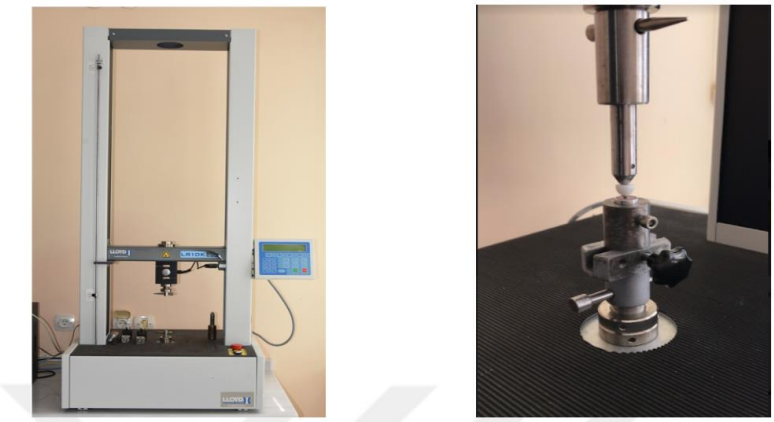


Figure 1. Universal Test Device (A) and Fracture Test (B)

Figure 2. Dimensional Jaw Models

Figure 3. Crown Design (Buccal) (A) and Crown Design (Apical) (B)

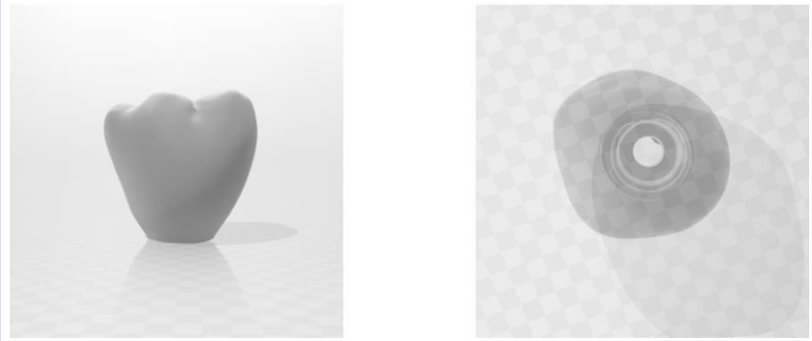


Figure 4. Zirconia Disc (A) and Zirconia Disc (B)

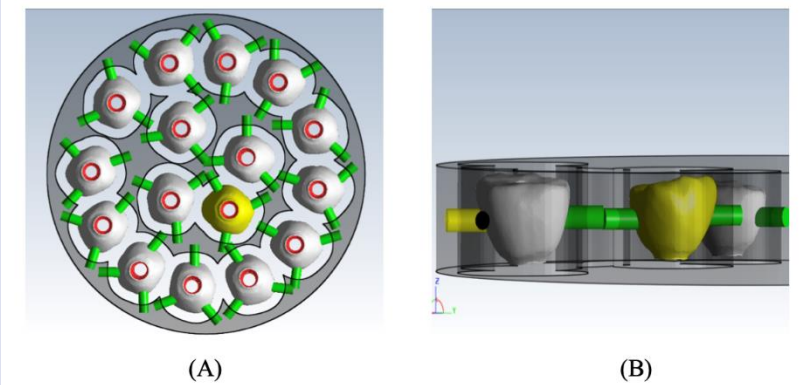
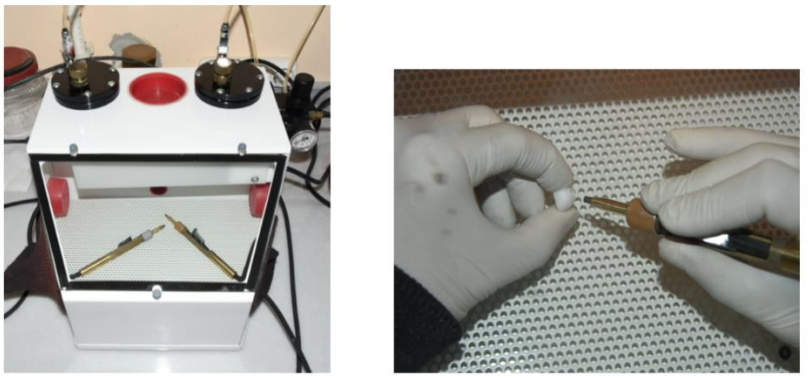


Figure 5. Zirconia Disc (A) and Zirconia Disc (B)

(A) (B)

Figure 6. Zirconia Crowns

Figure 7. Shot Blasting Device (A) and Shot Blasting Process (B)



(A) (B)

Figure 8. Resin Cement Material (A) and Polymerization of Resin Cement (B)

Figure 9. Autopolymerising Acrylic Resin (A) and Torquing process (B)

Figure 10. Graph of Fracture Strength According to Implant Material and Ti-Base Chimney Length

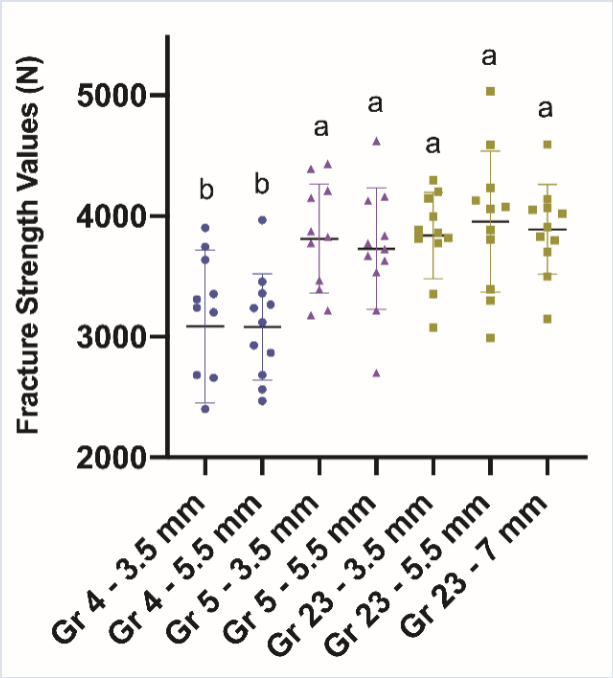


Figure 11.

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Light in the Horizon: A Perspective on Photodynamic Therapy

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Review

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ABSTRACT

Dental treatment, in general, has been associated with fear and anxiety. The prospect of undergoing a painful experience compels many prospective patients to postpone his/her dental appointment. A previous occurrence of the distressful event has often left patients traumatized. Repeated visits for follow-up treatments also serve as a deterrent for seeking dental consultation. Alternative methods need exploration to mitigate such inconveniences.

Photodynamic therapy is emerging as an extension of dental therapeutic options with the benefits of improved treatment outcomes and patient acceptability. The present narrative review explores its applications in general dentistry and highlights its potential in the periodontal discipline.

Being minimally invasive, it offers promise in pain-free management of dental conditions, particularly infections. It has relevance in managing oral mucosal lesions, periodontitis, and dental caries. Current evidence suggests photodynamic therapy as an adjuvant to contemporary measures of dental rehabilitation.

Key words: Dental Caries, Lasers, Mouth Mucosa, Photodynamic Therapy, Periodontitis.

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Introduction

Periodontal disease is a chronic ailment affecting the tissues investing and supporting the dentition, leading to its progressive loss, with possible loss of teeth, related functions, and disfigurement. The disease is often attributed to the persistence of a sub-gingival biofilm on the tooth surfaces, harbouring numerous bacterial colonies, some commensal, some pathogenic and others opportunistic. This disruption of the local homeostatic balance unzips the tooth-soft tissue attachment creating a morbid pocket environment, favouring the colonization of several pathogenic bacterial species, most notably, *Fusobacterium nucleatum, Aggregatibacter actinomycetemcomitans, Porphyromonas gingivalis, Prevotella intermedia* and *Tannerella forsythia*.[1] Consequently, features of periodontal breakdown ensue, such as gingival bleeding, exudation, loss of clinical attachment, root exposure, abscess formation and, in extreme cases, tooth exfoliation.

Periodontal treatment involves supra and subgingival tooth debridement, chemical lavage/irrigation solutions, and antimicrobial mouth rinses. Often, adjunctive systemically or locally delivered antimicrobials are also provided. Alternatively, resective or regenerative periodontal therapy focuses on altering the affected bone morphology and eliminating niches of microbial repopulation through surgical means, wherever warranted. Therefore, reducing the levels of these pathogenic bacteria is critical to improving periodontal health with these conventional strategies. However, uneven tooth morphology in furcation areas or root concavities often limits effective instrumentation. Likewise, the possibility of rising antibiotic resistance hinders widespread and frequent use of anti-infective therapy.

A low-intensity laser-based photodynamic treatment (PDT) is currently advocated for different therapeutic procedures in dentistry and medicine. This treatment modality directs light of a specific wavelength to the site of concern, where a previously applied photosensitizing agent is applied. Light activation of this agent generates free radicals and singlet oxygen, which would interact with bacteria and intracellular molecules that uptake the photosensitizer in surrounding tissues, obliterating them. Singlet oxygen produced in PDT appears to significantly induce tissue damage, with a 100 nm diffusion distance and half-life <0.04 µs.[2] Therefore, only cells in the vicinity are affected, without harming distant cells, suggesting the localized effect of PDT.

The concept of 'Photodynamic therapy' has evolved, spanning applications across various fields of dentistry, and aptly termed 'photo-activated disinfection.' Other synonymous terms include photodynamic disinfection, photodynamic antimicrobial chemotherapy (PACT) and light-activated disinfection (LAD).[3]

PDT detects premalignant oral lesions finding a place in treating oral cancer, and bacterial and fungal infections.[4] Other indications include actinic keratosis, severe lip

dysplasia due to nicotine abuse, psoriasis, Bowen's disease, Paget's disease, Kaposi's sarcoma, HIV-associated molluscum contagiosum and basal cell carcinoma.[5] PDT benefits cutaneous vascular malformations and patchy alopecia areata with excellent cosmetic results. It is proposed as an antimicrobial intervention for periodontitis due to its effects on microbial flora. The review examines photodynamic therapy, a new dimension in managing dental maladies. Further, the role of this emerging alternate therapy in periodontal treatment is discussed.

Principles of functioning of PDT

PDT involves photosensitizers triggered by a source of light.

Photosensitizer

The photosensitizer can be a dye or chemical that absorbs specific wavelengths of light energy and passes it on to nearby molecules. Hematoporphyrin derivatives have been the first generation of photosensitizers. Porphyrin-based dyes (like Photofrin) have a characteristic tetrapyrrole ring structure, termed porphyrin. Others include chlorophyll-based photosensitizers, such as chlorins and bacteriochlorins, having reduced double bonds, while dyes like phthalocyanines and naphthalocyanines have an extended ring structure. A Soret band around 400 nm and 500 – 600 nm characterizes these photosensitizers.[6]

Subsequent second-generation photosensitizers or benzoporphyrin derivatives (with absorption at 650 to 800 nm) have good tissue penetration.[7] Examples include 5-aminolevulinic acid and Focsan. However, caution must be exercised during use as even minimal lighting can lead to severe skin photosensitivity and pain during therapy.

Methyl aminolevulinate (Metvix) 5-aminolevulinic acid (ALA or Levulan) and Porfimer sodium (Photofrin) are Food and Drug Administration (FDA) approved photosensitizers.

Modifying the existing dyes by conjugating proteins, receptors or antibodies with radioactive tags or nanoparticles allowed the evolution of a successive generation of photosensitizers with the advantage of fluorescence, which helps in the detection of malignancy due to uptake by affected cells.[8]

Acridine orange, proflavine, riboflavin, fluorescein and erythrosine are another group of tricyclic dye photosensitizers. Another distinct variety is Psoralen and its derivatives (xanthotoxin, bergaptene) belonging to the furocoumarin group.[9]

Periodontal therapy employs phenothiazinium dyes (toluidine blue, methylene blue) to lower bacterial and fungal species. Curcumin is another agent used for PDT in dentistry.[10] Erythrosine and malachite green, used to disclose dental plaque, are photosensitizers.

Other photosensitizers with potential include chloro-aluminium phthalocyanine (AlClPc), methyl aminolevulinate, and poly-L-lysine-chlorine conjugates.[11, 12] Other photosensitizing agents used in periodontal therapy are phenothiazinium chloride and indocyanine green. Antimicrobials like tetracyclines show a photosensitizer effect by producing singlet oxygen.

Methylene blue, with an absorption peak at 670 nm (dark red), has effective light penetration, permitting access to deeper infection sites. Apart from its routine use as a marker dye, it has a role in detecting premalignant lesions. Therapeutically, it is safe for local application, as evident in PDT of bladder and oesophageal cancers. Anti-infective uses were demonstrated against *H. pylori* in the rat gastric mucosa and *Aggregatibacter actinomycetemcomitans* in dental biofilms.[13]

While light activation is unnecessary for Toluidine blue (Tolonium chloride or TBO), effective bacteria elimination occurs with concomitant exposure to a 630 nm laser. Hence, toluidine blue and methylene blue are appropriate for endodontic infections with diverse bacteria.[10]

The FDA has also permitted the use of the anionic, hydrophilic, and lipophilic 'indocyanine green' (ICG). ICG can be used in subgingival regions with anaerobic conditions, particularly in reducing *Porphyromonas gingivalis* and *Aggregatibacter actinomycetemcomitans,* leaving less than 10% viable bacteria. With absorption around 800-810 nm, it is similar to Diode laser wavelengths, suggesting the combination to be synergistic in reducing periodontal pocket bacteria.[14] While visible light sources activate toluidine blue, methylene blue and malachite green, indocyanine green activates with near-infrared light.

Specific oral, black-pigmented bacteria have natural photosensitizers (protoporphyrin IX), making them amenable to PDT. Light in the range of 380 to 520 nm wavelength diminished *P. gingivalis P.intermedia, P. nigrescens,* and *P. melaninogenica* growth by almost three times within dental plaque.[15] Visible light used as PDT may have similar effects.[16]

Another photosensitizer proposed is curcumin, which has antimicrobial properties and is hydrophobic. It can absorb blue light and produce reactive oxygen species. It has peak absorption at 430 nm. Further, when exposed to blue light, riboflavin, a vitamin B2 supplement, is also considered a biocompatible photosensitizer, which does not discolour the teeth like toluidine blue.[17]

Light Source

PDT uses either noncoherent or coherent laser light as a source of activation.[18] Noncoherent light sources include lamps with a tungsten filament, sodium pump, quartz halogen, and metal halide, providing diverse wavelength spectra. However, neither the dose of light delivered can be controlled nor the associated thermal effects are lessened. Recent LED light sources are attractive as they can be custom-assembled to produce light of desired wavelengths.

Laser light, in contrast, is a coherent source of energy of a specific wavelength only delivered to target sites over optic fibre cables and through lenses customized to achieve homogenous illumination. For PDT, laser light wavelengths of 633 nm (Helium-neon), 630–690/ 830/ 906 nm (gallium-aluminium-arsenide), and 488–514 nm (argon) are often employed.[19] Diode lasers offer advantages in ease of use and portability and are therefore preferred.

Certain factors affect the effectiveness of PDT after the photosensitizer has been applied and light directed at the treatment site. Fluence (radiant energy), light wavelength (long/short) and the availability of oxygen, the molar extinction coefficient of the photosensitizer,

photosensitizer concentration, type, location of the photosensitizer and incubation time are some of these determinants.[20] Long wavelengths of light have a deeper penetration. The presence of adequate amounts of dye ensures effective antibacterial action. Red light (630-700 nm) is adequate for most photosensitizers, achieving a light penetration depth of 0.5 – 1.5cm. This distance defines the therapeutic effect, usually via cell death resulting from autophagy, apoptosis, or cellular necrosis.

General applications of PDT

PDT initially found scope in treating viral lesions like herpes keratitis and genital herpes (PDT using methylene blue/neutral red), although recurrence could not be prevented. It is also used to manage HPV-related lesions like epidermodysplasia verruciformis, papillomatosis and warts. Hematoporphyrin ester activated by a 630 nm laser improved cervical intraepithelial neoplasia and eradicated HPV.[21]

Skin lesions have been the primary focus of PDT, with a substantial role in treating lesions such as wrinkles, rosacea, hidradenitis suppurativa, actinic keratosis, non-melanoma skin cancer, and psoriasis. In actinic keratosis, a 20% topical solution of Aminolevulinic (Levulan ®, DUSA Pharmaceuticals, Inc., Wilmington, MA 01887, USA) is applied for 14–18 hours, followed by blue light illumination (417–432 nm) of the target lesions. Acne, leishmaniasis and fungal skin infections have also been treated with ALA–PDT. Indocyanine green dye and chlorophyll are other photosensitizers used for acne.[22, 23] Rosacea, erythrasma, tinea pedis, tinea cruris, toenail onychomycosis, Malassezia folliculitis, and Pityriasis versicolor have all shown improvement with PDT.[24]

Ophthalmologic conditions requiring PDT include macular degeneration and pathologic myopia. Verteporfin (trade name Visudyne®, CHEPLAPHARM Arzneimittel GmbH, Ziegelhof 23-24, 17489 Greifswald, Germany) has been reported as the accompanying photosensitizer administered intravenously.

Porfimer sodium, a hematoporphyrin derivative, is commonly used in oncology to treat lung cancer (non-small cell) and oesophageal pre-cancer and cancer. Another potent photosensitizer is temoporfin (brand name Foscan® (biolitec Pharma Ltd., Otto-Schott-Str. 15, 07745 Jena, Germany), which is required in small doses (0.1 mg/kg body weight) with low doses of light energy (10 J/cm^2). These photosensitizers selectively accumulate in tumour regions, allowing cell and tumour apoptosis during PDT. Gross oedema and erythema are the first clinical signs of PDT response.[25]

Deep tissue abscesses are polymicrobial infections where prolonged antibiotic use may result in the development of resistance. Hence, photodynamic therapy can be an option as it is effective against many microorganisms.

Acinetobacter baumannii infections and *Pseudomonas aeruginosa* are important pathogens posing a life-threatening risk in burn patients. Photodynamic therapy can be effective against these bacteria with fewer side effects without posing a risk of drug resistance.[26]

Diagnosis and treatment of dental disease

i. Oral premalignant lesions

PDT causes superficial necrosis of the oral mucosa, with minimal scarring and no toxicity, when using 5-ALA for treating oral leukoplakia. Maloth *et al.* (2016) compared PDT outcomes in oral leukoplakia and lichen planus lesions. They used blue light LED (420 nm) with 5-ALA to provide around 500 mW/cm^2 intensity to a spot size of 1 cm^2 for 10 mins over lesions and surrounding tissue. In cases of oral leukoplakia, 16.6% showed complete response, with 66.6% showing partial response. Similarly, in oral lichen planus cases, 80 % of cases showed partial response. Therefore, PDT promises to be an option for premalignant lesions.[27]

ii. Oral candidiasis

In a study by Scwingel (2005) on HIV-infected patients, PDT for ten seconds [660 nm, 30 mW power, 7.5 J/cm^2 fluence, in contact mode] eradicated 100% of candidiasis colonies with no recurrence when observed for a month. The comparator, Fluconazole, could not prevent the recurrence of candidiasis.[28] Fungal infections in the oral cavity requiring PDT use toluidine blue, porphyrins, and methylene blue as photosensitizers and 455 nm–660 nm diode lasers.[29]

Carmello *et al.* (2016) found PDT with red LED light at 660 nm and photodithazine® as effective as nystatin treatment for treating oral candidiasis in a study on female mice.[30] Using 660 nm red light with InGaAIP laser inactivated oral Candida from those with children and without almost comparably, with methylene blue photosensitizer.[31]

iii. Restorative dentistry

Antibiofilm effect:

Bacterial elimination within carious lesions can be achieved non-invasively with PDT. In an animal study, samples of *S. mutans* were observed at various intervals before and after photosensitization with methylene blue (100 µM for 5 min). Bacterial counts were notably lower than in controls treated without PDT.[32]

Photodynamic treatment with erythrosine resulted in bacterial cell death in *S. mutans* biofilms *in vitro*.[33] Similarly, red light and Toluidine blue significantly reduced cariogenic bacteria within dentine caries.[34]

Nassaj *et al.* (2020) suggested using PDT with indocyanine green to manage micro-leakage in composite restorations. It could disinfect cavities within enamel and cementum by decreasing the microbial load and preventing secondary caries.[35]

Endodontics:

Photodynamic treatment synergizes with the antimicrobial intra-canal cleaning and shaping in conventional endodontics to kill microorganisms in root canals, which is particularly relevant in single-session endodontic therapy. There are reports of toluidine blue with red light and urea peroxide for sterilization of root canals of deciduous teeth. The instrumentation alone reduced viable bacteria by 82.59%, while using PDT resulted in a 98.37% decrease in bacterial load.[36] Bonsor *et al.* (2006) found PDT to be as efficacious as the combination of NaOCl and citric acid irrigation after root canal

biomechanical preparation.[37] Similarly, Borba *et al.,* (2017) observed that LED with erythrosine eliminated almost all planktonic forms of *Enterococcus faecalis*.[38]

Contradictory reports state no significant additional effect of PDT on chemo-mechanical preparation in reducing bacterial counts due to low oxygen concentration within the root canal irregularities, dentinal tubules, or bacterial biofilms on the canal walls. Complete photosensitizer permeation into the root canals is uncertain and may diminish the outcome of root canal treatment. Some reports suggest that 17% EDTA irrigation before PDT overcomes this limitation.[39]

Factors considered critical for intra-canal microbial killing using PDT include the energy and time of irradiation. Pourhajibagher & Bahador (2018) utilized a 635 nm wavelength laser for 60 s at a power of 220 mW to obtain a significantly diminished microbial count.[40] Therefore, sufficient time for photosensitizer uptake by the microorganism is necessary to achieve either cell wall damage or nucleic acid breaks.[41]

Periapical surgery:

PDT had shown accelerated healing of periradicular lesions in the maxillary incisors when PDT was used along with methylene blue. It is opined that red laser light enhances bone repair.[42]

Peri-apical cysts:

Conventional root canal therapy is ineffective in managing periapical cysts. Hasna *et al.* (2019) report on administering root canals with methylene blue for 5 min and irradiation with a 660 nm red laser at 100 mW/cm^2 for 2 minutes, allowing approximately 120.0 J/cm^2 of energy density into each canal. Subsequently, Ca $(OH)_2$ paste is placed into the root canals with laser radiation repeated twice weekly for 45 days. They suggested that this combination strategy caused remission of clinical signs and symptoms, with evidence of bone repair, thus averting the need for surgical therapy.[43] Similarly, the strategy may effectively manage alveolar osteitis and pain related to the extraction.

iv. Pediatric Dentistry

Conservation of deciduous teeth with pulpal involvement is challenging. In this context, antimicrobial photodynamic therapy promises to eliminate persistent microorganisms following chemo-mechanical preparation.

Methylene blue with papain has been used to treat deep caries in a primary tooth, along with caries excavation, and 660 nm red laser PDT with 30 J of energy and 100 mW power for 5 mins before restoring it with glass ionomer. Using the photosensitizer prevented pulp exposure and preserved tooth structure.[44]

Pourhajibagher & Bahador (2018) noted decreased microbial counts within infected root canals of primary teeth when PDT was used with toluidine blue.[45] Barbosa *et al.* (2014) suggested the use of methylene blue for root canal decontamination (50 μg/mL for 3–5 minutes; energy density 40 J/cm^2), with the benefit of reduced treatment time in children using lasers.[46]

Anand *et al.* (2020) observed that PDT for pulp therapy in deciduous molars obtained similar results to sodium hypochlorite and clotrimazole disinfection, with comparable postoperative *C. albicans* colony-forming units.[47]

v. Oral surgery

Camilo-Silva *et al.* (2021) report PDT used for treating alveolar osteitis. Curettage of the alveolus was done under local anaesthesia. Next, methylene blue photosensitizer was syringed into the alveolus for 5 mins. Then, laser light of 660 nm was irradiated with a 321 J/cm^2 dose for 90 seconds (100 mW power, radiance energy 9 J, spot area 0.028 cm^2) and repeated after seven days. Closure of the alveolus with no inflammation was noted within fifteen days.[48]

Sarkarat *et al*. (2019) demonstrated that PDT assisted subsidence of symptoms related to bisphosphonate-related osteonecrosis of jaws (BRONJ). Twenty rats received zoledronic acid for five weeks and then underwent extraction. The PDT-treated group showed decreased bone exposure and clinical inflammation, and a higher percentage of healthy bone with neovascularization histologically compared to controls.[49]

Almeida *et al.* (2021) used adjunctive PDT in the management of bilateral medication-related osteonecrosis of the jaw (MRONJ) in the tuberosity of a breast cancer patient on zoledronic acid. The laser device (gaAIAs and InGaAIP) used continuous wave mode with 100 mW power settings and 0.03 cm^2 spot size. The injury site received a red wavelength (660 nm), emitted for 90 seconds, providing 9 J of energy, with a methylene blue gel photosensitizer. About twelve PDT sessions, with 48-hour intervals, facilitated reducing the symptoms and resolution of the lesion.[50]

vi. Periodontal therapy

PDT has relevance in managing periodontal disease, particularly in the initial phase and during recall maintenance. A decreased oxygen tension and pH alteration during inflammatory soft tissue changes allow the flourishing of anaerobic bacteria within the periodontal pocket. Photodynamic treatment improves tissue vascularity and oxygen perfusion to enable the resolution of inflammatory changes. Furthermore, it is effective as adjunctive antimicrobial therapy or Photodynamic antimicrobial chemotherapy (PACT). Using photosensitizers reduces and allows the localization of action within disease sites. Low levels of laser energy enable hemostasis, minimizing perceived pain and enhancing healing.

PDT and periodontal clinical parameters

PDT preserves cementum by reducing the need for aggressive root planing, thus enhancing tissue attachment to root surfaces and deterring hypersensitivity.[51] The antibacterial effects of PDT have a bearing on those who are immunosuppressed or show antibiotic resistance.

Braun *et al.* (2008) observed toluidine blue with PDT (670 nm laser, 100 mW/cm^2) to significantly improve the outcome of subgingival debridement.[52] A considerable diminishing of gingival bleeding after probing has also been noted in periodontal sites treated with PDT versus scaling and root planing (SRP).[53] Photodynamic therapy concomitant to SRP resulted in reduced probing depths and

better attachment gain up to twelve months compared to conventional nonsurgical treatment in another study.[54]

Clinical parameters such as the plaque index, gingival index, probing pocket depth, and clinical attachment loss were noted to improve with PDT. Similarly, microbiologic parameters were better in the group treated with scaling and root planing compared with SRP alone, with a single session of PDT in a study by Raj *et al* (2016).[55]

Malgikar *et al.* (2016) treated chronic periodontitis with a 980 nm Diode laser, methylene blue photosensitizer, and LLT. They observed reduced gingival bleeding and pocket depths with improved clinical attachment in the SRP, PDT, and low-level laser treatment groups compared to SRP and PDT combined and SRP alone.[56]

Martins *et al.* 2017 noted significant pocket depth reduction and greater elimination of the red complex periodontal pathogens with a single application of Diode laser and phenothiazine at three months post-surgery.[57]

Shignapurkar *et al.* (2017) used an 810 nm laser with indocyanine green as a photosensitizer. The combination significantly improved probing depth and relative attachment levels at three months compared to scaling and root planing alone.[58]

Similarly, Sethi *et al.* (2019) showed a reduction in clinical parameters in thirty subjects treated with scaling and root planing along with PDT compared with SRP as a monotherapy, when indocyanine green was used as the photosensitizer along with 810 nm Diode laser. They also observed a reduction of bacterial colonies within the pockets.[59]

Sgolastra *et al*., however, in a meta-analysis, suggest only short-term benefits occur, like reduced pocket depths and gain in clinical attachment with PDT when used in addition to conventional periodontal treatment.[60] A systematic review by Chambrone *et al.* (2018) suggests PDT provides a significant reduction in probing depth and attachment loss unlike conventional periodontitis and peri-implantitis treatment protocols.[61] Meimandi *et al.*[62] (2017) surmised from a review that multiple sessions of PDT would be more beneficial than a single PDT session. In the meta-analysis by Azaripour *et al.*[63] (2018), PDT adjunctive to scaling/root planing results in 0.21 mm probing depth reduction and 0.36 mm gain in attachment by three months itself unlike that achieved conventionally by around six months.

Yet contrasting reports suggest beneficial effects in terms of bleeding on probing only with no changes in the probing depth or attachment levels when photodynamic therapy is used as an adjunct to scaling and root planing.[64] Azarpazhooh *et al.*[65] (2010), in their systemic review, opined no superiority of PDT alone to the nonsurgical phase of periodontal therapy.

When smokers with chronic periodontitis received phase 1 periodontal debridement with or without a single session of antimicrobial photodynamic therapy (phenothiazine photosensitizer), the observed clinical probing depth and attachment improvement seen within the groups did not extrapolate to between-group comparisons. A slight benefit was perceived with suppression of GCF IL-1beta and IL-8 in the PDT group.[66]

Therefore, antimicrobial PDT shows clinical benefits in the short term. Presently, there needs to be more consistency in the results of long-term evaluations. Nevertheless, PDT may be an option for those who do not prefer extended periodontal surgical procedures.

PDT and periodontal microbes

Periodontal pathogens within a biofilm are vulnerable to PDT with photosensitizers like methylene blue, indocyanine-green, phthalocyanine, safranine O, toluidine blue and hematoporphyrin.[67] Laser wavelengths ranging from 380 nm-520 nm can inhibit the growth of dental plaque bacteria by almost threefold, including *Porphyromonas gingivalis*, *P. intermedia*, *Prevotella melaninogenica* and *P. nigrescens.* While PDT killed 63% of bacteria in planktonic conditions, this effect reduced the plaque biofilm to 31%, attributed to the protective phenotype observed with tooth attachment.[16]

Dental plaque biofilm treated with photosensitizer and PDT are relatively thin and less dense, with fewer channels. Such biofilms showed bacterial membrane damage and cytoplasmic vacuoles after PDT.[68]

Light wavelength and energy density can influence the extent of bactericidal activity. Diode lasers at 665 nm and 830 nm using methylene blue photosensitizer carrying an energy density of 21.2 J/cm^2 almost eliminated black-pigmented bacteria (*P. gingivalis* and *P. intermedia*) and *S. sanguis,* and 95% of *A. actinomycetemcomitans* and *F. nucleatum.*[69]

Pinheiro *et al.* 2009 observed that 81.24% of bacteria within periodontal pockets reduce after scaling compared to 95.90% with adjunctive photodynamic therapy (Diode laser energy of 4 J/cm^2 for 3 mins). Therefore, photodynamic therapy proved effective clinically in affecting viable bacterial counts.[70] However, another study showed that treatment with PDT resulted in 80.11% and 91.37% bacterial count reduction after one month and three months.[52]

A systematic review by Akram *et al.* (2016) evaluated seventeen clinical studies with wavelengths ranging from 470 – 810 nm. Follow-up visits in these studies showed reduced microbial counts with PDT.[71]

Another study compared antimicrobial PDT and locally placed minocycline microspheres in deep periodontal pockets. Although clinical and microbiological parameters improved from the pretreatment status, no additional influence of either PDT or minocycline was apparent compared to SRP alone.[72] Furthermore, photosensitizer application may not be required in all instances, as several oral bacteria naturally possess photosensitizer.[16]

PDT and periodontal structure

A 70 ^{0}C increase in the temperature of periodontal tissues defines the threshold limit to avoid periodontal tissue damage.[73] Further, the light dosage intended for bacterial killing does not induce host cell photo-cytotoxicity as the dose falls below the toxicity of fibroblasts and keratinocyte cells.[74]

Qiao *et al*. (2014) showed PDT (Diode 675 nm, Pmax = 280 mW) produced no cytotoxicity on the human periodontal ligament and gingival fibroblast cells. It was observed to stimulate fibroblast proliferation, attachment, and collagen synthesis. Similarly, stimulative action on alkaline phosphatase activity of periodontal ligament cells was noted.[75]

Interestingly, Kashef *et al.* (2012) observed that exposure to a Diode laser (660 nm, 35 mW, 163.8 J/cm^2) and methylene blue reduced human fibroblast mitochondrial activity by 27%, while the absence of photosensitizer showed no significant cytotoxicity. Similarly, a 630 nm Diode laser exposure (46.8 J/cm^2 for 24 h) with toluidine blue photosensitizer resulted in the inactivation of 39.6% of the fibroblasts, unlike PDT without toluidine blue.[74] However, curcumin as a photosensitizer showed no cytotoxicity or inhibition of fibroblast viability during PDT.[76]

Red light (665 nm, 20 or 40 mW/cm^2, five minutes duration) with methylene blue photosensitizer showed moderate effects on osteoclasts, and no apoptosis was evident at 24 hours in a study by Xu *et al.*[77] (2009).

PDT, combined with low-level laser therapy (LLLT), manifested less bone loss in experimentally induced furcations compared to only LLLT or methylene blue photosensitizer in a study on rat models by de Almeida *et al.* 2008.[78] Hence PDT application can promote the healing of tissues following treatment.

PDT and Aggressive Periodontitis

Chatzopoulos *et al*.[79] (2016) opine that for effectively treating aggressive periodontitis, repeat sessions of PDT application along with nonsurgical treatment would be necessary. A study comparing clinical outcomes of PDT (690 nm laser, phenothiazine photosensitizer) vs SRP in ten aggressive periodontitis cases inferred similar efficacy of the two treatment modalities.[80]

PDT and Peri-implantitis

Peri-implantitis management warrants decontaminating the dental implant surface, often with mechanical methods or antimicrobial irrigation using chlorhexidine or hydrogen peroxide. PDT can also be combined with surgical exposure of the implant site to decontaminate the implant surface.[81]

Laser treatment of implant surfaces increases the temperature of the implant surface, regardless of whether photosensitizer is used or not. Nevertheless, this raised temperature is less than 4.3 ^{0}C. Therefore, tissues surrounding the implant are relatively safe during peri-implantitis treatment.[82]

According to Shibli *et al.* (2003), PDT reduced *Streptococcus beta hemolyticus, Fusobacterium* and *Prevotella* counts in most peri-implantitis samples. Azulene is an effective photosensitizer for microbial inhibition at peri-implantitis sites, with no staining of the adjacent soft tissues and implant surfaces.[83]

PDT with CO_2 laser around 'ailing' implants is reported as being more effective than conventional methods. Using 810 or 980 nm Diode laser wavelengths to decontaminate implant surfaces was effective, without any dramatic temperature increase.[84]

Pourhajibagher *et al.* (2020) found a reduction in bacterial counts by using 'photo-sonodynamic antimicrobial chemotherapy' (810 nm Diode laser) using an indocyanine-green photosensitizer with a nanoparticulate form of chitosan.[85]

According to a systematic review, adjunctive antimicrobial photodynamic therapy has benefits in reducing pocket depth and clinical bleeding on probing akin to established peri-implant treatment.[86]

PDT & healing of periodontal tissues

In an animal study, less alveolar bone loss with reduced cytokine production was evident with Toluidine-blue mediated-PDT [650 nm Diode] for four weeks.[87] PDT also tended to improve bleeding on probing with treatment. Further, enhanced gene expression of fibroblast growth factor (FGF2), receptor activator of nuclear factor-kappa B (RANK), and osteoprotegerin (OPG), was observed in biopsy samples, thus mitigating osteoclastogenesis and promoting periodontal repair.[88]

Procedure

Phase 1 debridement usually precedes photodynamic therapy. The periodontal pocket is flushed with a photosensitizer, allowing pigment uptake for one minute before laser radiation. This is followed by navigation of the laser tip into the pocket with exposure to an appropriate laser wavelength. The laser fibre is moved laterally within the pocket and drawn coronally upwards and out of the gingiva.

Similarly, for disinfection of root canals, after biomechanical preparation, photosensitizer irrigation allows contact with the bacterial biofilm. The laser tip is then introduced into the canal and irradiated for 30 seconds.

PDT guidelines have been given for oral mucosal application, such as in leukoplakia. PDT is advised to be carried out in a dark room or a strict light-proof environment. The site to be treated must be isolated from saliva. A cotton swab soaked with the photosensitizer solution is gently placed over the lesion. A starch film is placed over the cotton swab to improve the adhesion of the photosensitizer to the oral mucosa. Finally, the site is layered with a cling film and gauze to protect the photosensitizer from saliva and incubated for 2-3 hours.

After removing the swab, the site is tested by UV light (wavelength, 370–470 nm). The patient then rinses off the excess photosensitizer. Local anesthesia (2% lidocaine or 4% primacaine) is administered. The patient, clinician and assistant should wear safety goggles before laser irradiation. Laser power settings may be performed according to the literature. A power of 100 mW/cm^2 is recommended at 630 nm for 3 mins followed by 3 mins of rest. The laser beam is directed perpendicular to the surface of the lesion with an optimal distance between the end of the optical fibre and the surface of the lesion. Lasing can be repeated once in 2-3 weeks. Exposure of the treated site to light should be avoided for the next 48 hours. Irritable foods may be avoided during this period. Topical

0.01% dexamethasone paste and 0.1% chlorhexidine mouth rinse can be prescribed to reduce associated inflammation. The lesion should be treated once every 2–3 weeks, depending on the healing of the lesion.[89]

Advantages of PDT

As PDT is delivered to the target area through fiberoptic cables, where it provides concentrated light energy, it is safe for the healthy tissues nearby. Further, it does not require local anaesthesia. Unlike the usual antimicrobial regimen, the procedure eliminates bacteria quickly, with no added systemic toxicity. It is of particular benefit in areas difficult – to – access with mechanical instrumentation around the teeth, dental implants, and pockets like furcations and root concavities. There is no risk of bacteremia as well. The effects of nonsurgical therapy are hastened while precluding the need for root planing. It is a valuable tool during the maintenance recall phase, as biofilm removal in deep pockets can be achieved non-intrusively. It is a safer approach for systemically compromised patients and the geriatric population.

The Limitations of PDT

PDT may sometimes induce side effects like erythema, burns, oedema, and desquamation. Further, laser-induced tissue damage or nerve stimulation can result in pain. Rare instances of urticaria, contact dermatitis, erosive pustular dermatosis, and squamous cell carcinoma have been observed during skin lesion treatment. Some reports also suggest that PDT causes DNA alterations. Photophobia, scars, allergic reactions, sensitivity to sun exposure and hyperpigmentation/hypopigmentation are other unwanted effects of PDT. Thermal injury due to increased temperature changes within tissues can cause irreversible damage to the gingival tissues, root surface [with attachment loss], dentin, pulp, and bone. The type of bacterial species present, the dosage of photosensitizer and laser light parameters such as depth of penetration may impact the effectiveness of PDT. [90]

Methylene blue can stain the teeth. Extending the irradiation time beyond five minutes allows deep penetration of the photosensitizer almost to the enamel–dentine interface.[91] Often irrigants, bleaching agents (2.5% NaOCl), solvents, photosensitizer efflux pump inhibitors, chitosan nanoparticles and ultrasonics have been used to remove this discolouration.[92] Methylene blue, a non-porphyrin dye, has inherent cytotoxicity by methylation and localizes intracellularly in the cytoplasm targeting the nucleus and mitochondria, promoting apoptosis. When used for clinical indications other than PDT, it has been shown to lead to blue-green discoloration of urine. It is advised to use caution when using methylene blue along with serotonergic drugs and in those with renal failure. It is known to cause central nervous system-related symptoms like dizziness and headaches. It is contraindicated in those with hypersensitivity to it, those with glucose-6-phosphate dehydrogenase deficiency and in pregnant women.[93]

Most photosensitizer dyes are also insoluble, hydrophobic and aggregate at sites increasing the chances of complications. [94] Photosensitizers like Photofrin® can accumulate not solely at target sites but in other distant organs, such as the liver, kidney, and spleen. Further, it persists in the skin for prolonged periods and may cause severe photosensitization reactions in patients long after treatment ceases. It has also been reported that it competes with melanin for light absorption, and its effectiveness in treating malignant conditions like melanoma is doubtful.

Nausea, exanthema, urtication, and itchiness have been reported with Indocyanine green.[95] Anaphylaxis and cross-reaction in patients with iodine sensitivity have also been reported.[96] Ocular complications have been noticed with PDT in patients undergoing multiple sessions of verteporfin. Risks are decreased with reduced dose/fluence settings. [97]

Hence, attention to laser parameters and selecting an appropriate photosensitizer can avoid these side effects. Operators should also exercise caution with PDT due to the risk of non-ionizing radiation from the light source causing eye and skin hazards. Blue light wavelengths can induce retinal damage (photoretinitis). Therefore, eye protection for patients, operators and assistants is mandatory. Reflection from metal surfaces can be avoided by covering them with wet gauze or use of tape. Additionally, high-speed evacuation to capture the laser plume is necessary. Habits like smoking and alcohol intake are also discouraged during PDT.

Advances in PDT

Conjugation of photosensitizers in PDT with antibodies against specific bacteria is an area of thrust.[98] Another variation of PDT employs polymeric or gold nanoparticles incorporated into the photosensitizer to allow bacterial cell wall disruption and thereby destruction of the oral biofilm.[99] Ultrasound activation of microbubbles through a sonosensitizer combined with molecular oxygen is another strategy that leads to the formation of pores in cells along with free oxygen radicals, causing cell death.[100] Similarly, the biofilm within the root canals has been treated with photosensitizer-containing oxidizers.[101] Another modification of PDT is the use of “photo-brushing" for plaque control.

Commercial kits

Various commercial kits are available for photodynamic treatment. 'Periowave' (Periowave Dental Technologies Inc., 888-1100 Melville Street, Vancouver, British Columbia V6E 4A6, Canada) with methylene blue has been advocated for treating periodontitis. Phenothiazine chloride is the photosensitizer in the Helbo® (Photodynamic Systems GmbH & Co. KG, Grieskirchen, Austria) system. Similarly, PAD™ uses toluidine blue.[16]

Conclusion

Photodynamic therapy offers a substitute for conventional antimicrobial treatment mitigating the development of resistance, especially while treating infectious diseases like periodontitis. The diverse applications of PDT, with the possibility of pain-free management, lend credence to this mode of treatment. The growing popularity of dental lasers has ensured that photodynamic treatment has a place in mainstream dental management.

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Conflict of Interest

There are no potential conflicts of interest to declare.

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Halterman Appliance For Impacted Mandibular Permanent First Molar – A Case Report

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Case Report

History

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ABSTRACT

In pediatric dentistry, Stainless Steel Crowns (SSC) are widely used. However, insufficient reduction for primary tooth preparation performed SSC distally can cause overhanging margins, obstructing adjacent permanent teeth eruption, and alignment problems. Treatment of ectopic erupted permanent first molars involves various management strategies. In 1982, Halterman introduced a specialized appliance for impacted maxillary first molars. This case report presented to utilization of the Halterman appliance for the orthodontic uprighting of the mandibular left permanent first molar in an 8-year-old boy who presented for a routine dental examination after previous dental treatment with SSCs performed under general anesthesia.

Key words: Impacted Permanent First Molar, Halterman Appliance, Overhanging, Stainless Steel Crown.

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Introduction

Ectopic eruption of the first permanent molars is a localized disturbance whereby these molars deviate from their normal eruption trajectory and instead emerge beneath the distal region of the second primary molars. Additionally, the first permanent molars exhibit a failure to erupt in their expected position.[1] The literature has explored diverse approaches for the clinical management of ectopic eruption. One notable clinical strategy for handling ectopically erupting permanent first molars was proposed by Kennedy and Turley in 1987.[2]

In 1982, Halterman introduced an appliance specifically designed to address impacted permanent maxillary first molars. This innovative device incorporated a bondable occlusal button, chain elastic, and a curved distal hook. Notably, the support for this appliance was derived from the second primary molar, ensuring the effective correction of the impacted molars.[3]

Since 1947, Stainless Steel Crowns (SSC) have been widely utilized as the primary choice for post-endodontic management following pulpectomy in primary teeth. The remarkable success rate of SSC can be attributed to the material's exceptional reliability, durability, adaptability, and cost-effectiveness.[4] As a result, SSCs have emerged as the preferred material in pediatric dental practice, cementing their status as the material of choice.[5]

Insufficient tooth preparation, especially in the distal aspect, can result in the formation of overhanging margins, particularly when there is a missing adjacent tooth. Consequently, this can lead to the impaction of the adjacent permanent teeth during their eruption, hindering their proper alignment within the dental arch.[6] The deviated eruption pathway or impaction caused by overhanging margins is primarily observed on the distal surface of the second primary molar, occurring prior to the eruption of the first permanent molar.[7]

The primary aim of this case report was to document and visually depict the successful management of an impacted permanent mandibular first molar attributed to an overhanging SSC on the primary mandibular second molar in an 8-year-old male child. Furthermore, the article sought to delve into the causative factors and therapeutic approaches for similar instances, drawing upon a meticulous review of pertinent literature in the field.

Case Report

Patient Information

An 8-year-old male patient was referred to the Department of Paediatric and Preventive Dentistry for a follow-up visit following previous dental treatment under general anesthesia. The patient had undergone treatment for early childhood caries four years ago, including multiple teeth treated with endodontic therapy and

restoration using SSC. The patient was currently asymptomatic with no relevant medical or family history.

During further intraoral examination, it was noted that the mandibular left permanent first molar did not erupt at the same pace as the contralateral permanent first molar, considering the child's chronological age. Radiographic findings using radiovisiography (RVG) showed the presence of an overhanging SSC concerning the mandibular left second primary molar. Consequently, the eruption path for the mandibular left permanent first molar was obstructed, and the mesial aspect of the tooth was found to be impacted beneath the distal surface of the overhanging SSC on the mandibular left second primary molar. (Figure 1)

Clinical and Radiographic Findings

In the intra-oral examination, SSC was present concerning the mandibular right and left first and second primary molar and maxillary right and left second primary molar. Maxillary right and left first primary molar was missing which was extracted 4 years back under general anaesthesia.

Diagnostic Assessment

RVG was taken for all the SSCs. SSCs concerning the mandibular left second primary molar was found to be overhanging. The mandibular left permanent first molar was found to be impacted below the distal edge of the SSC in the mandibular left second primary molar. Thus, impaction of the mandibular left permanent first molar under the SSCs was confirmed

Timeline

Treatment was planned for 4 to 6-week period from the start of the impression making to debonding of the appliance.

Case Managements

Treatment

Halterman appliance incorporates both wire components and elastics, strategically utilized to apply controlled forces to induce upright tooth movement.

Halterman appliance was planned for the distal movement of the mandibular left permanent first molar. Upper and lower alginate impressions were made for the diagnostic cast. Banding with 0.018X0.005” SS banding material was done in the Lower left primary second molar over the SSC. A lower alginate impression was made, and a band transfer was done. Halterman appliance was fabricated, trimmed. and polished. The appliance was trial-fitted and adapted.

An occlusal button was placed on the occlusal surface of the mandibular left permanent first molar as mesially as possible using transbond light cure adhesive. After bonding of the occlusal button, Halterman appliance was luted with Glass ionomer cement (GIC) in concerning the second left primary molar. A short elastic chain was engaged onto the distal extension of the wire component of the Halterman appliance. The engaged elastic chain was extended and the other end was engaged on the occlusal button on the mandibular left permanent first molar. This provided the distal force necessary for the movement of the teeth. (Figure 2)

Follow-Up and Outcomes

The Patient was followed up after 1 week to check the compliance. The patient was later followed in the 3rd and 6th weeks. At the end of 3rd week elastic chain was changed. At the end of the 6th week, the mandibular left permanent first molar was at the level of the occlusal plane, and the desired movement of the teeth was achieved which was confirmed through RVG. (Figures 3 and 4)

Discussion

Multiple strategies can be utilized for the treatment of impaction of permanent mandibular first molars. These approaches encompass techniques like precise striping of the distal surfaces of deciduous mandibular second molars and the insertion of orthodontic separators to create a distinct separation between the mandibular left permanent first molar and the mandibular left primary second molar.[8] The principal use of the Halterman appliance is to reposition the ectopically erupted teeth.[3] The literature reports several variations of the Halterman appliance, incorporating specific modifications to enhance its effectiveness. Such modification involves the addition of a U-shaped bend in the distal extension of the appliance and utilizing a reverse band and loop appliance with a bonded button attached to the permanent molar.[9,10] On the other hand in the case report, the appliance was used to reposition the mesially impacted left permanent first molar due to an overhanging SSC in the left primary second molar. The simple modification in the appliance provided sufficient force for the distal movement of the impacted left permanent first molar. Care was taken to monitor the direction of movement of the tooth via periodic recall and review. The patient was followed up for 3 months postoperatively after the removal of the appliance.

The case elucidates the proficient management of an incidental identification of an impacted mandibular left permanent first molar. This impaction was attributed to the presence of an adjacent overhanging SSC in the mandibular left primary second molar. SSC have become integral within the domain of pediatric dentistry, necessitating meticulous placement and adhesive techniques while considering prospective complications. In this context, the Halterman appliance emerged as an efficacious tool for expediently and conservatively repositioning the tooth.

Conclusions

Proper adaptation of SSC, especially on the distal surface is crucial to avoid impaction of the adjacent teeth. Pediatric dentists must be cautious of potential consequences of minor negligence of the SSC treatment performed under general anesthesia and must possess knowledge about different treatment options and appliances to effectively address specific cases. Additionally, regular monitoring and follow-up

examinations are essential to ensure the success of the treatment and maintenance of the long-term oral health of the patient.

Informed Consent

Informed consent was obtained from the patient's parent prior to the start of the treatment.

Conflig of Interest

None.

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None.

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A B

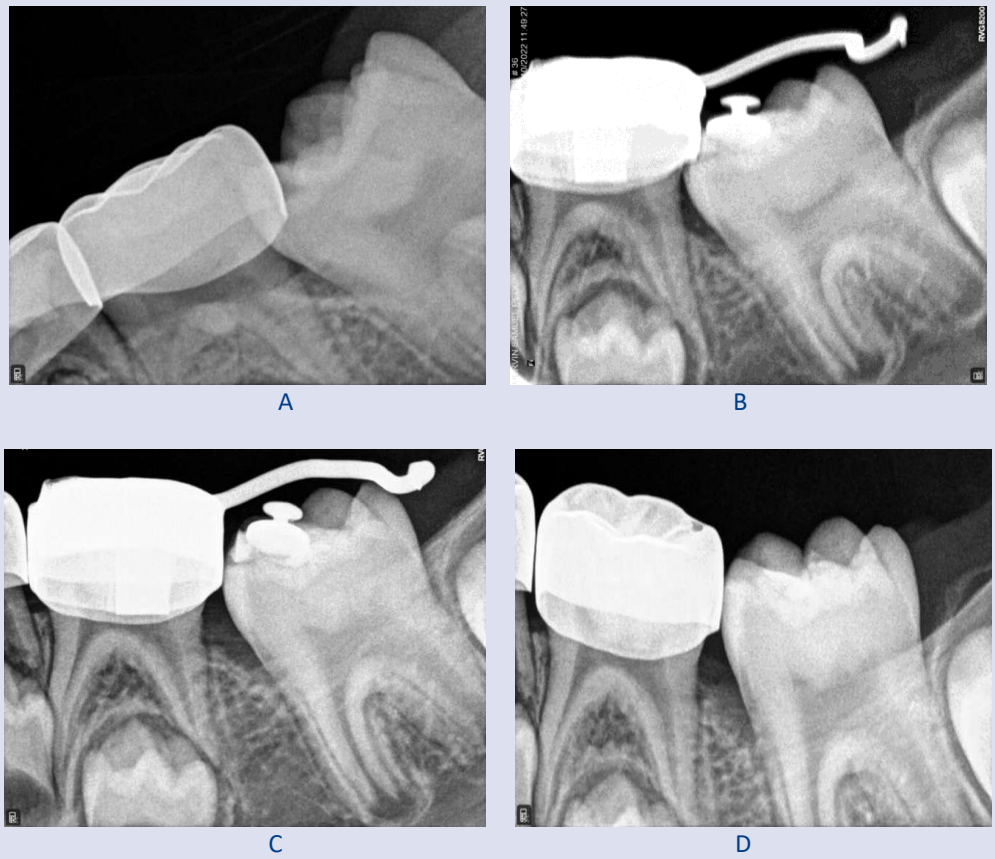
Figure 1. Pre-operative clinical images (A) occlusal view (B) left lateral view

A B

Figure 2. Intra operative clinical images with halterman appliance (A) occlusal view (B) left lateral view

A B

Figure 3. Post-operative clinical images with orthodontic elastic separator (A) occlusal view (B) left lateral view



A B C D

Figure 4. Radiographic Images (A) pre-operative images (B) after insertion of appliance (C) 3RD week follow-up (D) post-operative images