INTERNATIONAL ARCHIVES OF DENTAL SCIENCES

IADS

Volume 46
Issue 1
December 2025

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International Archives of Dental Sciences

Volum: 46 Number: 1 - 2025

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RESEARCH ARTICLE

REVIEW

Decreased Salivary Gremlin-1 Levels in Periodontitis Patients

Periodontitis Hastalarında Azalan Tükürük Gremlin-1 Düzeyleri

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Citation: Turkmen E, Balcı N, Yılmaz M, Toygar H. Decreased Salivary Gremlin-1 Levels in Periodontitis Patients. *Int Arc Dent Sci*. 2025;46(1):1-7.

ABSTRACT

INTRODUCTION: Gremlin-1, a member of the Transforming Growth Factor-Beta protein superfamily, is an antagonist of Bone Morphogenetic Proteins involved in processes such as angiogenesis, inflammation, fibrosis, and osteogenesis. The aim of this study is to compare salivary Gremlin-1 levels in individuals with periodontitis to those in periodontally healthy individuals and to evaluate the relationship of these levels with clinical parameters.

METHODS: A total of 40 systemically healthy individuals were included, comprising 20 stage III/grade B periodontitis and 20 periodontal healthy individuals. Clinical periodontal parameters (plaque index (PI), probing depth (PD), clinical attachment loss (CAL) and bleeding on probing (BOP)) were recorded. Salivary Gremlin-1 levels were analyzed using an ELISA.

RESULTS: All periodontal measurements were significantly higher in the periodontitis group rather than controls (p<0.0001). Salivary Gremlin-1 levels were significantly lower in the periodontitis compared to the control group (p<0.0001). Negative correlations were found between Gremlin-1 levels and PI (r=-0.592, p=0.011), PD (r=-0.452, p=0.003), and CAL (r=-0.453, p=0.003). No significant correlation was observed between Gremlin-1 levels and BOP (p>0.05).

CONCLUSION: Decreased saliva Gremlin-1 levels in periodontitis patients and their negative correlation with clinical periodontal parameters suggest that saliva Gremlin-1 might modulate the inflammation and limit tissue remodeling as a systemic compensation mechanism in periodontitis.

Keywords: *Gremlin-1, Periodontitis, Saliva*

ÖZ

GİRİŞ ve AMAÇ: Gremlin-1, Transforming Growth Faktör-Beta protein süper ailesinin bir üyesi olup, Bone Morfogenetik Protein'lerin antagonistidir ve anjiyogenez, inflamasyon, fibrozis ve osteogenez gibi süreçlerde rol oynar. Bu çalışmanın amacı, periodontitisli bireylerdeki tükürük Gremlin-1 seviyelerini periodontal olarak sağlıklı bireyler ile karşılaştırmak ve bu seviyelerin klinik parametrelerle ilişkisini değerlendirmektir.

YÖNTEM ve GEREÇLER: Çalışmaya 40 sistemik olarak sağlıklı birey dahil edildi; bunlardan 20'si evre III/derece B periodontitisli ve 20'si periodontal olarak sağlıklı bireylerdi. Klinik periodontal parametreler (plak indeksi (Pİ), sondalama derinliği (SD), klinik ataşman kaybı (KAK) ve sondalamada kanama (SKİ)) kaydedildi. Tükürük Gremlin-1 seviyeleri ELISA yöntemi kullanılarak analiz edildi.

BULGULAR: Tüm periodontal ölçümler, kontrol grubuna kıyasla periodontitis grubunda anlamlı derecede daha yüksek bulundu (p<0.0001). Tükürük Gremlin-1 seviyeleri, periodontitis grubunda kontrol grubuna göre anlamlı derecede daha düşük bulundu (p<0.0001). Gremlin-1 seviyeleri ile Pİ (r=-0.592, p=0.011), SD (r=-0.452, p=0.003) ve KAK (r=-0.453, p=0.003) arasında negatif korelasyonlar gözlendi. Gremlin-1 seviyeleri ile SKİ arasında anlamlı bir korelasyon bulunmadı (p>0.05).

SONUÇ: Periodontitis hastalarında azalmış tükürük Gremlin-1 seviyeleri ve klinik periodontal parametrelerle olan negatif korelasyonu, tükürük Gremlin-1'in sistemik bir kompansasyon mekanizması olarak inflamasyonu modüle edebileceğini ve doku yeniden şekillenmesini sınırlayabileceğini düşündürmektedir.

Anahtar Kelimeler: *Gremlin-1, Periodontitis, Tükürük*

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Received Date: 16.07.2024
Accepted Date: 13.10.2024

INTRODUCTION

Periodontitis is a chronic inflammatory condition marked by the progressive destruction of the supporting tissues of the teeth, including the alveolar bone. It is primarily caused by the host's immune response to a dental biofilm and influenced by various factors, including genetic predisposition, environmental factors, and systemic conditions.[1] Numerous studies have identified key molecules and signaling pathways, such as Transforming Growth Factor-beta (TGF- β), Bone Morphogenetic Proteins (BMPs) and Nuclear Factor Kappa B (NF-κB) that play a critical role in periodontal inflammation-induced alveolar bone loss.[2] As periodontitis progresses, NF-κB serves as a central regulator of inflammatory responses through orchestrating a network of mediators influencing the body's reaction to pathogenic organisms.[3]

Gremlin-1 is a member of the TGF-β protein superfamily and has recently been identified as a antagonists for BMPs and is involved in various metabolic processes including angiogenesis, inflammation, adipogenesis, fibrosis, and osteogenesis.[4] Previous studies have shown that Gremlin plays a role in the pathological processes of inflammation-related diseases.[5,6] It has been reported that Gremlin-1 exacerbates osteoarthritis by activating the NF-κB pathway.[7] Additionally, Gremlin-1's pro-inflammatory function has been associated with renal inflammation and thrombo-inflammation.[8] Gremlin-1, through its interaction with BMPs, regulates various cellular processes critical for tissue homeostasis and repair. By antagonizing BMPs, Gremlin-1 can modulate bone formation and resorption,[5] which is particularly relevant in the context of periodontal disease where bone loss is a hallmark feature. The dual role of Gremlin-1 in promoting inflammation through the NF-κB pathway and regulating bone metabolism makes it a molecule of significant interest in understanding the pathogenesis of periodontitis.

Recently, Gremlin-1 has been associated with oral related diseases. Gremlin-1 has been shown to contribute to the formation of dental hard tissues and the pathological development of cleft lip and palate.[9] It has been reported that Gremlin-1 is related in oral squamous cell carcinoma (OSCC)[10] and the development of apical periodontitis[11] through the NF-κB signaling pathway, and its inhibition can suppress the progression of these lesions. Also, Gremlin-1 has been shown to be distributed in periodontal tissues and to play a site-specific role in regulating cell growth and differentiation.[12] Gremlin-1 has been detected in the gingival tissue of patients with periodontitis and has been shown to mediate the activity of the NF-κB signaling pathway through the TGF-β1/Smad3/β-catenin and JNK signaling pathways, thereby regulating the development of periodontitis.[13]

To our knowledge, there are no studies evaluated that salivary Gremlin-1 levels in individuals with periodontitis. We hypothesized that Gremlin-1 levels in saliva reflect its systemic role in regulating inflammatory responses and tissue remodeling in periodontal disease, potentially decreasing as a compensatory mechanism to prevent excessive inflammation and tissue destruction in periodontitis. Therefore, the aim of this study is to compare the salivary Gremlin-1 levels in individuals with periodontitis to those in periodontally healthy individuals and to evaluate the relationship of these levels with clinical parameters.

MATERIAL AND METHODS

Study population

This study is a cross-sectional study conducted on individuals who applied to the departments of periodontology at Medipol University, Istanbul, from October 2023 to April 2024. A total of 40 subjects were included, including a systematically healthy control group with a healthy periodontium and systematically healthy periodontitis group with stage III grade B generalized periodontitis. The Ethics Committee of Istanbul Medipol University approved the study (No: E-10840098-202.3.02-1081, on 08.02.2024), which was conducted in accordance with the Declaration of Helsinki. All participants provided informed consent.

Inclusion criteria required participants to be (1) between 18 and 65 years old, (2) have at least 20 natural teeth, excluding third molars, (3) be systemically healthy, and (4) provide consent to participate in the study. Exclusion criteria included (1) the use of antibiotics, nonsteroidal anti-inflammatory drugs, steroids, immunosuppressants, beta-blockers, calcium channel blockers, anticoagulants, or hormonal contraceptives within the 3 months prior to the study, (2) received periodontal treatment in the last 6 months, (3) smoking, (4) pregnancy or lactation, (5) have any systemic conditions that might impact immune response, (5) using orthodontic appliances.

Clinical periodontal examination and diagnosis

The periodontal status was determined based on the 2017 AAP/EFP classification for periodontal and peri-implant diseases.[14] A probing depth (PD) of 3 mm or less, along with less than 10% of sites exhibiting bleeding on probing and with intact periodontitum, was defined as a healthy periodontium.[14] Individuals were diagnosed with periodontitis if they showed clinical attachment loss (CAL) of 2 mm or more at two or more non-adjacent teeth. The highest loss interdental clinical attachment loss was recorded for each tooth, and a clinical attachment loss of 5 mm or more and periodontitis-related tooth loss of 4 or fewer teeth were defined as stage III periodontitis.[14] Periodontitis grade was determined based on the ratio of radiographic bone loss to the patient's age.[14] Patients with a ratio between 0.25 and 1.00 were classified as Grade B.

Two calibrated periodontal experts (E.T, N.B.) recorded all clinical periodontal measurements, including plaque index (PI), pocket depth (PD), bleeding on probing (BOP) and CAL by measuring six regions of all teeth using a William's periodontal probe. The two examiners were calibrated by training on 10 non-study volunteers.[15] The probing depth scores showed high reliability, as confirmed by inter-examiner analysis (κ = 0.896) conducted prior to the study. The assessment revealed that the mean of repeated probing measurements was within 1 mm for 90% of the sites.

Samples collection and laboratory analysis

Unstimulated saliva samples were collected between 9:00 and 11:00 in the morning after an overnight fast to facilitate the analysis of selected markers. Participants avoided any oral hygiene procedures on the morning of sample collection. They were instructed to sit in a relaxed position, rinse with distilled water, and then spit into a sterile plastic tube for 10 minutes. Then saliva samples were centrifuged at 2800 g for 10 minutes. The flow rate of saliva (SFR) was measured by dividing the volume of saliva collected by the duration of the collection period.[15] All samples were transferred to Eppendorf tubes and stored at −80 °C until the day of analysis.

Saliva samples were analyzed for Gremlin-1 using commercial Enzyme-Linked Immunosorbent Assay (ELISA) kits (Elabscience, Houston, Texas, USA) following the manufacturer's instructions. All samples were tested in duplicate, and the values were averaged.

Statistical analyses

Statistical analyses were conducted using GraphPad Prism 10 software. The Shapiro-Wilk test was used to evaluate the normality of the parameters. Group comparisons were conducted using the t-test for normally distributed data and the Mann-Whitney test for data that were not normally distributed. Spearman correlation analysis was performed to determine correlations between biochemical and clinical periodontal parameters. A significance level of $p<0.05$ was considered statistically significant.

RESULTS

Table 1 presents the demographic and clinical findings of the study groups. A total of 40 systemically healthy subjects were included in this study. The control group (C) consisted of 20 individuals with healthy periodontium (11 females and 9 males; mean age: 38.2 ± 6.43 years), and the periodontitis group (P) included 20 patients diagnosed with Stage III, Grade B periodontitis (12 females and 8 males; mean age: 41.5 ± 7.1 years).

There were no significant differences according to age and gender between the periodontitis and control groups ($p>0.05$). There was no significantly difference was found between the periodontitis and control groups for SFR *(p>0.05)*. Periodontal measurements (PI, BOP, PD, CAL) were significantly higher in the periodontitis group rather than control *(p < 0.001)*.

Gremlin-1 levels were significantly lower in the periodontitis group compared to the control group *(p<0.0001)*. (Table 2, Figure 1).

Table 3 presents the correlations between Gremlin-1 levels and clinical periodontal parameters. Gremlin-1 was showed a significantly moderate negative correlation with PI (r=-0.592, $p=0.011$), PD (r=-0.452, $p=0.003$), and CAL (r=-0.453, $p=0.003$), however was not correlated with BOP ($p>0.05$).

Table 1. Demographic, and clinical parameters of periodontitis and control groups

Parameters	Control (C) n=20	Periodontitis (P) n=20	*p*
Age (year)	38.2 ± 6.43	41.5 ± 7.1	*0.107**
Gender F/M	11/9	12/8	*0.215*
SFR	0.41 ± 0.08	0.40 ± 0.10	*0.633**
PI	0.93 ± 0.28	2.40 ± 0.19	***<0.001****
PD (mm)	1.33 ± 0.17	2.95 ± 0.54	***<0.001****
BOP (%)	3.8 ± 2.39	57.19 ± 17.36	***<0.001****
CAL (mm)	1.33 ± 0.17	3.34 ± 0.69	***<0.001****

*Student-t test was used. Data shown as mean ± standard deviation

Abbreviations: SFR, saliva flow rate; PI, plaque index; PD, probing depth; BOP, bleeding on probing; CAL, clinical attachment lost.. Statistical difference with the control group $p<0.05$. Significantly different values are shown in boldface type.

Table 2: Saliva levels of Gremlin-1 in periodontitis and control groups

Biochemical	Control (C) n=20	Periodontitis (P) n=20	*p*
Gremlin-1 (ng/ml)	3.36 (1.01-9.68)	1.12 (0.17-3.38)	***<0,0001****

* Mann Whitney test was used. Data shown as median (min-max).

Statistical difference with the control group $p<0.05$. Significantly different values are shown in boldface type.

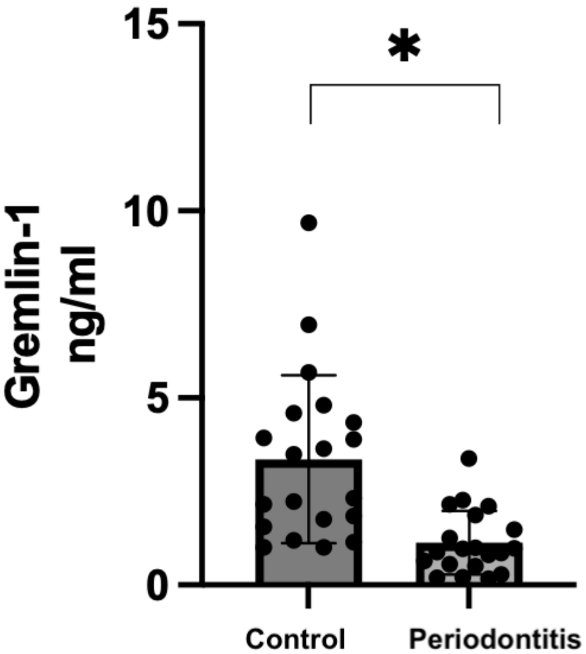

Fig 1: Saliva levels of Gremlin-1 in control volunteers and periodontitis patients. Box-and-whisker plots with the median (horizontal line), interquartile range (box) and outlier (circles) values are shown. *Significantly different *($p < 0.05$)* from the control group.

Table 3: Correlations between biomarkers and periodontal clinical parameters (Spearman correlation coefficients, *r values*) (*n* = 40).

Variables	SFR	PI	BOP	PD	CAL
PI	-0.150	-	-	-	-
BOP	-0.115	0.266	-	-	-
PD	-0105	0.854	0.014	-	-
CAL	-0.148	0,742	0,034	0,824	-
Gremlin-1	0.123	**-0.592***	-0.192	**-0.452***	**-0.453***

Significantly different values are shown in boldface type, * *p<0.05;*

DISCUSSION

Periodontitis is defined as a chronic inflammatory disease in which TGF-β regulates tissue repair and inflammation, while NF-κB contributes to tissue destruction and disease progression by promoting the production of pro-inflammatory cytokines.[16] Gremlin-1, a member of the TGF-β superfamily, has been shown to exacerbates periodontitis by stimulating NF-κB signaling pathway.[13] However, no studies have assessed the saliva levels of Gremlin-1 in periodontitis patients. Consequently, we investigted saliva levels of Gremlin-1 in patients with stage III/grade B periodontitis.

In this study, no differences were observed between the groups in terms of age, gender, and SFR. Saliva flow rate is known to be associated with individuals' overall health status and systemic conditions.[17] The fact that all participants in our study were systemically healthy might have contributed to the stability of SFR. The total unstimulated saliva flow rate is typically around 0.3-0.4 ml/min. During sleep, this rate drops to approximately 0.1 ml/min, whereas it rises to about 4.0-5.0 ml/min during activities such as eating, chewing, and other forms of stimulation.[17] The wide range of variation in saliva flow rate under normal physiological conditions and natural variations among individuals may also influence this result. The balanced distribution of age and gender between the two groups suggests that these demographic factors do not have a significant impact on saliva flow rate. Additionally, the similarity in age and gender between the groups emphasizes that the study included a homogeneous population in terms of demographic characteristics, and these factors are not significant variables in the evaluation of periodontitis.

The present study shown that lower saliva Gremlin-1 levels in stage III/grade B periodontitis patients compared to the healthy controls and negatively correlated with plaque index, probing depth, and clinical attachment loss. We have demonstrated for the first time lower Gremlin-1 levels in saliva were associated with periodontitis . Gremlin-1 is known to crucial regulator of the TGF-β1/Smad3/NF-κB axis and JNK/NF-κB. It has been shown that Gremlin-1 modulates inflammation in a tissue-dependent manner.[18] Gremlin-1 has been shown to aggravate osteoarthritis in human models by activating the NF-κB pathway.[7] Corsini et al. (2013), showed that in endothelial cells, Gremlin-1 triggers the production of pro-inflammatory chemokines and adhesion molecules through activating NF-κB pathways.[7] Besides, Gremlin-1 plays a protective role in vascular inflammation and atherosclerotic plaque progression. Various studies have demonstrated that Gremlin-1 Various studies have demonstrated that Gremlin-1 suppresses macrophage migration inhibitory factor (MIF)-dependent monocyte activation and movement, and it reduces leukocyte infiltration, thereby limiting the development of atherosclerotic plaques,[19,20] also it promotes angiogenesis both in vitro and in vivo by binding to and activating vascular endothelial growth factor receptor 2.[21] It is known that periodontitis is a chronic inflammatory disease marked by enhanced macrophage infiltration and activation.[22] The decreased salivary Gremlin-1 levels in our study may suggest that it may have a similar protective role during inflammation in periodontitis. Muller et al. (2021), highlighted the protective role of Gremlin-1 in myocardial function, demonstrating its involvement in regulating fibrosis and wound healing across various tissues, including the heart.[23] Gremlin-1 interacts with BMP signaling pathways to modulate collagen production and fibrosis.[23] This suggests that

Gremlin-1 acts as a BMP antagonist, blocking BMP signaling to precisely control BMP gradients essential for tissue repair and fibrosis regulation. Our findings align with these insights, indicating that decreased salivary levels of Gremlin-1 in periodontitis may be relate to its regulatory role in tissue remodeling and inflammatory response modulation.

Gremlin-1's involvement in periodontitis might also extend to its interaction with BMP and TGF-β pathways. Gremlin-1 has been shown to inhibit BMP-dependent apoptosis of myofibroblasts and cause extracellular matrix accumulation, impacting fibrotic processes in chronic diseases such as kidney and liver fibrosis.[24] The presence of Gremlin-1 in various inflammatory and fibrotic conditions suggests a complex role in mediating tissue responses to chronic injury and inflammation. Interestingly, while Gremlin-1 promotes fibrosis in some tissues, it appears to have an inhibitory effect on TGF-β-induced collagen production in myocardial fibroblasts, as shown by Muller et al. (2021).[23] This dual role may depend on the specific tissue environment and the balance of signaling pathways involved. A recent short report was showed that Gremlin-1 is essential for M2-like polarization of macrophages, enhancing this process in response to Th2 cytokines IL4 and IL13, and its depletion inhibits M2 polarization, highlighting a novel mechanism in fibrosis and remodeling in lung diseases.[25] The decreased salivary Gremlin-1 levels in periodontitis observed in our study might reflect a tissue-specific regulatory mechanism where Gremlin-1 modulates the inflammatory response and remodelling in periodontitis.

Additionally, Nagatomo et al. (2008), reported that transgenic overexpressing Gremlin-1 in mice caused defects in enamel and dentin, and they argued that this may also affect periodontal disease involving both bone and soft tissues.[9] A study by Ghuman et al. (2019), revealed that gingival fibroblasts express Gremlin-1, which inhibits BMP-mediated osteoblastic differentiation. They have been reported that the inhibitory effect of Gremlin-1 on osteoblastic differentiation may contribute to the impaired bone regeneration observed in periodontitis.[12] A recent study investigated the role of Gremlin-1 in inflammatory apical periodontitis and showed that Gremlin-1 expression was significantly increased in inflamed periapical tissues.[11] Guan et al. (2022), reported that Gremlin-1 expression was increased in inflamed periodontal tissues, contributing to the activation of the NF-κB signaling pathway and interleukin-1β (IL-1β).[13] Also they showed that Gremlin-1 regulated the osteogenesis ability of human periodontal ligament stem cells and that blocking Gremlin-1 suppressed alveolar bone loss and reduced inflammation by affecting ICAM-1, VCAM-1, and IL-1β levels.[13] On the contrary to these studies, our study found decreased saliva Gremlin-1 levels in patients with stage III/grade B periodontitis. This discrepancy may be suggests that while Gremlin-1 is upregulated in local tissues to manage inflammation and bone remodeling, its systemic levels in saliva may decrease as a compensatory mechanism to prevent excessive inflammation and tissue destruction. This could highlight the possibility of complex regulatory mechanisms of Gremlin-1, reflecting different roles in local tissue environments versus systemic circulation. However, examining it together with saliva samples, especially gingival crevicular fluid (GCF) samples, which better reflect the local response, may elucidate the role of Gremlin-1 in periodontal disease and its precise regulatory mechanisms.

Additionally, our study revealed negative correlations between salivary Gremlin-1 levels and PI, PD and CAL. Guan et al. reported increased Gremlin-1 expressions in gingival samples of patients with periodontitis, but the severity of periodontitis was not specified and they did not examine the correlation in terms of clinical periodontal parameters.[13] Our study findings indicate that higher Gremlin-1 levels are associated with better periodontal health outcomes in in these parameters. This may be because, at the local tissue level, Gremlin-1 helps to regulate inflammation and facilitate tissue repair. The lack of correlation with BOP, however, suggests that Gremlin-1's role might be more related to the structural aspects of periodontal health rather than the acute inflammatory response that causes bleeding. This could indicate that while Gremlin-1 is involved in longer-term tissue remodeling and inflammation regulation, it does not directly affect the acute inflammatory response measured by bleeding on probing. BOP is a more immediate indicator of gingival inflammation and might be influenced by other factors that do not involve Gremlin-1.

This study has some limitations. Main limitations can be considered the lack of an analysis of GCF. GCF composition largely reflects the inflammatory state of periodontal tissues, making it essential for understanding periodontal pathogenesis. Analyzing GCF offers the advantage of site-specific information regarding periodontal health. While saliva analysis can also provide insights into the periodontal condition by reflecting GCF composition,[26] evaluating together with GCF directly could further validate and compared our findings. Other limitation is the relatively small sample size. Nevertheless, salivary analysis can alone still offer substantial insights into the role of Gremlin-1 in periodontitis. Additionally, the cross-sectional design of our study limits our ability to monitor the progression of the disease over time.

In the current study, the results highlight the significance of Gremlin-1 in periodontitis and its correlation with periodontal status. These findings suggest that decreased salivary Gremlin-1 levels may serve as a systemic compensatory mechanism to regulate inflammation and limit tissue destruction in severe periodontitis, highlighting its potential as a biomarker for disease progression. However, further analysis and larger sample size are required to fully clarify the role of Gremlin-1 in the pathogenesis of periodontitis.

CONCLUSION

This is the first study investigating saliva levels of Gremlin-1 in stage III grade B periodontitis. With the limitations, the present study demonstrated that decreased salivary Gremlin-1 levels in patients with periodontitis compared to healthy controls and negatively correlated with PI, PD and CAL. This study suggest that salivary Gremlin-1 might modulate to the inflammation and limit tissue remodelling by acting as a systemic compensation mechanism in periodontitis in the future with using different sample analysis methods and large-cohort studies.

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Evaluation of Two-Body Wear of Different Resin Composite Restorations and the Effect of Layer Thickness

Farklı Kompozit Rezin Restorasyonlarda Direkt Temas Aşınması ve Tabakalama Kalınlığının Aşınmaya Olan Etkisinin Değerlendirilmesi

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Citation: Şenol A A, Atalı Yılmaz P, Kahramanoğlu E. Evaluation of Two-Body Wear of Different Resin Composite Restorations and the Effect of Layer Thickness. *Int Arc Dent Sci.* 2025;46(1):9-18.

ABSTRACT

INTRODUCTION: This in-vitro study aims to comparatively assess the two-body wear of methacrylate/ormocer-based composites, methacrylate/ormocer-based bulk-fill composites(BFC), and nanohybrid CAD/CAM block restorations exposed to thermo-mechanical chewing simulation.

METHODS: Mesial–occlusal–distal cavities were prepared in 100 noncarious extracted molars, and restored with Admira Fusion/A+Admira Fusion Flow/AF; Admira Fusion x-tra/AFX+Admira Fusion x-base/AFB; x-tra fil/X+x-tra base/XB; Tetric N-Ceram Bulk Fill/TB+Tetric N-Flow Bulk Fill/TFB; Tetric N-Ceram/T+Tetric N-Flow/TF; GrandioSo/G+GrandioSo Flow/GF; and Grandio Block/GB as per the manufacturer's instructions. The composites in bulk-fill groups were applied in 2-and 4-mm thick layers to investigate the effects of material thickness on wear. Restorations were exposed to 240,000 thermomechanical cycles in chewing simulator. Surfaces were scanned using laser scanner before and after loading. Volume loss was calculated using Geomagic Control program. The Kruskal–Wallis and Dunn tests were used for statistical analysis of the data.

RESULTS: No significant difference was found between groups of the same materials layered with different thicknesses. A statistically significant difference in median wear values was observed between restorative material groups (p=0.006), and the wear values of A+AF(0.351) were higher than TB (4 mm)+TFB (2 mm)(0.045).

CONCLUSION: CAD/CAM block and direct resin composite restorations did not differ in wear resistance. Also, all tested direct materials exhibited similar two-body wear resistance, except for ormocer-based composite, which had higher wear values.

Keywords: *CAD/CAM, Chewing simulator, Nanohybrid resin composite, Wear*

ÖZ

GİRİŞ ve AMAÇ: Bu in vitro çalışmada, çiğneme simulatörü ile termo-mekanik döngüye maruz bırakılan metakrilat/ormoser esaslı kompozitlerin, metakrilat/ormoser esaslı bulk-fill kompozit rezinlerin ve nanohibrit CAD/CAM blok restorasyonların direkt temas aşınmasını karşılaştırmalı olarak değerlendirmek amaçlanmaktadır.

YÖNTEM ve GEREÇLER: Çürüksüz, çekilmiş 100 adet azı dişinde hazırlanan mesial-oklüzal-distal kaviteler Admira Fusion/A+Admira Fusion Flow/AF; Admira Fusion x-tra/AFX+Admira Fusion x-base/AFB; x-tra fil/X+x-tra base/XB; Tetric N-Ceram Bulk Fill/TB+Tetric N-Flow Bulk Fill/TFB; Tetric N-Ceram/T+Tetric N-Flow/TF; GrandioSo/G+GrandioSo Flow/GF; ve Grandio Block/GB ile üreticinin talimatlarına göre restore edildi. Bulk-fill gruplarındaki kompozitler, materyal kalınlığının aşınmaya olan etkisini araştırmak amacıyla 2 ve 4 mm kalınlığında tabakalar halinde uygulandı. Restorasyonlar çiğneme simülatöründe 240.000 termomekanik döngüye maruz bırakıldı. Yükleme öncesinde ve sonrasında yüzeyler lazer tarayıcı kullanılarak tarandı. Hacim kaybı Geomagic Control programı kullanılarak hesaplandı. Verileri karşılaştırmak ve analiz etmek için Kruskal-Wallis ve Dunn testleri kullanıldı.

BULGULAR: Aynı materyalin farklı kalınlıklarda tabakalandığı gruplar arasında anlamlı bir fark bulunmadı. Farklı restoratif materyal grupları arasında medyan aşınma değerlerinde istatistiksel olarak anlamlı bir fark gözlendi (p=0,006), ve A+AF grubunun (0,351) aşınma değerleri TB (4 mm)+TFB (2 mm) grubuna (0,045) göre daha yüksekti.

SONUÇ: Nanohibrit CAD/CAM blok restorasyonlar ve direkt rezin kompozit restorasyonlar aşınma direnci açısından farklılık göstermedi. Ayrıca daha yüksek aşınma değerlerine sahip olan ormoser esaslı kompozit restorasyonlar dışında, test edilen tüm direkt kompozit restorasyonlar benzer direkt temas aşınma direnci sergiledi.

Anahtar Kelimeler: *Aşınma, CAD/CAM, Çiğneme simülatörü, Nanohibrit rezin kompozit*

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Received Date: 21.12.2023
Accepted Date: 24.10.2024

INTRODUCTION

Composite restorations have many complementary mechanical factors such as shrinkage, wear resistance, water absorption, and fracture resistance that can impact clinical performance.[1] In some clinical situations, wear may adversely affect the function and esthetics of restorations and also cause systemic consequences through ingestion or inhalation of the abraded materials.[2] Therefore, the wear resistance of restorative materials plays a crucial role in the maintenance of the restorations as well as the antagonist teeth in the opposing arch, highlighting the importance of investigating both in relation to one another. It aims to identify restorative materials resembling enamel tissues in terms of their physical and biological properties to maintain a balance in wear resistance between the two.[3]

Abrasion and attrition are the main mechanisms of dental material wear.[4] Abrasive wear is caused by the movement of hard particles or protrusions against firm surfaces and can be classified into two-body and three-body wear. Attrition is a type of two-body wear in which the teeth or restorations are in occlusal contact, while three-body wear can be defined as abrasive wear caused by the presence of food particles between the teeth or restorations and their antagonists during mastication. These mechanisms and their combinations often lead to material loss and changes in morphology.[5]

Variable conditions in the oral environment and differences in mechanisms make it difficult to evaluate wear using a single test method, resulting in the development of a range of different wear resistance tests. ISO/TS 14569-2, which defines wear caused by occlusal contact between the teeth and their antagonists, aims to define wear tests and parameters.[6] Several laboratory studies have used chewing simulators to predict the clinical wear resistance of restorative materials.[7, 8] The results showed that wear produced by 240,000–250,000 thermo-mechanical cycles in a chewing simulator was equivalent to that produced by a year of clinical performance.[9] Profilometers,[10] laser scanners,[11] and other similar methods have also been used to measure wear with limited material loss.

The amount and pattern of wear may vary depending on the content and mechanical properties of the restorative material and the antagonist as well as the severity and duration of forces it is exposed to.[9, 12, 13] Parafunctional occlusal habits such as bruxism, which generate increased forces on the restoration and teeth, are frequently encountered and are reported to cause faster wear.[3, 14] The development of resin composites and improvements in the inorganic and organic matrix content have aimed to increase wear resistance.[15] Studies have suggested that this may be affected by silicon dioxide which forms the inorganic and organic structures of ormocer composites, or by the high degrees of polymerization conversion of bulk-fill composites (BFC).[16]

Moreover, while some studies suggest that the volume percentage [12] and the size of filler particles may affect wear, others have demonstrated contradictory results on the effect of particle size and volume percentage on wear.[10, 17, 18] The current study aimed to compare the wear resistance rates of several resin composite restorations differing in techniques, fillers, and matrix types under *in vitro* abrasive conditions created by exposure to thermo-mechanical cycles. For this purpose, ormocer-based resin composites, ormocer-based BFC, methacrylate-based resin composites, methacrylate-based BFC composites, and nanoceramic hybrid CAD/CAM block were tested using a dual-axis chewing simulator.

The null hypotheses tested were as follows:

1) Direct resin restorative materials and indirect resin restorative material, the nanoceramic hybrid CAD/CAM block, would exhibit similar two-body wear resistance.

2) Different types of matrix structure (ormocer vs. methacrylate) would not affect the wear values of the restorations.

3) Groups restored with BFC of different thicknesses (2 mm–4 mm) would exhibit similar two-body wear resistance.

MATERIALS AND METHODS

This study was approved by the ethics committee of Marmara University, Faculty of Dentistry in Istanbul, Türkiye (Protocol number 2020/58).

Standardized mesial–occlusal–distal (MOD) cavities (an occlusal isthmus of 3 mm in width/2 mm in depth and proximal boxes of 4 mm in depth/2 mm in width) were prepared in noncarious, nonrestored mandibular molar teeth extracted within the last 6 months and stored in thymol for 24 hours before commencement of the procedure. MOD cavities were randomly divided into groups and restored using ormocer-based composites (Admira Fusion/A + Admira Fusion Flow/AF); ormocer-based bulk-fill composites (Admira Fusion x-tra/AFX + Admira Fusion x-base/AFB); methacrylate-based bulk-fill composites (X-tra fil/X + X-tra base/XB and Tetric N-Ceram Bulk Fill/TB + Tetric N-Flow Bulk Fill/TFB); methacrylate-based composites (Tetric N-Ceram/T + Tetric N-Flow/TF and GrandioSo/G + GrandioSo Flow/GF); and nanohybrid CAD/CAM block (Grandio Blocs/GB), as per the manufacturer's instructions.

Methacrylate and ormocer-based BFC (AFX + AFB, X + XB, and TB + TFB) were applied at different thicknesses in two experimental groups to evaluate their effects on wear. Using the restorative materials shown in Table 1, a total of 10 experimental groups were obtained (n = 10 per material; Table 2).

Table 1. Materials and equipment used in the restoration of MOD cavities

	Restorative material	Matrix and filler contents	Flowable restorative material (As a liner)	Matrix and filler contents
Direct restorative materials Bulk-fill resin composites	***Admira Fusion x-tra*** VOCO, Cuxhaven, Germany (Ormocer-based)	Ormocer matrix, silicon dioxide, glass ceramics; Filler (% w/w): 84	***Admira Fusion x-base*** VOCO, Cuxhaven, Germany (Ormocer-based)	Ormocer matrix, silicon dioxide, glass ceramics; Filler (% w/w):72
	X-tra fil VOCO, Cuxhaven, Germany (Methacrylate-based)	Bis-GMA, TEGDMA, UDMA, barium aluminium silicate, fumed silica, pigments; Filler (% w/w): 86	***X-tra base*** VOCO, Cuxhaven, Germany (Methacrylate-based)	Bis-EMA, aluminium, barium silicate; Filler (% w/w): 75
	Tetric N-Ceram Bulk Fill Ivoclar Vivadent, Schaan, Liechtenstein (Methacrylate-based)	Bis-GMA, UDMA, barium glass, prepolymer, ytterbium trifluoride, mixed oxide; Filler (% w/w): 75-77	***Tetric N-Flow Bulk Fill*** Ivoclar Vivadent, Schaan, Liechtenstein (Methacrylate-based)	Bis-GMA, UDMA, TEGDMA, barium glass, ytterbium trifluoride, copolymers; Filler (% w/w):68.2
Direct restorative materials Resin composites	***Admira Fusion*** VOCO, Cuxhaven, Germany (Ormocer-based)	Ormocer matrix, glass-ceramic, silicon oxide; Filler (% w/w): 84	***Admira Fusion Flow*** VOCO, Cuxhaven, Germany (Ormocer-based)	Ormocer matrix; Filler (% w/w):74
	GrandioSo VOCO, Cuxhaven, Germany (Methacrylate-based)	Bis-GMA, TEGDMA, Bis-EMA, glass-ceramic and silica nanoparticles; Filler (% w/w): 89	***GrandioSo Flow*** VOCO, Cuxhaven, Germany (Methacrylate-based)	Bis-GMA, TEGDMA, HEDMA, glass ceramic, silicon dioxide; Filler (% w/w):81
	Tetric N-Ceram Ivoclar Vivadent, Schann, Liechtenstein (Methacrylate-based)	Bis-GMA, UDMA, barium glass, ytterbium trifluoride, mixed oxide; Filler (% w/w): 80	***Tetric N-Flow*** Ivoclar Vivadent, Schann, Liechtenstein (Methacrylate-based)	Bis-GMA, UDMA, TEGDMA, Bis-EMA, barium glass, ytterbium trifluoride, mixed oxide, silicon dioxide; Filler (% w/w): 63.8

	Brand name and manufacturer	Matrix and filler contents
Indirect restorative materials	***Grandio Blocs*** VOCO, Cuxhaven, Germany (Nanohybrid CAD/CAM block)	86% w/w inorganic fillers in a polymer matrix-14% UDMA+DMA
Adhesive and luting system	***Futurabond U Universal (***VOCO, Cuxhaven, Germany)	HEMA, Bis-GMA, HEDMA, acidic adhesive monomer, UDMA, catalyst, silica nanoparticle, ethanol
	Bifix QM Dual-cure (VOCO, Cuxhaven, Germany)	Bis-GMA, HEMA, benzoyl peroxide, high fluoride amin
	Tetric N-Bond Universal (Ivoclar Vivadent, Schann, Liechtenstein)	Phosphoric acid acrylate, HEMA, Bis-GMA, UDMA, ethanol
	Futura Bond DC Universal (VOCO, Cuxhaven, Germany)	Bis-GMA, HEMA, ethanol, acidic adhesive monomer
	Ceramic bond (VOCO, Cuxhaven, Germany)	Organic acid, 3-methacryloxypropyltrimethoxysilane and acetone
Light device: *Valo Cordless (*Ultradent, USA) Standard mode: 1000 mW / cm^2		

*Bis-EMA: Bisphenol A polyethylene glycol diether dimethacrylate, Bis-GMA: Bisphenol A dimethacrylate, DMA: Dimethylacetamide, HEDMA: hexamethylene dimethacrylate, HEMA: 2-hydroxyethyl methacrylate, TEGDMA: Triethylene glycol dimethacrylate, UDMA: Urethane dimethacrylate

Table 2. Restoration stages of groups by materials used

<table>
<tr><th colspan="6">Groups</th></tr>
<tr><td>Group 1
AF as a liner in 1 mm layer, and A in 2 mm layers.</td><td>Group 2
AFB as a liner in 2 mm layer, and AFX in 4 mm layer.</td><td>Group 3
AFB as a liner in 4 mm layer, and AFX in 2 mm layer.</td><td>Group 4
XB as a liner in 2 mm layer, and X in 4 mm layer.</td><td>Group 5
XB as a liner in 4 mm layer, and X in 2 mm layer.</td><td>Group 6
GF as a liner in 1 mm layer, and G in 2 mm layers.</td></tr>
<tr><td colspan="6">In groups 1-6:
Etching and adhesive protocol: The enamel surface was etched with Vococid (35%-H_3PO_4; VOCO, Cuxhaven, Germany) in selective mode. Futurabond U was applied to enamel and dentin surface (10 s).
Polishing protocol: Finishing and polishing of the restoration was completed using Dimanto (VOCO, Cuxhaven, Germany).</td></tr>
<tr><th colspan="6">Groups</th></tr>
<tr><td colspan="2">Group 7
TF as a liner in 1mm layer, and T in 2 mm layers.</td><td colspan="2">Group 8
TFB as a liner in 2 mm layer, and TB in 4 mm layer.</td><td colspan="2">Group 9
TFB as a liner in 4 mm layer, and TB in 2 mm layer.</td></tr>
<tr><td colspan="6">In groups 7-9:
Etching and adhesive protocol: The enamel surface was etched with N-Etch (37%-H_3PO_4; Ivoclar Vivadent, Schann, Liechtenstein) in selective mode. Tetric N-Bond (Ivoclar Vivadent, Schann, Liechtenstein) was applied to the enamel and dentin surface (10 s).
Polishing protocol: Finishing and polishing of the restoration was completed using OptraPol (Ivoclar Vivadent, Schann, Liechtenstein).</td></tr>
<tr><td colspan="6">Group 10
Grandio Blocs</td></tr>
<tr><td colspan="6">In group 10:
Etching and adhesive protocol: The enamel surface was etched with Vococid (35%-H_3PO_4; VOCO, Cuxhaven, Germany) in selective mode. Futurabond DC was applied to the enamel, dentin, and restoration surface (10 s), followed by application of Ceramic Bond to the restoration surface (60 s). Nanoceramic hybrid (GB) restorations were luted with Bifix QM Dual-cure.
Polishing protocol: Finishing and polishing of the restoration was completed using Dimanto (VOCO, Cuxhaven, Germany).</td></tr>
</table>

*H_3PO_4: Phosphoric acid

The teeth were embedded in the molds of the chewing simulator using self-cure acrylic (Imicryl, Konya, Türkiye), and samples of each restorative material were thermodynamically loaded in a dual-axis chewing simulator (CS-4.8, SD Mechatronic, Feldkirchen, Westerham, Germany) with steel balls as the antagonist (1.7 Hz, 50 N load; 240,000 mechanical cycles; and thermal cycling 5°C–55°C at 60 sec dwell time) (Figure 1). Two-way movements along the vertical and horizontal axes were carried out using a force of 50 N, and steel balls with a diameter of 6 mm were used as the antagonists.

Parameters of chewing simulator	Test conditions
Number of thermo-mechanical cycles	240 000 cycles
Antagonist material/shape/size	Steel/ball/6mm diameter
Applied force	50 N
Dwell time	60 s
Cycle frequency	1.7 Hz
Cold/hot bath temperature	5◦C/55◦C
Z-axis (Vertical);	
Stroke up/down	3.0 mm/3.0 mm
Speed up	55.0 mm/s
Speed down	30.0 mm/s
X-axis (Horizontal)	
Stroke horizontal	0.3 mm
Speed horizontal	30.0 mm/s

Figure 1. Chewing simulator parameters

High-resolution (10 µm) topography scanning of the wear craters was performed using a laser scanner (LAS-20, SD Mechatronic, Münich, Germany), and surface topography analyses were carried out before and after loading to calculate the volume loss of samples. The starting and ending points of the surfaces of the samples to be scanned were marked. The measurement step of the scanning was adjusted to 0.02 mm and 3D surface scanning operations were carried out. The data transferred to the Geomagic Control (3D Systems Inc., Rock Hill, USA) program was superimposed to detect areas where wear occurred (Figures 2 and 3).

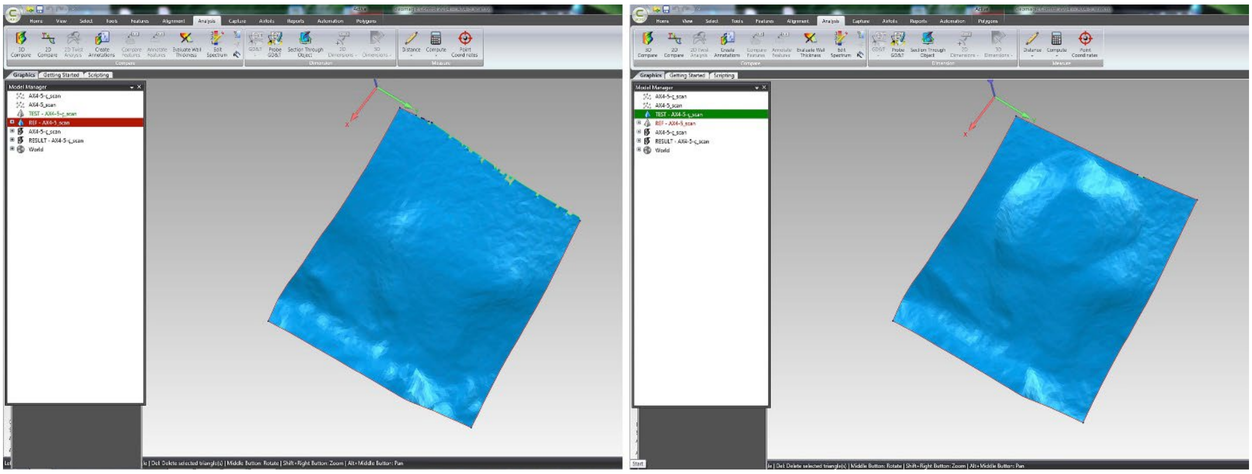

Figure 2. Obtaining a virtual model from three-dimensional surface analysis before (a) and after (b) loading

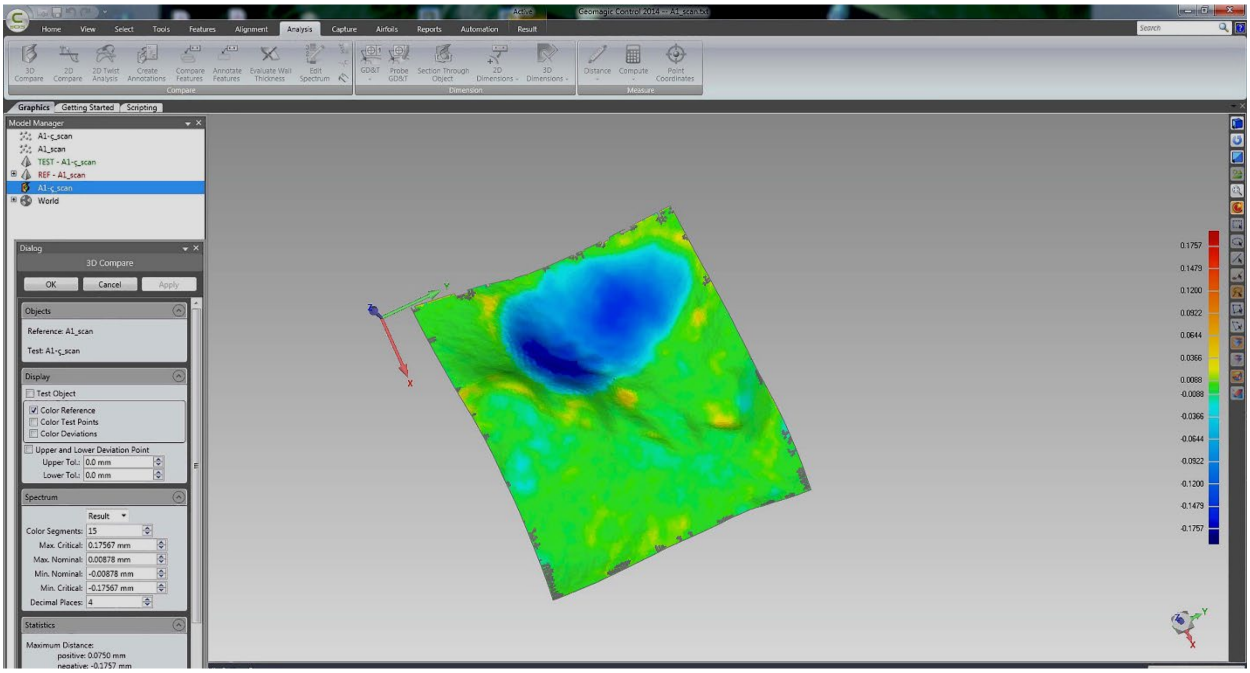

Figure 3. Superimposed 3D images with the three-point alignment method

The superimposed images were kept at the same time and cut to equal sizes. After arrangement, the volumetric distances of the initial and final states of each sample to a certain plane were calculated separately and the amount of volumetric wear that occurred was determined (Figure 4).

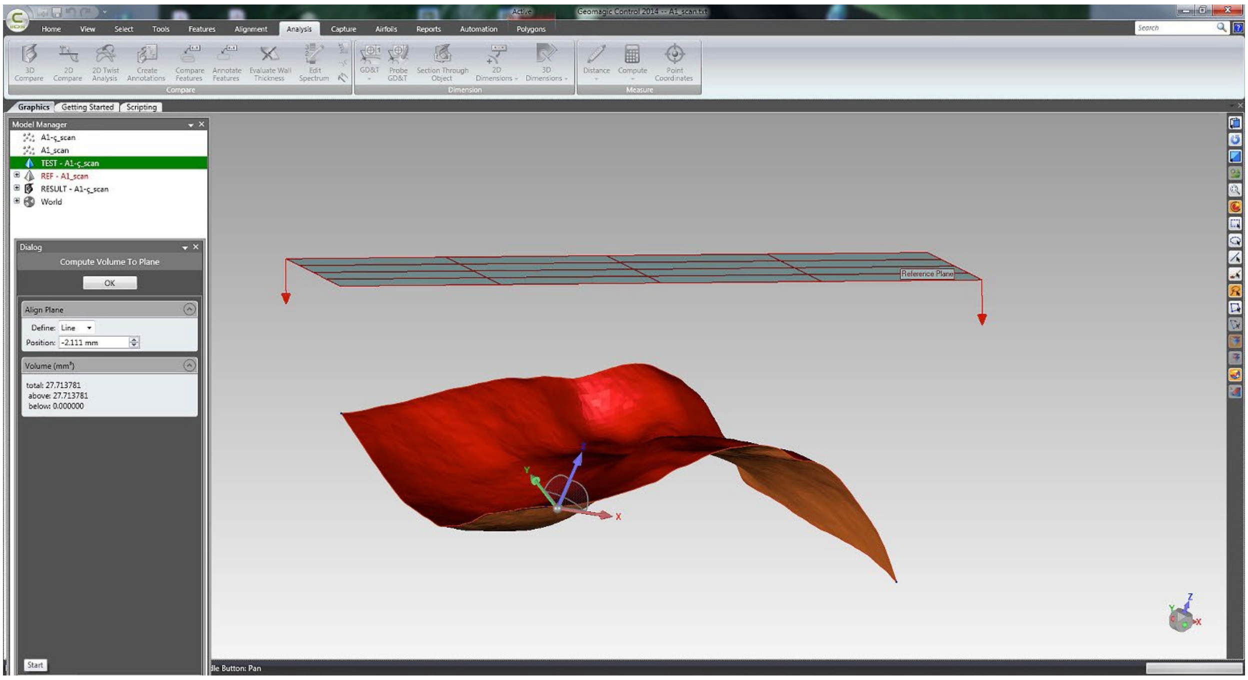

Figure 4. Calculation of the volumetric distance of the 3D images (before and after loading) to the plane

Statistical analysis

Data were analyzed using the SPSS V23 (IBM SPSS, Armonk, USA), and conformity to the normal distribution was evaluated using the Shapiro–Wilk test. The Kruskal–Wallis test was used to carry out group-wise comparisons of data that were not normally distributed, while multiple comparisons were analyzed using the Dunn test. The analysis results were presented as mean ± standard deviation and median (α = 0.05).

RESULTS

Descriptive statistics for volume loss after chewing simulation in each group are shown in Table 3.

Table 3. Comparison of wear values (mm^3) according to groups

Groups	Mean ± s. deviation	Median (min. - max.)	Test statistic	p
Group 1 (Admira Fusion+ Admira Fusion Flow)	0.460 ± 0.303	0.351(0.187 - 1.002)[a]	X^2=23.321	**0.006**
Group 2 (Admira Fusion x-tra 4 mm+ Admira Fusion x-base 2 mm)	0.316 ± 0.390	0.107 (0.001 - 1.191)[ab]		
Group 3 (Admira Fusion x-tra 2 mm+ Admira Fusion x-base 4 mm)	0.270 ± 0.338	0.118 (0.030 - 1.135)[ab]		
Group 4 (x-tra fil 4 mm+ x-tra base 2 mm)	0.077 ± 0.074	0.049 (0.022 – 0.161)[ab]		
Group 5 (x-tra fil 2 mm+ x-tra base 4 mm)	0.119 ± 0.085	0.109 (0.016 – 0.314)[ab]		
Group 6 (GrandioSo+ GrandioSo Flow)	0.158 ± 0.203	0.092 (0.011 – 0.503)[ab]		
Group 7 (Tetric N-Ceram+ Tetric N-Flow)	0.054 ± 0.069	0.014 (0.014 – 0.133)[ab]		
Group 8 (Tetric N-Ceram Bulk Fill 4 mm+ Tetric N-Flow Bulk Fill 2 mm)	0.059 ± 0.049	0.045 (0.007 – 0.138)[b]		
Group 9 (Tetric N-Ceram Bulk Fill 2 mm+ Tetric N-Flow Bulk Fill 4 mm)	0.068 ± 0.043	0.060 (0.030 – 0.114)[ab]		
Group 10 (Grandio Blocs)	0.115 ± 0.083	0.099 (0.035 – 0.228)[ab]		

∗ χ^2: Kruskal Wallis test, a-b: No difference between groups with the same letter

Group A+AF showed the maximum mean wear value (0.460 ± 0.303 mm^3), followed by groups AFX 4 mm+AFB 2mm (0,316 ± 0,390 mm^3), AFX 2 mm+AFB 4 mm (0.270 ± 0.338 mm^3), G+GF (0.158 ± 0.203 mm^3), X+XB 4 mm (0.119 ± 0.085 mm^3), GB (0.115 ± 0.083 mm^3), X 4 mm+XB 2 mm (0.077 ± 0.074 mm^3), TB 2 mm+TFB 4 mm (0.068 ± 0.043 mm^3), TB 4 mm+TFB 2 mm (0.059 ± 0.049 mm^3) and T+TF (0.054 ± 0.069 mm^3), respectively. A statistically significant difference in median wear change was observed between the groups ($p = 0.006$), and this could largely be attributed to the differences between groups A + AF and TB (4 mm) + TFB (2 mm).

DISCUSSION

Numerous *in vivo* and *in vitro* studies have compared the wear resistance of dental materials,[1,19] by using chewing simulators; simple configuration tests such as pin-on-plate, ball-on-plate, or pin-on-disc; and wear simulation devices to mimic wear conditions.[9,20,21] Steatite, stainless steel, aluminum, enamel, and zirconia have been used as antagonists in the studies.[11,18,22] The oral environment and chewing conditions are difficult to mimic in a standardized manner due to several parameters and, the current study used a chewing simulator to replicate them. Stainless steel balls were preferred in this study due to the challenges in standardizing the morphological and physical properties of enamel as an antagonist.[22] Based on previous evidence that suggests teeth and restorative materials are exposed to forces ranging between 20 and 120 N in the oral environment, a force of 50 N was applied to the restorations in the current study.[7]

Although composite restorative materials were developed as a solution to the limitations of amalgam (e.g., mercury toxicity and poor esthetic properties), their comparatively lower elastic modulus suggests that they may be more susceptible to deformation and abrasion.[15] Various advancements and modifications in resin composites have resulted in improved mechanical properties, although wear and fracture of the tooth restorations as a result of parafunctional activity still play a crucial role in the failure of restorations.[15, 23] CAD/CAM blocks have been predicted to exhibit higher wear resistance based on previous evidence that suggests the beneficial effects of polymerization under high pressure and temperature during the production process.[24] Grandio Blocs were preferred in the current study due to limited evidence on their wear resistance. Comparison of two-body wear resistance between nanohybrid CAD/CAM blocks and direct composites with different matrix structures showed no significant differences. Therefore, the hypothesis that direct resin restorative materials and indirect resin restorative material, the nanoceramic hybrid CAD/CAM block, would exhibit similar two-body wear resistance was accepted. A similar outcome was also observed in the study of Mörmann *et al.*; it was reported that there were no significant differences in two-body wear resistance between CAD/CAM block nanocomposites and direct light-cured composites, although examination under X1.00 K revealed singular thin microcracks on the surfaces of the CAD/CAM blocks and circular microcracks, micropores, and defects on the surfaces of the direct composites.[25]

Composites with different matrix structures have different functional groups, molecular weights, and reactivity ratios that affect the degree of conversion and cross-linking density. The wear that occurs initially in the organic matrix due to the biting force and lateral movement mechanism results in volume loss and surface roughness in inorganic monomer structures. The particles broken off from the inorganic monomer structure are compressed by the grinding process, preventing deformation of the organic matrix structure.[26] This process reveals the determining role of monomer structure and cross-linking density on the mechanical properties of the composite, such as two-body wear behavior.[27] The organic matrix exhibiting higher cross-linking density has a rigid and more stable polymer chain network. This network results in a lower breakdown or degradation risk under thermal stress. On the other hand, it should be considered that the correlation between cross-linking density and degradation temperature is multifactorial, such as the matrix chemical composition and the type or amount of fillers in the resin composite. UDMA has a higher degree of cross-linking compared to Bis-GMA, which may result in improved mechanical properties and wear resistance. It is thought that the properties of TEGDMA, which are vulnerable to water absorption and degradation, may negatively affect its wear resistance in the long term.[27, 28] In order to improve the esthetic and mechanical properties of composite materials, their matrix structure and filling content have been modified, and innovative dental restorative materials, such as Bis-GMA free ormocers, have been introduced. It has been suggested that the large matrix monomer content of ormocer-based composites decreases polymerization shrinkage and wear,[29] although studies examining the effects of brushing on Admira Fusion X-tra reported increased surface roughness and wear when compared to other composites.[30-32] Augusto *et al*. evaluated the effect of toothpaste on composites with different organic matrixes and found that ormocer-based composites exhibited higher wear values compared to methacrylate-based composites.[33] In contrast, Hahnel *et al*. reported that an ormocer-based composite, Admira, exhibited similar wear resistance when compared to micro and nano-filled materials.[11] In the current study, a statistically significant difference in two-body wear resistance was observed between groups A + AF and TB (4 mm) + TFB (2 mm), and no difference was observed between any of the other groups. Therefore, the hypothesis that different types of matrix structure (ormocer vs. methacrylate) would not affect the wear values of the restorations was partially rejected. Despite its higher filler content, Admira Fusion (84% w/w; silicon oxide, glass-ceramic filler size <1 µm; mean 0.7 µm, range 0.04–1.2 µm) exhibits higher wear values compared to Tetric N-Ceram Bulk Fill (75%–77% w/w; inorganic filler particle size 0.04–3 µm, mean 0.6 µm), which can be attributed to its organic matrix structure. The organic matrix of Tetric N-Ceram Bulk Fill composites, consisting of UDMA and Bis-GMA, may explain their relatively high wear resistance.

Wear resistance plays an important role in the clinical performance of restorations, highlighting the importance of material selection, and it is affected by various factors such as filler content, silanization, surface properties, and exposure and duration of force and temperature.[34] Some studies argue that high filler volume and small filler particle content contribute to wear resistance, while prepolymerized fillers increase the tendency to wear.[28, 35, 36] However, differences in filler particle shape, stiffness, and interparticle spacing make it difficult to establish a correlation between wear resistance, filler particle size, and filler volume.[19] With regards to the previous studies, Shinkai *et al*. reported that increased filler particle size resulted in lower two-body wear resistance, while filler loading had no significant effect on it.[37] Johnsen *et al*. suggested that effective wear resistance could be achieved with medium filler content, and particle size was not as important as previously reported.[38] Inconsistent outcomes may be due to differences in testing methods. Even though the filler content of the materials included in the current study is listed as follows; GrandioSo (% w/w: 89) > X-tra fil (% w/w: 86) ≈ Grandio Blocs (% w/w: 86) > Admira Fusion (% w/w: 84) ≈ Admira Fusion x-tra (% w/w: 84) > Tetric N-Ceram (% w/w: 80) > Tetric N-Ceram Bulk Fill (% w/w: 75-77). According to the result, group A+AF showed the maximum mean wear value, followed by groups AFX (4 mm) + AFB (2 mm), AFX(2mm)+AFB(4mm), G+GF, X (2 mm) + XB (4 mm), GB, X (4 mm) + XB (2 mm), TB (2 mm) + TFB (4 mm), TB (4 mm) + TFB (2 mm) and T+TF, respectively. Among BFCs, the higher wear resistance of methacrylate-based composites despite their lower filler content compared to ormocer-based bulk-fill composites can be attributed to their matrix structure and the photoinitiator Ivocerin, which increases the polymerization depth.

In bulk-fill resin composites, it is aimed to enable better light penetration and enhance curing depth by larger size of the filler content incorporated into the composition and the increasing translucency of the organic matrix.[39] It can be concluded that the increased size of filler particles compared to conventional composites has a negative effect on wear and roughness in bulk-fill composites such as X-tra fill and Tetric N-Ceram Bulk Fill. This can be explained by the presence of large depressions on the SEM images of the surface of the resin composite samples, indicating the separation of large filler particles.[40]

Sumino *et al*. compared the wear and flexural properties of flowable composites and universal resin composites and found that the mechanical properties of the former were superior.[41] For this reason, flowable composites were preferred as cavity liners during the restorations in the current study. The restorations were completed by capping the flowable composites with conventional composites. In order to investigate the indirect effects of material thickness on wear, cavities were restored using flowable BFC in two different thicknesses, 2 mm and 4 mm. The findings showed no statistically significant differences in wear resistance between groups AFX (4 mm) + AFB (2 mm) and AFX (2 mm) + AFB (4 mm); X (4 mm) + XB (2 mm) and X (2 mm) + XB (4 mm); and TB (4 mm) + TFB (2 mm) and TB (2 mm) + TFB (4 mm). Therefore, the hypothesis that groups restored with BFC in 2 mm and 4 mm layer thicknesses would exhibit similar two-body wear resistance was accepted.

The main limitations of this study were a) the use of a two-body abrasion test instead of a three-body abrasion device, and b) a partial simulation of the oral environment and chewing forces using a chewing simulator.

CONCLUSION

Within the limitations of this study, it can be concluded that:

1) Direct resin composite restorations and indirect composite CAD/CAM block restorations exhibit similar two-body wear behavior;
2) Comparison of ormocer and methacrylate-based resin composites revealed that wear behavior was not solely dependent on the matrix structure.
3) The wear resistance of bulk-fill composite restorations was not affected by the thickness of the layer.

Therefore, further *in vivo* and *in vitro* studies are necessary to improve the understanding of wear, a complicated process influenced by numerous factors.

Conflict of Interest

The authors had no conflict of interest to declare.

Financial Disclosure

The authors declared that they have received no financial support.

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Exploring AI-Driven Insights on Oral Implant Surgery: A Study of Four Different AI Applications

Oral İmplant Cerrahisinde Yapay Zeka Destekli Hasta Bilgilendirmesi: Dört Farklı Sistem Üzerine Karşılaştırmalı Bir İnceleme

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Citation: Yüce M Ö, Adalı E, Yaman İ, Alpaguter B, Karadeniz B. Exploring AI-Driven Insights on Oral Implant Surgery: A Study of Four Different AI Applications. *Int Arc Dent Sci.* 2025;46(1):19-25.

ABSTRACT

INTRODUCTION: Artificial intelligence (AI) chatbots are increasingly influential in healthcare, including in dental procedures like implants. However, their accuracy and reliability of the information they provide have not been comprehensively evaluated.This study aimed to assess the responses of four AI chatbots—ChatGPT-4, Gemini, Claude, and Microsoft Copilot—by comparing them with those provided by oral surgeons in response to common patient queries about dental implants.

METHODS: This study aimed to assess the responses of four AI chatbots—ChatGPT-4, Gemini, Claude, and Microsoft Copilot—by comparing them with those provided by oral surgeons in response to common patient queries about dental implants. Fifteen frequently asked questions were posed to the chatbots, and five oral surgeons scored their responses using the Global Quality Scale (GQS).

RESULTS: Statistical analysis revealed that ChatGPT received a significantly higher median rating than both Gemini and Copilot. Notably, Copilot exhibited negative Cronbach's α values, suggesting a lack of response consistency and raising concerns about reliability.

CONCLUSION: While all four AI chatbots provided responses that were at least satisfactory, the risk of patient misunderstanding remains. Patients are advised to validate AI-provided information obtained from these platforms with healthcare professionals and trusted sources, highlighting the importance of professional guidance in patient education

Keywords: *Artificial intelligence, patient information, implant surgery, chatbot*

ÖZ

GİRİŞ ve AMAÇ: Yapay zeka (AI) sohbet robotları, implantlar gibi dental prosedürler de dahil olmak üzere sağlık hizmetlerinde giderek daha etkili hale gelmektedir. Ancak, sağladıkları bilgilerin doğruluğu ve güvenilirliği kapsamlı bir şekilde değerlendirilmemiştir. Bu çalışmanın amacı, dört yapay zeka sohbet robotunun yanıtlarını, dental implantlarla ilgili yaygın hasta sorularına yanıt olarak ağız cerrahları tarafından verilen yanıtlarla karşılaştırarak değerlendirmektir.

YÖNTEM ve GEREÇLER: Sık sorulan on beş hasta sorusu oluşturulmuş ve dört YZ sohbet robotuna (Chat GPT-4, Gemini, Claude ve Microsoft Copilot) sunulmuş ve yanıtlar Orijinal Global Kalite Ölçeği (GQS) kullanılarak beş ağız cerrahı tarafından puanlanmıştır.

BULGULAR: İstatistiksel analiz ChatGPT'nin hem Gemini hem de Copilot'tan önemli ölçüde daha yüksek bir medyan derecelendirme aldığını ortaya koymuştur. Özellikle Copilot'un negatif Cronbach α değerleri sergilemesi, yanıt tutarlılığının eksik olduğunu göstermekte ve güvenilirlikle ilgili endişeleri artırmaktadır.

SONUÇ: Dört YZ sohbet robotu da en azından tatmin edici yanıtlar vermiş olsa da, hastaların yanlış anlama riski devam etmektedir. Hastalara, bu platformlardan elde edilen YZ tarafından sağlanan bilgileri sağlık uzmanları ve güvenilir kaynaklarla doğrulamaları tavsiye edilmekte ve hasta eğitiminde profesyonel rehberliğin önemi vurgulanmaktadır

Anahtar Kelimeler: *Yapay zeka, hasta bilgilendirme, implant cerrahisi, chatbot*

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Received Date: 01.11.2024
Accepted Date: 22.11.2024

INTRODUCTION

Artificial Intelligence (AI), encompassing diverse technologies that emulate human cognition, has brought about transformative changes across multiple sectors, including health care.[1] Among AI applications; chatbots—utilizing natural language processing (NLP) to simulate human conversation—are increasingly prevalent. Enabled by NLP, these chatbots interpret and respond to user queries in a conversational manner.[2]

With rapid advancements in AI, AI-powered chatbots have become increasingly common. These chatbots engage with users and enhance their capabilities through a variety of AI techniques.[3] They are widely used across numerous sectors including but not limited to finance, customer service, and education and are now making significant inroads in the healthcare industry as well[4,5]

In dentistry, however, the application of chatbots remains largely under-researched. AI-powered chatbots have substantial potential to provide patients with valuable information. Patients frequently turn to the internet for insights into their health concerns and possible treatment options, especially when faced with barriers in reaching a healthcare provider or seeking second opinions.[6] NLP platforms offer numerous advantages, including 24/7 availability, enabling patients to access information they need at any time. Nevertheless, chatbot responses can be inconsistent and may even mislead patients[7]

While NLP platforms provide advantages like 24/7 accessibility for patients, they also pose significant limitations. Chatbots may lack the empathy and understanding, which is crucial in health care,[8] and their responses might lead to miscommunication or misinformation, which could affect patients' health decisions. Often, these AI systems cannot fully grasp the nuances and emotional context of human language, making them a less reliable source of information compared to direct communication with healthcare professionals.[9]

This study aimed to assess the accuracy, quality and reliability of responses generated by four AI chatbots—ChatGPT, Gemini, Claude, and Microsoft Copilot—compared with responses from oral surgeons regarding common dental implant-related queries. 15 questions frequently asked by patients at our clinic were developed and posed to each chatbot as queries. Five oral surgeons rated these responses based on the Original Global Quality Scale (GQS).[10]

MATERIAL and METHODS

In this study, 15 frequently asked questions about dental implant procedures—covering topics such as risks, recovery times, and implant types—were developed to capture a comprehensive range of patient concerns.

In order to conduct this study, new accounts for the chatbots ChatGPT-4 (https://chat.openai.com), Google Gemini (https://gemini.google.com), Claude (Anthropic) (https://claude.ai) and Microsoft Copilot (https://copilot.microsoft.com) were created. Each question was posed to each chatbot three times on the same day each session began with a new chat to reduce potential biases and each question was asked three times in a row. Five oral surgeons who were blinded to each other's responses, evaluated the chatbot replies. Each question was carefully crafted to prevent any grammatical or syntactical mistakes.

Responses were rated on a five-point Likert-type GQS, providing scores based on specific quality criteria:[10]

Table 1. Global Quality Scale (GQS) Classification

1. Poor quality; poor flow of the video; most information missing; not at all useful.
2. Generally poor quality and poor flow; some information listed, but many important topics missing; of very limited use
3. Moderate quality; suboptimal flow; some important information adequately discussed, but other information poorly discussed; somewhat useful
4. Good quality and generally good flow; most of the relevant information listed, but some topics not covered; useful
5. Excellent quality and flow; very useful.

Table 2. The queries that were asked to ChatGPT-4, Google Gemini, Claude and Microsoft Copilot

Queries
1. What is the lifetime of a dental implant?
2. What is the duration of dental implant surgery?
3. Can a tooth be fitted immediately after the dental implant has been placed?
4. Will dental implants look like my natural teeth?
5. How many days of rest do I need after dental implant surgery?
6. Is it difficult to clean dental implants?
7. Is dental implant treatment painful?
8. How long does it take for a dental implant to heal?
9. What will happen if there is not enough bone in the jaw for dental implant treatment?
10. Is dental implant treatment expensive?
11. Is there a possibility that the body might reject the dental implant?
12. When can I start eating and drinking normally after dental implant operation?
13. Can a dental implant fall out?
14. Can my jawbone be damaged during a dental implant procedure?
15. Could a dental implant cause allergy?

Since the study was based on publicly available information, approval from the Institutional Review Board was not necessary.

Statistical analysis

The main analysis metric was the experts' ratings for each question across different AI systems. Cronbach's α score was used to assess reliability, while descriptive statistics (median, mean, and standard deviation) summarized the data. The Shapiro–Wilk test checked data normality, and the Kruskal–Wallis test compared ratings among AIs, with Bonferroni correction for multiple comparisons. The Friedman test was used to assess response consistency within each AI system over time. All statistical analyses were performed using SPSS 15.0 software for Windows (SPSS, Inc., Chicago, Illinois).

RESULTS

Three responses per question were collected, and we analyzed potential variations within each AI's responses per question (Table 3). The Friedman test results revealed significant differences for Claude in ratings of Q4, Q8, Q9, Q10, and Q12. For Q4, there was a statistically significant difference between the median rating at T0 (5) and T1 and T2 (3; $p < 0.05$). For Q8 and Q12, the median rating changed from 4 at T0 and T1 to 3 at T2, indicating significant differences ($p < 0.05$). For Q9, the median rating was 5 at T0 and 4 at T1 and T2, and this difference was also statistically significant (p=0.05). Finally, for Q10, the median rating was 4 at T0 and 3 at both T1 and T2, a difference that is borderline significant ($p = 0.050$). Overall, these results suggest that while ChatGPT, Gemini, and Copilot were consistent in their responses and received similar ratings repeatedly per question, Claude's responses somehow changed for 5 questions out of 10, and these changes were reflected in its quality ratings.

Table 1. Descriptive Statistics for Ratings (per Question and AI) and comparison of mean ratings among AIs per question.

	Chat GPT		Gemini		Claude		Copilot		
	Median	Mean± Std dev.	Median	Mean± Std dev.	Median	Mean± Std dev.	Median	Mean± Std dev.	p
Q1	4.00	3.87±0.69	3.00	3.40±0.55	3.00	3.40±0.72	3.67	3.40±0.72	0.546
Q2	4.00	3.87±0.51	4.00	3.60±0.55	3.00	3.53±1.10	3.33	3.27±0.49	0.566
Q3	4.33	4.40±0.37	4.00	4.33±0.47	3.33	3.67±0.67	3.00[b]	3.13±0.87	0.031*
Q4	4.00	4.20±0.45	4.00	3.80±0.45	3.33	3.80±0.84	3.00	3.27±0.43	0.115
Q5	3.00	3.20±0.45	3.00	3.27±0.43	3.67	3.60±0.43	3.00	3.00±0.00	0.086
Q6	4.00	4.07±0.15	3.67	3.53±0.51	3.67	3.87±0.69	4.00	4.00±0.00	0.124
Q7	4.00	3.93±0.15	3.00	3.47±0.65	4.00	4.20±0.65	3.00	3.40±0.55	0.154
Q8	4.00	4.27±0.43	3.00	3.40±0.55	3.67	3.53±0.38	3.00	3.20±0.45	0.025*
Q9	4.33	4.47±0.38	3.67	3.53±0.51	4.33	4.40±0.28	3.67	3.67±0.33	0.005*
Q10	4.00	4.00±0.24	4.00	3.67±0.62	3.33	3.27±0.49	3.67	3.80±0.18	0.136
Q11	4.00	3.73±0.55	4.00	4.00±1.00	3.67	3.87±0.69	3.33	3.47±0.51	0.755
Q12	4.00	3.80±0.45	4.00	3.47±0.96	3.67	3.73±0.49	4.00	3.93±0.15	0.922
Q13	4.00	3.80±0.84	4.00	4.33±0.62	3.67	3.80±0.18	3.67	3.80±0.87	0.528
Q14	3.00	3.40±0.55	4.00	3.80±1.30	3.33	3.53±0.61	3.00	3.20±0.84	0.748
Q15	4.00	3.87±0.51	4.00	3.60±0.55	4.00	3.87±0.77	4.00	4.07±0.28	0.529

*$p<0.05$

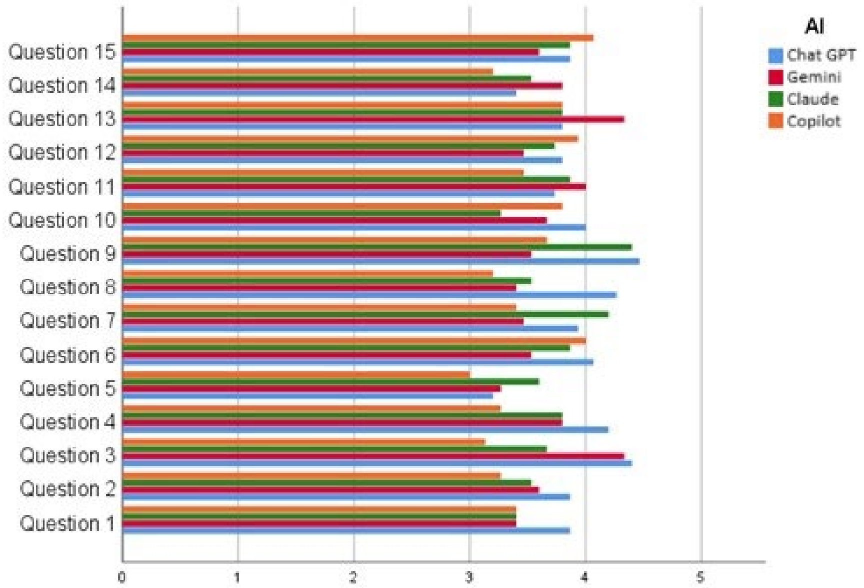

Figure 1. Mean scores for AI responses to 15 frequently asked questions, each asked three times

In addition to the question-by-question analysis (Table 1), we calculated overall scores for each AI system and conducted a comparative analysis using the Kruskal–Wallis test (Table 2). Results indicated statistically significant differences among the AI systems ($p < 0.001$), with ChatGPT' median rating notably higher than those of Gemini and Copilot. However, no significant differences were found between Claude's ratings and those of the other AIs.

Table 2. Overall evaluation of AI performances based on expert ratings

	Median	Mean± Std dev.	p
Chat GPT[a]	4.00	3.92±0.54	0.000*
Gemini[b]	4.00	3.68±0.70	
Claude[a,b]	3.67	3.74±0.64	
Copilot[b]	3.67	3.51±0.58	

*$p<0.05$

Table 3. Cronbach's Alpha Values for Rating Consistency of Different AIs for Each Question

Questions	ChatGPT	Gemini	Claude	Copilot
1	0.837	1.000	0.830	0.894
2	0.913	1.000	0.944	0.682
3	0.500	0.900	0.488	0.971
4	1.000	1.000	0.833	0.882
5	1.000	0.882	0.441	-
6	-	0.913	0.558	-
7	-	0.947	0.711	1.000
8	0.882	1.000	0.462	1.000
9	0.692	0.913	0.429	0.600
10	0.000	0.943	0.682	-1.000
11	0.889	1.000	0.558	0.913
12	1.000	0.976	0.341	-
13	1.000	0.943	-	0.949
14	1.000	1.000	0.591	1.000
15	0.913	1.000	0.849	-

In order to investigate the differences among AIs Kruskal Wallis tests were run per question, and significant differences were found among the AI systems (ChatGPT, Gemini, Claude, and Copilot). More specifically, median ratings of Q3 (4.33) and Q8 (4.00) for ChatGPT, were significantly greater than the median ratings of Q3 (3) and Q8 (3) for Copilot ($p<0.05$). This result indicates ChatGPT performed better compared to Copilot on these questions. On the other hand, ChatGPT and Claude both received median ratings of 4.33, but Gemini and Copilot had lower median ratings of 3.67 each ($p<0.05$), suggesting that ChatGPT and Claude responses for Q9 were received higher ratings than those of Gemini and Copilot (see Table 1 for detailed descriptives and test results).

Table 3 represents Cronbach's Alpha values for the expert ratings of different AI (ChatGPT, Gemini, Claude, and Copilot) responses for 15 questions. The Cronbach's Alpha values provide insights into the internal consistency of responses generated by each AI system for each question. The Cronbach's Alpha values for different AI methods range between 0.341 and 1.000, indicating generally consistent responses. Specifically, values between 0.70 and 1 suggest high reliability, values between 0.30 and 0.70 suggest moderate reliability, and values between 0 and 0.30 indicate low reliability. An inspection of Table 3 shows that $\alpha = 1.000$ under Copilot, this negative value for Cronbach's Alpha suggests that there was a potential issue with response reliability.

Table 4. Comparison of Repeated Ratings Within Each AI Per Question.

		T0		T1		T2		
		Median	Mean± Std dev.	Median	Mean± Std dev.	Median	Mean± Std dev.	p
Question 1	Chat GPT	4	4±1.22	4	3.8±0.45	4	3.8±0.45	0.717
	Gemini	3	3.4±0.55	3	3.4±0.55	3	3.4±0.55	-
	Claude	4	3.6±0.55	3	3.6±0.89	3	3±1	0.150
	Copilot	3	3.4±0.55	4	3.4±0.89	4	3.4±0.89	1.000
Question 2	Chat GPT	4	4±0.71	4	3.8±0.45	4	3.8±0.45	0.368
	Gemini	4	3.6±0.55	4	3.6±0.55	4	3.6±0.55	-
	Claude	4	4±1	3	3.4±1.14	3	3.2±1.3	0.061
	Copilot	3	3.2±0.45	3	3.2±0.45	4	3.4±0.89	0.717
Question 3	Chat GPT	5	4.6±0.55	4	4.2±0.45	4	4.4±0.55	0.368
	Gemini	4	4.2±0.45	4	4.4±0.55	4	4.4±0.55	0.368
	Claude	4	4.2±0.45	3	3.6±0.89	3	3.2±1.3	0.319
	Copilot	3	3.2±0.84	3	3.2±0.84	3	3±1	0.368
Question 4	Chat GPT	4	4.2±0.45	4	4.2±0.45	4	4.2±0.45	-
	Gemini	4	3.8±0.45	4	3.8±0.45	4	3.8±0.45	-
	Claude	5[a]	4.6±0.55	3[b]	3.6±0.89	3[b]	3.2±1.3	0.024*
	Copilot	3	3.2±0.45	3	3.2±0.45	3	3.4±0.55	0.368
Question 5	Chat GPT	3	3.2±0.45	3	3.2±0.45	3	3.2±0.45	-
	Gemini	3	3.4±0.55	3	3.2±0.45	3	3.2±0.45	0.368
	Claude	4	4±0	4	3.8±0.45	3	3±1	0.061
	Copilot	3	3±0	3	3±0	3	3±0	
Question 6	Chat GPT	4	4±0	4	4±0	4	4.2±0.45	0.368
	Gemini	3	3.4±0.55	4	3.6±0.55	4	3.6±0.55	0.368
	Claude	5	4.8±0.45	3	3.6±0.89	3	3.2±1.3	0.060
	Copilot	4	4±0	4	4±0	4	4±0	-
Question 7	Chat GPT	4	3.8±0.45	4	4±0	4	4±0	0.368
	Gemini	3	3.4±0.55	3	3.6±0.89	3	3.4±0.55	0.368
	Claude	4	4.2±0.45	4	4.4±0.55	4	4±1.22	0.607
	Copilot	3	3.4±0.55	3	3.4±0.55	3	3.4±0.55	-
Question 8	Chat GPT	4	4.4±0.55	4	4.2±0.45	4	4.2±0.45	0.368
	Gemini	3	3.4±0.55	3	3.4±0.55	3	3.4±0.55	-
	Claude	4[a]	3.8±0.45	4[a]	3.8±0.45	3[b]	3±0.71	0.050*
	Copilot	3	3.2±0.45	3	3.2±0.45	3	3.2±0.45	-
Question 9	Chat GPT	5	4.8±0.45	4	4.4±0.55	4	4.2±0.45	0.097
	Gemini	4	3.6±0.55	4	3.6±0.55	3	3.4±0.55	0.368
	Claude	5[a]	4.8±0.45	4[b]	4.4±0.55	4[b]	4±0	0.050*
	Copilot	4	4±0	4	3.6±0.55	3	3.4±0.55	0.097
Question 10	Chat GPT	4	4±0	4	4±0.71	4	4±0	1.000
	Gemini	4	3.6±0.55	4	3.6±0.55	4	3.8±0.84	0.368
	Claude	4[a]	3.8±0.45	3[b]	3±0.71	3[b]	3±0.71	0.050*
	Copilot	4	3.6±0.55	4	4±0	4	3.8±0.45	0.368
Question 11	Chat GPT	4	4±0.71	4	3.6±0.55	4	3.6±0.55	0.135
	Gemini	4	4±1	4	4±1	4	4±1	-
	Claude	5	4.8±0.45	3	3.6±0.89	3	3.2±1.3	0.060
	Copilot	4	3.6±0.55	3	3.4±0.55	3	3.4±0.55	0.368
Question 12	Chat GPT	4	3.8±0.45	4	3.8±0.45	4	3.8±0.45	-
	Gemini	4	3.6±1.14	4	3.4±0.89	4	3.4±0.89	0.368
	Claude	4[a]	4.2±0.45	4[a]	4±0	3[b]	3±1.22	0.039*
	Copilot	4	4±0	4	4±0	4	3.8±0.45	0.368
Question 13	Chat GPT	4	3.8±0.84	4	3.8±0.84	4	3.8±0.84	-
	Gemini	4	4.4±0.55	4	4.4±0.55	4	4.2±0.84	0.368
	Claude	4	4±0	4	4±0	3	3.4±0.55	0.050
	Copilot	4	4±1	4	3.8±0.84	3	3.6±0.89	0.223
Question 14	Chat GPT	3	3.4±0.55	3	3.4±0.55	3	3.4±0.55	-
	Gemini	4	3.8±1.3	4	3.8±1.3	4	3.8±1.3	-
	Claude	4	4±0.71	3	3.4±0.55	3	3.2±1.1	0.257
	Copilot	3	3.2±0.84	3	3.2±0.84	3	3.2±0.84	-
Question 15	Chat GPT	4	4±0.71	4	3.8±0.45	4	3.8±0.45	0.368
	Gemini	4	3.6±0.55	4	3.6±0.55	4	3.6±0.55	-
	Claude	4	4.4±0.55	4	3.8±0.84	3	3.4±1.14	0.060
	Copilot	4	4±0	4	4±0	4	4.2±0.84	0.717

*$p<0.05$

The Friedman test results show significant time-based differences in responses for Q4, Q8, Q9, Q10, and Q12 for only the Claude system. For Q4, Claude's median response decreased from 5 at T0 to 3 at T1 and T2, showing a significant reduction over time ($p < 0.05$). For Q8 and Q12, the median decreased from 4 at T0 and T1 to 3 at T2, indicating significant changes at T2 ($p < 0.05$). For Q9, the median changed from 5 at T0 to 4 at T1 and T2, with the reduction over time being statistically significant (p=0.05). For Q10, the median response dropped from 4 at T0 to 3 at both T1 and T2, with a borderline significance ($p = 0.050$). These results show a reduction in Claude's response scores over time for these specific questions.

DISCUSSION

With the widespread accessibility of online sources, individuals frequently seek answers to their health-related questions on major online platforms like YouTube, Google, and AI-driven chatbots, where access is simple and mostly free of charge. YouTube provides a vast array of professional discussions and visual content on health issues, enhancing user comprehension. However, as an ever-evolving media site, YouTube sees new content uploaded at a speed of roughly one video every minute. As a result, the outcomes of a search may differ based on when a query is made.[11]

Google offers a broad array of articles, research papers, and credible sources for exploring health concerns.[12] While it refrains from adding any commentary to the search results, which may reduce bias, it's important to recognize that Google as a search engine does not authenticate the information, which includes both academic sources but also advertisements. As such, individuals with limited knowledge may be at risk of encountering misinformation.[13]

In recent years, AI chatbots have also emerged as primary information sources for patients seeking accurate health data. However, as with many other fields, the quality of AI-generated data requires further examination, particularly regarding patient health.[14] This study evaluated responses from various AI chatbots, including ChatGPT-4, Google Gemini, Claude, and Microsoft Copilot, to patient-centered questions about dental implant procedures.

Our findings suggest that ChatGPT exhibits a relatively higher degree of internal consistency in its responses when the same questions are repeated. In contrast, Copilot's negative Cronbach's α value indicates low reliability, potentially due to a summarization approach across responses. However, this may result in patients receiving incomplete information.

As evidenced in Table 3, the greatest discrepancy was observed in the responses provided by the AI systems for questions 3, 8, and 9. Although some deviation was observed across other questions, these differences were not statistically significant. This demonstrates that the information accessible to patients online varies considerably depending on the specific circumstances and the quality of the questions. For example, Question 9, "What will happen if there is not enough bone in the jaw for dental implant treatment?" elicited responses ranging from general statements about bone supplementation to specific procedural details like "sinus lift, short implantation, all-on-four concepts, etc." This variability likely contributed to the observed statistical significance.

These results underscore the importance of healthcare professionals critically evaluating AI-generated content before sharing it with patients, as inconsistencies could lead to misunderstandings or misinformed treatment decisions.[15] Although AI has potential as a supplementary tool for patient education, it is essential to recognize its limitations. Ongoing updates and training for these AI systems are essential to align them with current medical guidelines and research, thereby enhancing their clinical utility.[16] Collaboration between healthcare professionals and AI developers could further enhance patient care by ensuring that AI complements, rather than replaces, human expertise.

This study concluded that ChatGPT, Google Gemini, Claude, and Microsoft Copilot generally provide satisfactory responses to patient inquiries and may be appropriate for patient use. However, it remains crucial for patients to interpret the source of the information accurately. Even with accurate data, misunderstandings are possible. Thus, patients should verify AI-provided information with healthcare professionals and the relevant channels.

In conclusion, the potential for chatbots to be trained and become more useful in the future is significant, with ongoing developments in various domains. Lifelong learning dialogue systems allow chatbots to learn from user interactions and external sources, enhancing their language understanding and conversational skills over time. (Kaynak) In healthcare, structured training methods for AI chatbots could be developed to ensure accuracy and safety, particularly in sensitive contexts like postpartum care.[17]

Limitations

This study has certain limitations, including the number of questions evaluated and potential changes in AI algorithms. While power analysis determined the sample size of expert surgeons, increasing the sample size could strengthen the study's conclusions.

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Comparison of Biomechanical Behavior of Dental All-Ceramics in Tooth or Implant Supported 3-Unit Fixed Partial Prosthesis with Finite Element Analysis

Dental Tam Seramiklerin Diş ve İmplant Destekli 3 Üyeli Sabit Bölümlü Protezlerde Biyomekanik Davranışlarının Sonlu Elemanlar Analizi ile Karşılaştırılması

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Citation: Botsalı M, Botsalı H. Comparison of Biomechanical Behavior of Dental All-Ceramics in Tooth or Implant Supported 3-Unit Fixed Partial Prosthesis with Finite Element Analysis. *Int Arc Dent Sci*. 2025;46(1):27-34.

ABSTRACT

AIM: The aim of the study is to calculate the stresses under vertical and oblique loadings in 3-unit fixed partial dentures using finite element analysis (FEA) and to evaluate the biomechanical behavior.

MATERIALS AND METHODS: 3-unit fixed partial dentures were designed as implant-supported and tooth-supported. Zirconia, lithium disilicate, and zirconia-reinforced lithium silicate were defined in geometric models. Occlusal forces of 400 N were applied vertically and 45° obliquely on the models, and the von Misses stresses occurring in the models were calculated with FEA. The safety factors of the materials were calculated and compared.

RESULTS: A higher amount of stress occurred in the models under 45° oblique loading compared to vertical loading. Under both loading conditions, it was observed that the stresses in implant-supported restorations were greater than the stresses in tooth-supported restorations. When the materials were compared, the high elastic modulus increased the value of stress and the highest safety factor belonged to zirconia.

CONCLUSION: The stresses occurring in fixed prosthetic restorations are affected by factors such as the direction of the force and the support of the restoration by the implant or prepared tooth. High elastic modulus increased the stress in the restoration, but the higher the bending strength value, the higher the safety factor.

Keywords: *Dental ceramic, Lithium disilicate, Finite element analysis, Zirconia-reinforced lithium silicate, Zirconia*

ÖZET

AMAÇ: Çalışmanın amacı; zirkonya ile güçlendirilmiş lityum silikat seramikten üretilen 3 üyeli sabit bölümlü protezlerde vertikal ve oblik okluzal kuvvetler altında oluşan streslerin sonlu elemanlar analizi (FEA) ile hesaplanması ve materyalin biyomekanik davranışının değerlendirilmesidir.

YÖNTEM ve GEREÇLER: Çalışmada 3 üyeli sabit bölümlü protezler implant destekli ve diş destekli olarak tasarlanarak geometrik modeller elde edilmiştir. Geometrik modellere zirkonya, lityum disilikat ve zirkonya ile güçlendirilmiş lityum silikat materyalleri tanımlanmıştır. Modeller üzerine 400 N'luk okluzal kuvvetler vertikal ve 45° oblik olarak uygulanmış ve modellerde oluşan von Misses stresleri FEA ile hesaplanmıştır. Materyalde oluşan en yüksek von Mises stres değerinin materyalin bükülme dayanımına oranlanarak hesaplanan güvenlik katsayısı (safety factor) elde edilerek malzemelerin güvenlikleri karşılaştırılmıştır.

BULGULAR: Vertikal yükleme koşullarına kıyasla 45° oblik okluzal yükleme altında modellerde daha yüksek miktarda stres oluşmuştur. Her iki yükleme koşulu altında, implant destekli restorasyonlarda oluşan streslerin diş destekli restorasyonlarda oluşan streslerden fazla olduğu görülmüştür. Materyaller karşılaştırıldığında yüksek elastik modulü, oluşan stresin rakamsal değerini artırmıştır ve en yüksek güvenlik katsayısı zirkonyaya ait olmuştur.

SONUÇ: Sabit protetik restorasyonlarda oluşan stresler, kuvvetin yönü ve restorasyonun implant yada prepare edilmiş diş tarafından desteklenmesi faktörinlerden etkilenmiştir. Yüksek elastik modülü restorasyonda oluşan stresi artırmıştır ancak bükülme dayanım değeri ne kadar yüksekse güvenlik katsayısı da o kadar yüksek bulunmuştur.

Anahtar Kelimeler: *Dental seramik, Lityum disilikat, Sonlu elemanlar analizi, Zirkonya ile güçlendirilmiş lityum silikat, Zirkonya*

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Received Date: 08.05.2024
Accepted Date: 12.12.2024

INTRODUCTION

Fixed partial dentures are an important treatment option used in the rehabilitation of partial tooth deficiencies; they provide the restoration of missing teeth, function, phonetics, and aesthetics. In cases where there are natural teeth adjacent to the edentulous space and these adjacent teeth provide sufficient tissue support, tooth-supported fixed partial dentures can be preferred as a traditional treatment method.[1] Today, implant-supported fixed partial dentures are an important alternative to traditional treatment methods. Prosthetic treatments performed with the support of dental implants provide 91% satisfaction among patients by enhancing their speech and chewing functions, as well as their comfort, self-confidence, and aesthetics. Both approaches continue to be employed in clinical settings.

Before the creation of all-ceramic systems, metal-ceramic restorations were believed to combine the mechanical properties of metal frameworks with the aesthetic qualities of ceramics.[2] However, the need for metal-free materials with good optical qualities and translucency similar to natural teeth has increased due to growing aesthetic standards and technological advancements. Thus, all-ceramic restorations with high aesthetic properties and biocompatibility have been developed. Over time, the improvement of all-ceramic materials' mechanical qualities and clinical indications has become more significant in addition to satisfying aesthetic standards. In recent years, a large number of new dental ceramic materials have been developed to enhance the mechanical stability of all-ceramic restorations and meet aesthetic expectations. Among these materials, lithium disilicate (LD) glass ceramics and oxide ceramics such as zirconia have been found to be promising for different indications.[3]

Compared to polycrystalline ceramics like zirconia, which have excellent strength, lithium disilicate glass ceramics have superior translucency, which gives them high aesthetic qualities. However, their usage in posterior regions is limited by their inferior mechanical characteristics when compared to zirconia. Zirconia-reinforced lithium silicate (ZLS) ceramics are a new generation material that combines the positive mechanical properties of zirconia with the aesthetic qualities of LD glass ceramics.[4] The addition of zirconia to the structure is thought to increase the material's mechanical strength by stopping cracks from spreading. Because of this advantageous characteristic, ZLS ceramic material has lately emerged as one of the most popular and favored prosthetic materials and has been proven to be dependable for clinical application.

The quantity and distribution of stress in dental systems (prosthetic parts, implants, surrounding bone tissue, etc.) are examined using finite element analysis (FEA), a computer-aided digital testing technique used in dentistry. FEA is a probabilistic analysis used to examine the force-stress interaction and predict the reliability of all-ceramic restorations under occlusal loading.[5]

In recent years, many studies have proven that ZLS restorations possess fracture strength values that exceed physiological occlusal chewing forces.[6] The indications for ZLS ceramics have been expanded to include their use in posterior single crowns and multi-unit fixed partial dentures (up to 3 units) where the last abutment is the second premolar.[7] With the expanding range of indications, studies conducted on this material, which stands out in current clinical use, are gaining importance.

Glass ceramics are only indicated for a maximum of 3-unit restorations in multi-unit fixed partial dentures, where the second premolar serves as the final abutment.[7] This study start with the observation that, despite extensive experimental and clinical research[8] on the success rate and mechanical properties of zirconia-reinforced lithium silicate (ZLS) as a glass ceramic in anterior and posterior single crowns, there are very few studies examining the biomechanical properties in multi-unit restorations.

Therefore, our study examined ZLS ceramics, zirconia, and lithium disilicate ceramics regarding the stresses generated by tooth-supported and implant-supported 3-unit fixed partial dentures using FEA. Nevertheless, the stress generated in the restoration alone is inadequate to demonstrate the material's performance; so, the safety factor was determined by comparing the maximum von Mises stress in the restoration with the material's flexural strength, allowing for a comparison of material safety. The first null hypothesis proposes that the stress induced in zirconia restorations will be lower; the second hypothesis states that zirconia would have a greater safety factor, so enhancing its safety.

MATERIALS AND METHODS

In our study, 3-unit fixed partial dentures were designed in two different ways: tooth-supported and implant-supported. In the tooth-supported restoration model (D), a 3-unit fixed partial denture was designed using the canine and second premolar teeth as abutments, providing a treatment option for the absence of the mandibular right first premolar tooth (Figure 1a). In the implant-supported restoration model (I), a 3-unit fixed partial denture was designed using implants positioned in the locations of the mandibular canine and second premolar teeth as abutments (Figure 1b). All models were defined using zirconia (Zr; inCoris TZI; Sirona Dental Systems, Bensheim, Germany), lithium disilicate (LD; IPS e-max CAD; Ivoclar Vivadent AG, Schaan, Liechtenstein), and zirconia-reinforced lithium silicate (ZLS; VITA Suprinity PC; Vita Zahnfabrik, Bad Säckingen, Germany) (Table 1).

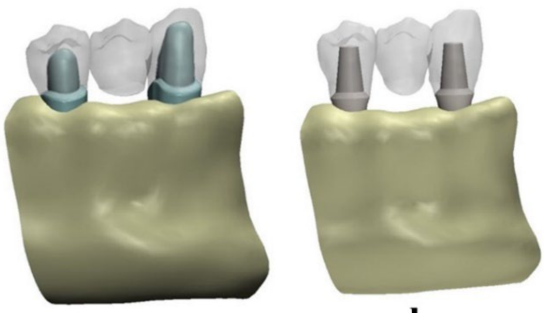

Figure 1. Finite element models used in the study; a: Tooth-supported 3-unit fixed partial denture model (D), b: Implant-supported 3-unit fixed partial denture model (I).

Table 1. Evaluated models, symbols, and specified materials

Models	Model Symbol	Product and Manufacturer
Tooth-supported zirconia	D-Zr	inCoris TZI; Sirona Dental Systems, Bensheim, Germany
Tooth-supported lithium disilicate	D-LD	IPS e-max CAD; Ivoclar Vivadent AG, Schaan, Liechtenstein
Tooth-supported zirconia-reinforced lithium silicate	D-ZLS	VITA Suprinity PC; Vita Zahnfabrik, Bad Säckingen, Germany
Implant supported zirconia	I-Zr	inCoris TZI; Sirona Dental Systems, Bensheim, Germany
Implant-supported lithium disilicate	I-LD	IPS e-max CAD; Ivoclar Vivadent AG, Schaan, Liechtenstein
Implant-supported zirconia-reinforced lithium silicate	I-ZLS	VITA Suprinity PC; Vita Zahnfabrik, Bad Säckingen, Germany

Obtaining Solid Models

The study's models included the mandibular canine, first and second premolar teeth, enamel, dentin, periodontal ligament, bone tissue (cortical bone and spongious bone), resin cement, titanium implant, and titanium abutment. To accurately represent the anatomical structure, the teeth were obtained from a tomographic image utilizing the Mimics® (Materialise, Belgium) tissue modeling software, and the standard tessellation language (STL) file extensions generated by this software were imported into the SOLIDWORKS® (Dassault Systemes, USA) application. In implant-supported models, depending on the standard abutment size, restoration thicknesses on the axial surfaces of anterior and premolar crowns can reach up to 2.5 mm, while in tooth-supported models, the restoration thickness for crowns is 2 mm. A connection cross-section of 16 mm² (4 mm × 4 mm), a pontic width of 8 mm, a shoulder step finish line of 1 mm, and a resin cement thickness of 50 µm were specified for all models.

Finite Element Analysis

The solid models have been imported into the SOLIDWORKS Simulation (SOLIDWORKS® Dassault Systemes, USA) software for FEA. Solid models were transformed into mathematical models via pre-processing processes, which included defining material properties before analysis, determining contact relationships, setting boundary conditions, and creating the finite element mesh. The elasticity modulus (Young's modulus) and Poisson's ratio values, which reflect the mechanical properties of each tissue and material, which reflect the mechanical properties of each tissue and material, have been determined based on the literature and the manufacturer's guidelines (Table 2). The cortical bone was fixed at the surfaces in contact with the jaw, and the other components were considered to be in bonded contact with each other, and analyses were performed accordingly.

Table 2. The modulus of elasticity, Poisson's ratio, and flexural strength values of tissues and materials

Tissues and Materials	Modulus of Elasticity (GPa)	Poisson's Ratio	Flexural Strength (MPa)	References
Enamel	84,1	0,33		9
Dentin	18,6	0,32		9
Periodontal Ligament	0,05	0,45		10
Spongious Bone	1,37	0,30		11
Cortical Bone	13,7	0,30		11
Titanium	110	0,30		11
inCoris TZI	210	0,26	900*	12
IPS e-max CAD	102,7	0,22	530*	13
VITA Suprinity PC	70	0,21	420*	7
Resin Cement	8,3	0,35		12

* Values provided by manufacturers.

The amplitude and direction of occlusal loads are critical for estimating the longevity of materials utilized in fixed partial dentures; therefore, 400 N loads were applied to the models in both a vertical and a 45° oblique direction (from lingual to buccal) to simulate maximum occlusal loading during mastication.

Vertical Loading: A occlusal load of 400 N was applied vertically throughout the entire occlusal surface of the restoration, paralleled with the long axis of the teeth (Figure 2a).

Oblique Loading: A occlusal load of 400 N was applied obliquely at the 45° angle to the long axis of the teeth throughout the entire occlusal surface of the restoration (Figure 2b).

Occlusal loads were applied on the surfaces of the teeth that interact with food. It has been assumed that the foods contact the palatal surface of the anterior crown[10] and the occlusal surface of the posterior crown[14] (Figure 2). Following confirming the loading conditions, the finite element mesh was created with second-order tetrahedral elements, as shown in Figure 3. After concluding the pre-processing phases, the 3-unit fixed-partial prosthesis models became appropriate for analysis, and finally, the analysis was solved to obtain the highest von Mises stress values.

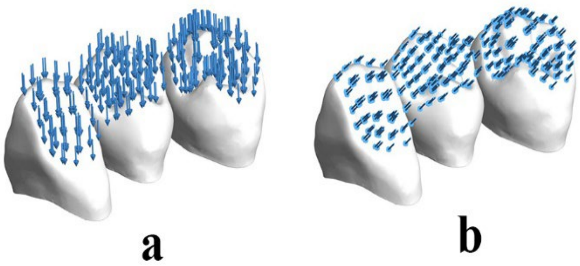

Figure 2. Occlusal loads applied to the models; a: Vertical loading, b: Oblique loading.

Calculation of The Safety Factor

The highest von Mises stress values were recorded after applying occlusal loading to the models. The safety factors for each model were obtained separately by using the flexural strength values obtained from the manufacturers and the highest von Mises stress values, with follow equation.

$$\textit{Safety Factor} = \frac{\textit{Flexural Strength}}{\textit{Maximum von Mises Stress}}$$

RESULTS

Assessment of The von Mises Stress Results Under Vertical Loading

Stress Level and Concentration Zones in Tooth-Supported Models (D)

The D-ZLS, D-LD, and D-Zr models exhibited peak von Mises stress in the connector regions, recorded at 65.64 MPa, 66.21 MPa, and 68.67 MPa, respectively. The second greatest value was recorded at the interface between the prepared tooth and restoration, as well as at the margins next to the connector area (Figure 3a).

Stress Level and Concentration Zones in Implant-Supported Models (I)

The I-ZLS, I-LD, and I-Zr models exhibited peak von Mises stress in the connector regions, recorded at 95,92 MPa, 97,83 MPa and 106,80 MPa, respectively. The second greatest value was recorded at the interface between the abutment and restoration, as well as at the margins next to the connector area (Figure 3b).

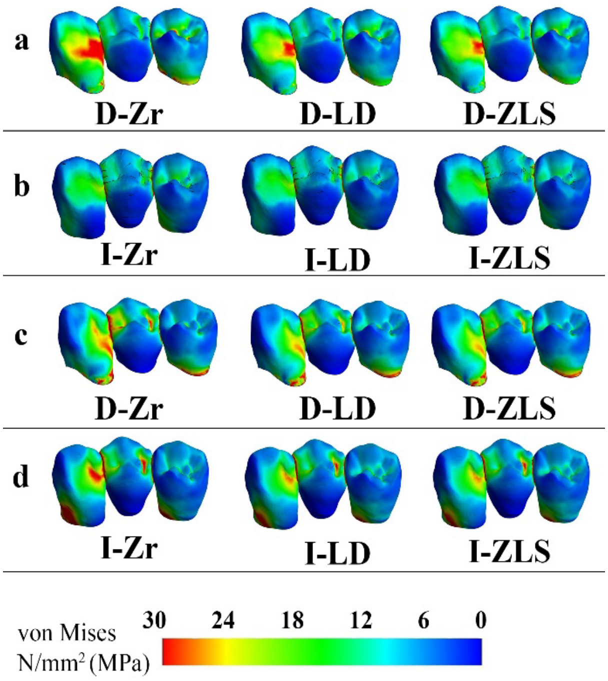

Figure 3. Stress distributions in the models resulting from loadings (a: Stress distributions in tooth-supported models resulting under vertical loading, b: Stress distributions in implant-supported models resulting under vertical loading, c: Stress distributions in tooth-supported models resulting under oblique loading, d: Stress distributions in implant-supported models resulting under oblique loading)

Assessment of The von Mises Stress Results Under Oblique Loading

Stress Level and Concentration Zones in Tooth-Supported Models (D)

The D-ZLS, D-LD, and D-Zr models exhibited peak von Mises stress in the connector regions, recorded at 123,56 MPa, 130,37 MPa and 153,02 MPa, respectively. The second greatest value was recorded at the interface between the prepared tooth and restoration, as well as at the margins next to the connector area (Figure 3c).

Stress Level and Concentration Zones in Implant-Supported Models (I)

The I-ZLS, I-LD, and I-Zr models exhibited peak von Mises stress in the connector regions, recorded at 188,83 MPa, 196,61 MPa and 227,64 MPa, respectively. The second greatest value was recorded at the interface between the abutment and restoration, as well as at the margins next to the connector area (Figure 3d).

Graphical Visualization of Results in Models

Evaluation of the graph showing von Mises stress values across all models reveals that the implant-supported 3-unit fixed partial denture models exhibit elevated stress levels, with oblique loading conditions inducing greater stress than vertical loading conditions in all restorations. Furthermore, the differences between oblique loading and vertical loading is greater in implant-supported models (Figure 4).

Evaluation of Safety Factors in Models

The safety factor, obtained by relating the maximum von Mises stress in the models to the material's flexural strength, was computed for each model and presented in Table 3. Upon examination of the table, it is evident that in both tooth-supported and implant-supported models, zirconia exhibits the maximum safety factor under both loading conditions, therefore indicating that zirconia is the safest alternative.

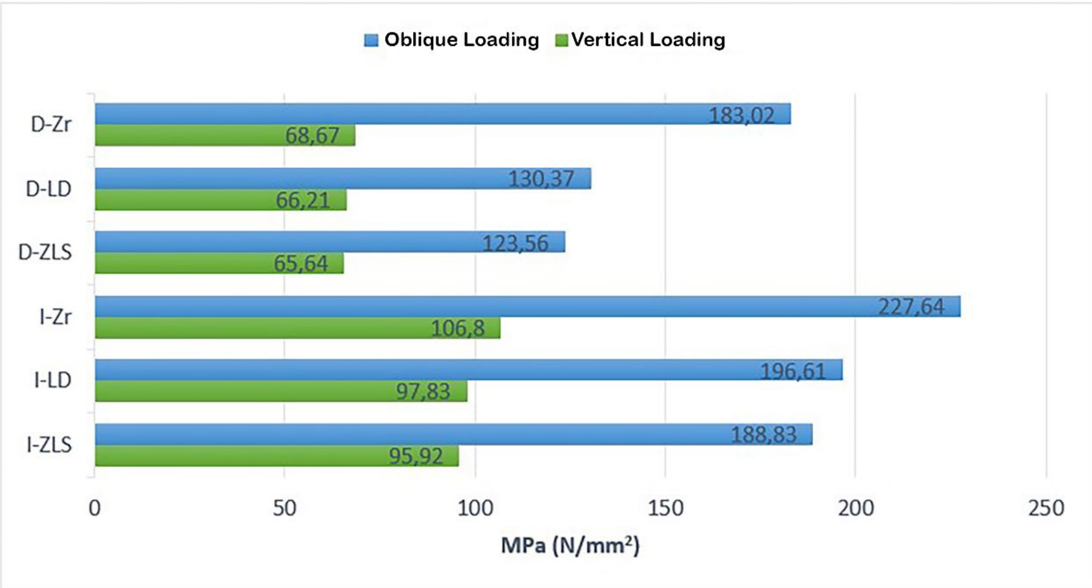

Figure 4. The highest von Mises stress values generated in the models

Table 3. Safety factors of the models.

	Under Vertical Loading		Under Oblique Loading	
	Tooth-supported	**Implant-supported**	**Tooth-supported**	**Implant-supported**
Zr	13,10	8,42	4,91	3,95
LD	8,00	5,41	4,06	2,69
ZLS	6,39	4,48	3,39	2,27

DISCUSSION

A survey research (n=721) revealed that most dentists favored all-ceramics for fixed restorations. Twenty percent of these dentists favored ZLS for single-unit fixed prostheses in the anterior region, but they selected lithium disilicate for multi-unit fixed prostheses up to the second premolar in the posterior region. Neither ZLS nor lithium disilicate ceramics were favored for multi-unit fixed prostheses in the molar region, as the indications for these ceramics do not include posterior fixed prostheses.[15] This study aims to examine the biomechanical behavior of ZLS in three-unit fixed partial dentures, an area that has been inadequately explored compared to the extensive experimental and clinical research[8] validating its efficacy in single-unit restorations, and to compare it with lithium disilicate and zirconia, thereby enhancing its appeal to dental practitioners. A breakthrough designed to enhance restorations, namely monolithic restorations, has been created to prevent some complication, such as porcelain veneer chipping observed in zirconia-based restorations. Consequently, in our research, ceramics were formulated and assessed as monolithic.

Occlusal loads significantly influence the functional efficacy of the prosthesis. Occlusal loading during function depends on biting force, which is affected by variables including gender, age, dental condition, and the efficacy of the masticatory system. Varga et al. documented the bite force in the right posterior region as 777.7 ± 78.7 N for men and 481.6 ± 190.4 N for women.[16] In our study, average bite force values for men and women resulted in the application of 400 N forces to the models both obliquely and vertically. Oblique occlusal forces impose greater stress on prosthetic restorations than vertical and horizontal forces, necessitating increased clinical attention. The research revealed that the von Mises stresses under oblique loading exceeded those under vertical loading across all models. Numerous research investigating the impact of occlusal loading direction on mechanical response have demonstrated that oblique loading influences the mechanical response and results in increased stress values relative to vertical loading.[17]

The findings indicate that the method is considered honest due to the similarity of results from FEA with the comparative test results, and that the outcomes derived exclusively from FEA are adequate.[29] Consequently, the study employed the FEA method. During the assessment of the analytical outcomes, von Mises stresses were computed. The von Mises stresses, which express the equivalent stress in the material under load, convey information regarding the stresses and densities within the material, while also assessing the material's stress resistance.[5] The safety factor values, calculated from The maximum von Mises stresses and the materials' bending strength, have been acquired, yielding the most precise data regarding material safety.

Dental caries, traumas, and periodontal diseases resulting in tooth loss are prevalent concerns in dentistry requiring treatment. Regardless of the etiology of partial tooth loss, appropriate function can be restored with tooth or implant-supported prostheses. In conventional tooth-supported treatment approaches, depending on the remaining hard and soft tissues of patients, the success rate is documented at 50% over 15 years, attributed to biological risk factors that may adversely impact the prognosis of adjacent teeth. Implant-supported fixed dentures, a significant alternative to conventional treatment procedures, demonstrate a success rate of up to 97% over a 10-year follow-up period.[1] Therefore, in our study, 3-unit restorations were fabricated with both tooth and implant supported and evaluated regarding the stresses they generated. FEA results indicate that the stresses in implant-supported restorations exceed those in tooth-supported restorations. Implant-supported restorations lack periodontal tissues and are incapable of absorbing intraoral stresses. Consequently, they have heightened sensitivity to occlusal forces, resulting in increased stress accumulation on the restorations.[19] Pjetursson et al. have indicated that the occurrence of technical complications for implant-supported fixed prostheses is considerably increased, with a 10-year survival rate of 86.7% for implant-supported fixed partial prostheses and 89.2% for tooth-supported fixed partial prostheses. In contrast to our findings, Rand et al. reported in their study that analyzed 4-unit fixed partial dentures designed from monolithic zirconia in three configurations (tooth-supported, implant-tooth combination, and implant-supported) using FEA, the highest stress was observed in the tooth-supported model, whereas the lowest stress was noted in the implant-supported model.[20] Their results indicated that increased rigidity of the support correlates with reduced stresses in the restoration. Consequently, additional research is required to assess the stresses generate in restorations of implant and tooth-supported models. In multi-unit fixed partial dentures, the unsupported area, termed as the body, which replaces the lost teeth, triggers deformations in the restorative structure, hence increasing stress in the connector regions. Research on multi-unit fixed restorations has demonstrated that variations in connector thickness influence stress, and that an increase in connector area substantially enhances mechanical strength.[21] This condition emphasizes the need of employing connectors of optimal thickness concerning the biomechanical aspects of 3-unit fixed partial dentures. Borba et al. highlighted in their experimental study that restorations with a connector area of 16 mm² produced superior mechanical outcomes and demonstrated their suitability for clinical application.[22] Nevertheless, while it has been documented that the stress produced reduces inversely with the thickness of the connector, research indicates that regardless of the restoration material and connector thickness, the stress in the restoration is predominantly concentrated in the connector regions.[23] In this context, the observation that the maximum von Mises stress value across all models in our study was recorded in the connector regions aligns with the biomechanical characteristics of 3-unit fixed-partial dentures, and the stress results obtained are not above the flexural strength thresholds of the materials. This issue is attributed to the thickness of the connector chosen (16 mm²). In clinical use, to enhance the longevity of 3-unit fixed partial dentures, a connector thickness of no less than 16 mm² (4 × 4 mm) is recommended.

In our research, the monolithic Zr exhibited the greatest von Mises stress value, leading to the rejection of our initial null hypothesis. Dal Piva et al. assessed the stress induced by different monolithic ceramic restorations in a posterior molar crown model utilizing FEA.[14] This study, including zirconia, lithium disilicate, and zirconia-reinforced lithium silicate specimens, indicated that an increase in the material's elastic modulus correlates with elevated stress in the restorations.

The safety factor for each model has been calculated and shown in Table 3. The results support our second null hypothesis and indicate that the Zr models have the highest safety factor. Notwithstanding the increased stress experienced by the models, Zr's superior safety factor can be attributed to its high flexural strength. Researches indicates that materials with increased crystalline content have superior mechanical performance.[24] Liu et al. evaluated the characteristic strength and estimated survive of Zr, LD, and ZLS dental ceramics, observing that Zr exhibits the highest characteristic strength among the three materials.[25] However, considering the limitations of our study, long-term clinical studies are required to corroborate our findings.

CONCLUSION

Our research revealed that the majority of stress occurred in the connector of the implant-supported zirconia restoration under oblique loading, although zirconia also exhibited the highest safety factor. The stress experienced in fixed prosthetic restorations made from zirconia, lithium disilicate, and zirconia-reinforced lithium silicate ceramics is determined by the load direction and the type of support, either an implant or a prepared tooth. The higher elastic modulus of the material increases the stress in the restoration, while the substantial safety factor relies on the high flexural strength value. Moreover, in 3-unit restorations, regardless of the material type, load direction, and support type, stress concentrations were noted in the connector regions, highlighting the significance of optimal connector thickness in clinical applications.

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Evaluation of Dentists' Knowledge on Dental Management in Hemodialysis Patients

Diş Hekimlerinin Hemodiyaliz Hastalarında Dental Yaklaşıma Yönelik Bilgi Düzeylerinin Değerlendirilmesi

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Citation: Özer N E, Turhal RI, Boyacıoğlu H, Güneri P. Evaluation of Dentists' Knowledge on Dental Management in Hemodialysis Patients. *Int Arc Dent Sci*. 2025;46(1):35-40.

ABSTRACT

INTRODUCTION: To determine knowledge levels of dentists, dental specialists, and dental students regarding dental approaches in hemodialysis patients.

METHODS: Recommendations for dental treatment of hemodialysis patients were identified by reviewing literature and guidelines from official organizations. Recommendations were translated from English to Turkish, reviewed, and revised by a committee. Survey containing eight questions was administered to 20 dentists, and feedback was collected. Survey was distributed digitally to participants as a link, demographic characteristics and education levels were recorded. Data were evaluated using descriptive analyses and chi-square test (p<0.05).

RESULTS: 314 individuals participated, including 193 general dentists, 39 specialists, and 82 dental students. The highest correct answers were for bleeding problems (87.9%) and infectious disease risk (87.3%). The most incorrect answers were on premedication (31.2%) and local anesthetic choice (58.3%). Students answered the prophylaxis question correctly more often than dentists and specialists (p=0.000), while dentists and specialists answered the infectious disease risk questions more accurately than students (p=0.009).

CONCLUSION: Dental curriculum and postgraduate programs should include current information on treating hemodialysis patients, and general dentists should participate in periodic training sessions.

Keywords: *Chronic kidney disease, hemodialisis, dental treatment, dentist*

ÖZ

GİRİŞ ve AMAÇ: Serbest ve uzman diş hekimleri ile diş hekimliği öğrencilerinin hemodiyaliz hastalarında dental yaklaşıma yönelik bilgi düzeylerinin belirlenmesi.

YÖNTEM ve GEREÇLER: Literatür ve resmi kuruluşların rehberleri incelenerek, hemodiyaliz hastalarının dental tedavilerine yönelik tavsiyeler belirlendi. Tavsiyeler İngilizceden Türkçeye çevrilerek bir kurul tarafından incelendi ve düzenlendi. Sekiz adet soru içeren anket 20 diş hekimine uygulandı ve geri bildirimler alındı. Anket dijital ortamda katılımcılara link olarak iletildi, demografik özellikleri ve eğitim düzeyleri kaydedildi. Veriler tanımlayıcı analizler ve ki-kare testi ile değerlendirildi (p<0.05).

BULGULAR: Çalışmaya toplam 193 diş hekimi, 39 uzman diş hekimi ve 82 diş hekimliği öğrencisi olmak üzere toplam 314 kişi katıldı. En yüksek oranda doğru yanıtlanan sorular kanama problemleri (%87,9) ve bulaşıcı hastalık riskine (%87,3) yönelikti. Katılımcılar en çok premedikasyon (%31,2) ve lokal anestezik tercihi (%58,3) konularında hatalı yanıtlar verdiler. Öğrencilerin profilaksiye yönelik soruya verdikleri doğru yanıtlar, serbest ve uzman diş hekimlerinden anlamlı şekilde yüksekti (p=0.000). Serbest ve uzman dişhekimleri ise bulaşıcı hastalık riskine yönelik soruları öğrencilere göre daha yüksek oranla doğru yanıtladılar (p=0.009).

SONUÇ: Diş hekimliği eğitim müfredatı ve mezuniyet sonrası eğitim programlarında hemodiyaliz tedavisi gören bireylerde dental tedavi yaklaşımına yönelik güncel bilgileri içeren eğitimlerin artırılması ve serbest diş hekimlerinin bu eğitimlere periyodik olarak katılması sağlanmalıdır.

Anahtar Kelimeler: *Kronik böbrek hastalığı, hemodiyaliz, dental tedavi, diş hekimi*

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Received Date: 29.07.2024
Accepted Date: 20.09.2024

INTRODUCTION

Chronic kidney disease (CKD) is a global public health concern, affecting around 10% of the population. It is characterized by a glomerular filtration rate (GFR) below 60 mL/min/1.73 m² for at least three months, along with structural or functional kidney abnormalities.[1] Given its progressive nature, some patients may require dialysis or kidney transplantation.[1] Hemodialysis, a medical procedure aimed at restoring impaired kidney function, plays a life-saving role in the management of advanced-stage CKD. During dialysis, blood circulation is accessed via an arteriovenous shunt or fistula, allowing excess fluids and metabolic waste to be removed from circulation through semipermeable membranes. However, since hemodialysis cannot fully replicate kidney function, patients often experience uremic syndrome and various systemic complications related to CKD and dialysis.[2] Uremic syndrome is a clinical condition primarily characterized by microangiopathic hemolytic anemia, thrombocytopenia, and acute kidney injury, and it is recognized as one of the leading causes of acute kidney injury, especially in pediatric patients.[2]

Oral manifestations associated with CKD and hemodialysis include pale mucosa, uremic stomatitis, petechiae, ecchymoses, gingival inflammation and hypertrophy, attachment loss, taste alterations, decreased salivary flow, spontaneous bleeding, hairy tongue, lichenoid reactions, mucosal ulcerations, angular cheilitis, and candidiasis.[3] Chronic periodontitis, commonly observed in adult hemodialysis patients, amplifies chronic inflammation, increasing the risk of cardiovascular disease and elevating CKD-related morbidity and mortality.[3-5] Invasive dental procedures in CKD patients are complicated by altered drug metabolism, immune dysfunction, bone metabolism changes, and increased risks of bleeding and infection. Timely oral examinations and regular dental check-ups are crucial for identifying potential infection foci, ensuring adequate oral hygiene, and improving disease prognosis.[3,6]

Hemodialysis patients, who frequently receive multiple blood transfusions, are at high risk for hepatitis B and C infections.[7,8] Although infective endocarditis is a relatively rare complication of hemodialysis, it remains a serious condition that must be taken into consideration.[7-9] While scientific evidence is insufficient to confirm that invasive dental procedures alone cause bacterial endocarditis, the immunosuppressive state and increased infection risk in hemodialysis patients warrant careful consideration of prophylactic antibiotic administration.[9-11] These patients are particularly prone to complications, including increased bleeding tendencies from anemia and anticoagulant therapy, elevated circulating nitrogenous compounds, and platelet function disorders.[12]

As the number of patients undergoing hemodialysis for chronic kidney disease increases, the number of CKD patients seeking dental care is expected to rise as well. Simple modifications in dental treatment planning and appropriate precautionary measures can significantly reduce the risk of disease- or procedure-related complications.[13] Precautions that dentists should consider in cases of cardiovascular diseases and immunosuppressive conditions have been addressed in both pre- and post-graduate education.[13] However, with ongoing advancements in the field, it is essential for dentists to remain informed on potential complications and best approaches for managing hemodialysis patients. This study aims to assess the knowledge of general dentists, dental specialists, and dental students regarding dental management of hemodialysis patients.

MATERIALS AND METHODS

The study protocol was approved by the Research Ethics Committees of the Faculty of Medicine, Ege University (16-3.2/8). Currently, no institution or organization has established official guidelines for the dental treatment of hemodialysis patients. Therefore, recommendations and guidelines for dental care in hemodialysis patients were established by reviewing the prophylactic recommendations of organizations such as the American Heart Association (AHA) for infective endocarditis, along with the existing dental and medical literature.[6-8,14-17] These recommendations and measures were translated from English to Turkish and then back into English to evaluate the consistency of the Turkish text with the original version. The comprehensibility and accessibility of the text were reviewed by a panel comprising 5 dental specialists, a bilingual individual fluent in both Turkish and English (a native English speaker), and 3 experts in Turkish Language and Literature. Based on their feedback, further refinements were made, resulting a survey that containing 8 questions on dental treatment timing, anesthetic use, premedication, antibiotic prophylaxis, and the risk of infectious diseases in hemodialysis patients. In a pilot study, the survey was administered to 20 dentists, and feedback was collected for its finalization. The questions were structured on a three-point scale: "Correct," "Don't know," and "Incorrect" and were distributed digitally via an online platform to general dentists, dental specialists, and final-year dental students in İzmir. The demographic characteristics and educational status of the participants were recorded. Differences in the knowledge levels of the participants were analyzed using descriptive statistical analyses and chi-square tests ($p<0.05$).

RESULTS

A total of 314 participants completed the survey, including 193 general dentists, 39 dental specialists, and 82 final-year dental students. The sample comprised 180 women (57.3%) and 134 men (42.7%), with ages ranging from 23 to 66 years (mean age = 27.7) (Table 1). Large proportion of the participants were aware of the potential bleeding problems during dental treatment in hemodialysis patients (87.9%) and the high risk of infectious diseases (87.3%) (Table 2). Seventy-eight percent of the participants answered that dental treatment should not be performed on dialysis days for hemodialysis patients. Similarly, 72.9% of the participants were aware that patients should not be on anticoagulants during dental treatment. When compared to dental specialist and students, the general dentists had significantly higher knowledge levels regarding the risk of infectious diseases (p=0.02) (Table 3). Fifty-eight point three percent of participants recognized that local anesthetics without adrenaline should be preferred for hemodialysis patients, while 58.9% were aware of the recommendation to avoid alcoholic mouthwashes.

Table 1. Distribution of participants based on gender and level of education

Gender	**n (%)**
Female	180 (57.3)
Male	134 (42.7)
Educational Status	
Dental student	82 (26.7)
General dentist	193 (60.8)
Dental specialist	39 (12.5)
Total	314 (100)

Table 2. Survey's content and participants' responses

	Correct Answer	Correct n (%)	Don't know n (%)	Incorrect n (%)
1. There is no harm in performing dental treatment on dialysis days.	Incorrect	40 (12.8)	29 (9.2)	**245 (78.0)**
2. Local anesthetics without adrenaline should be used.	Correct	**183 (58.3)**	26 (8.3)	105 (33.4)
3. Diazepam can be used for premedication.	Correct	**98 (31.2)**	110 (35.0)	106 (33.8)
4. Alcohol-based mouth rinses should be used for oral hygiene control.	Incorrect	68 (21.7)	61 (19.4)	**185 (58.9)**
5. Anticoagulant use should be discontinued during dental treatment.	Correct	**229 (72.9)**	26 (8.3)	59 (18.8)
6. Antibiotic prophylaxis should be administered before dental treatments.	Incorrect	96 (30.6)	9 (2.9)	**209 (66.9)**
7. Bleeding problems may occur during dental treatment.	Correct	**276 (87.9)**	9 (2.9)	29 (9.2)
8. These individuals have a high risk of infectious diseases.	Correct	**274 (87.3)**	18 (5.7)	22 (7.0)

Table 3. Distribution of responses by participants' educational status and statistical analysis (p<0.05*).

Questions	**Educational Status**	**Participant Responses (n)**			***p-value***
		Correct	***Don't know***	***Incorrect***	
1. There is no harm in performing dental treatment on dialysis days.	General dentist	25	19	149	0.26
	Dental specialist	8	1	30	
	Dental student	7	9	66	
2. Local anesthetics without adrenaline should be used.	General dentist	110	21	62	0.16
	Dental specialist	20	2	17	
	Dental student	53	3	26	
3. Diazepam can be used for premedication.	General dentist	63	60	70	**0.03***
	Dental specialist	5	19	15	
	Dental student	30	31	21	
4. Alcohol-based mouth rinses should be used for oral hygiene control.	General dentist	45	41	107	0.25
	Dental specialist	9	9	21	
	Dental student	14	11	57	
5. Anticoagulant use should be discontinued during dental treatment.	General dentist	134	19	40	0.06
	Dental specialist	29	0	40	
	Dental student	66	7	9	
6. Antibiotic prophylaxis should be administered before dental treatments.	General dentist	73	8	112	**0.00***
	Dental specialist	12	0	27	
	Dental student	11	1	70	
7. Bleeding problems may occur during dental treatment.	General dentist	173	4	16	0.07
	Dental specialist	30	1	8	
	Dental student	73	4	5	
8. These individuals have a high risk of	General dentist	175	9	9	**0.02***

infectious diseases.	Dental specialist	35	0	4	
	Dental student	64	9	9	

Only 31.2% of participants correctly identified diazepam as a premedication option for hemodialysis patients undergoing dental treatment. Final-year dental students demonstrated a significantly higher knowledge level regarding premedication compared to other groups (p=0.03). The AHA does not recommend antibiotic prophylaxis for non-invasive dental treatments in hemodialysis patients, but it states that the possibility of prophylaxis should be evaluated based on the type of procedure if there are cardiac comorbidities.[17] In our study, 66.9% of participants correctly recognized that prophylaxis is not required before all dental treatments. Final-year dental students demonstrated significantly higher knowledge on this topic compared to other participants (p=0.00).

DISCUSSION

Various oral complications associated with chronic kidney disease (CKD) and hemodialysis have been documented in the literature. The most common manifestations include uremic stomatitis, petechiae, ecchymoses in the oral mucosa, xerostomia, and an increased risk of infections.[3–5,18] With rising global life expectancy, the prevalence of CKD and renal failure-more common among older individuals-has also increased.[19] Hemodialysis is a long-term treatment, typically performed once or more per week. Increased session frequency elevates stress levels, negatively impacting patients' quality of life.[2,9] Long-term hemodialysis patients often experience oral health issues, which have been shown to significantly impact disease-related mortality and morbidity rates.[3,4,20] However, no official guidelines have been established by any institution or organization for the dental treatment of hemodialysis patients. Infective endocarditis, identified as a complication of hemodialysis since the 1960s, poses a significant risk. Studies indicate that hemodialysis patients have a 17% higher likelihood of developing infective endocarditis compared to the general population.[9] The American Heart Association (AHA) guidelines include recommendations for infective endocarditis prophylaxis during the dental treatment of hemodialysis patients.[15-17] The AHA states that there is no sufficient scientific evidence to link microorganisms from dental procedures to infections in peripheral vascular grafts and patches used in hemodialysis. Consequently, it does not recommend antibiotic prophylaxis for hemodialysis patients.[17] Similarly, the European Heart Academy's 2015 guidelines did not recommend antibiotic prophylaxis before invasive dental procedures for CKD patients undergoing hemodialysis.[21] However, the AHA's 2021 guidelines advise prophylaxis for hemodialysis patients with cardiac comorbidities, including heart valve prostheses, previous infective endocarditis, cyanotic congenital heart disease, congenital heart defects repaired with prosthetic materials, and heart transplants.[17] In our study, 33.5% of participants answered incorrectly the question on antibiotic prophylaxis. Similarly, a previous study found that 85% of dentists administered prophylaxis before simple tooth extractions, while 43% did so even for non-invasive dental procedures.[22] This suggests that a significant number of dentists prescribe prophylaxis without a clear indication, potentially increasing the risks of microbial resistance, unnecessary costs, and anaphylactic reactions.[23]

Another critical consideration in hemodialysis patients is anticoagulant use. Heparin is administered parenterally to prevent clotting during blood circulation through the dialysis machine. As heparin remains in circulation for approximately 4–6 hours after administration, scheduling dental treatments at least one day after dialysis is essential. It is recommended to assess INR levels before invasive procedures, and if the INR exceeds 2.5, consultation with a nephrologist should be sought. In emergency dental treatments, the use of a heparin antagonist, such as protamine sulfate, is advised to manage bleeding.[2-4] Local hemostatic measures, such as cold compression and sutures, should be applied after any bleeding procedure in hemodialysis patients. In our study, most participants correctly answered questions related to the timing of dental treatments, bleeding risks, and anticoagulant use, demonstrating awareness of bleeding complications—one of the most critical concerns during invasive procedures in hemodialysis patients. Additionally, due to frequent blood transfusions, hemodialysis patients are at a high risk of hepatitis B and C infections.[7–8] Participants also demonstrated a high level of awareness regarding the risk of infectious diseases (HBV, HCV, HIV) in this population.

Local anesthetics like lidocaine are considered non-nephrotoxic due to their hepatic elimination.[2] Additionally, the high prevalence of hypertension in hemodialysis patients makes adrenaline-free local anesthetics a safer option.[8–9,24] In our study, 58.3% of participants correctly answered the question regarding local anesthetic use. The question with the lowest correct response rate (31.2%) in our study concerned the use of diazepam for premedication in hemodialysis patients. Anxiety and fear during invasive dental procedures can increase the risk of complications in these patients.[9] In such cases, the intraoral administration of diazepam (0.1–0.8 mg/kg) before the procedure has been reported to be beneficial for enhancing patient comfort.[25]

Xerostomia, a common complication in CKD, is linked to hyposalivation in hemodialysis patients and is often accompanied by symptoms such as a tongue coating and taste alterations.[26] To prevent oral infections associated with xerostomia, alcohol-free mouthwashes are recommended alongside oral hygiene measures.[7–9,26] In our study, 58.9% of participants correctly answered the question regarding the use of alcohol-free mouthwash in hemodialysis patients.

In a recent study conducted in Brazil, 51.4% of dentists reported experiencing anxiety during tooth extractions in renal transplant patients.[22] Another study assessing endodontists' knowledge of dental treatment for CKD patients found that most participants had the knowledge and experience necessary to provide appropriate and safe dental care.[27] In our study, participants demonstrated sufficient knowledge about infection, infectious diseases, bleeding risks, and the appropriate timing of dental treatments. However, their awareness of diazepam premedication and the use of alcohol-free mouthwash were comparatively lower. Similarly, knowledge regarding the use of local anesthetics without adrenaline was relatively low. This may be attributed to differences in participant profiles, limited engagement with current literature among general practitioners, and the lack of a guideline regarding dental treatment for hemodialysis patients.

A 2016 study investigating the dental treatment protocols of North American dental schools for CKD patients highlighted the absence of a standardized treatment approach.[10] Notably, none of the participating institutions had their own established treatment protocol.[10] Similarly, Howell et al.[11] reported that 34% of dental schools in the United States followed their own protocols for treating CKD patients, while 65% adhered to the AHA guidelines. The increasing number of patients undergoing hemodialysis due to CKD necessitates that dentists acquire and continuously update their knowledge on the dental treatment of these patients and potential complications. For this purpose, guidelines developed by professional organizations will ensure the implementation of reliable, evidence-based, and standardized protocols in the dental treatment of hemodialysis patients.

CONCLUSION

Our findings highlight the need for dentists to update their knowledge on the dental treatment of hemodialysis patients with CKD. Undergraduate curricula and continuing education programs should incorporate updated guidelines, expand CKD-related content, and encourage general dentists to participate in relevant training programs periodically.

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The Effect of Panoramic Radiography Quality on the Agreement of Diagnosis of Apical Radiolucent Lesions in Maxillary Premolars

Panoramik Radyografi Kalitesinin Maksiller Premolar Dişlerdeki Apikal Radyolüsent Lezyonların Tanısal Doğruluğuna Etkisi

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Citation: Özsoy Çelik S, Şatır S, Osmanoğlu U Ö. The Effect of Panoramic Radiography Quality on the Agreement of Diagnosis of Apical Radiolucent Lesions in Maxillary Premolars. *Int Arc Dent Sci*. 2025;46(1):41-50.

ABSTRACT

INTRODUCTION: The aim was to evaluate the diagnostic agreement of apical radiolucent lesions in the maxillary premolars between panoramic radiography (PAN) and periapical radiography (PAR) and to examine the effect of PAN image quality on diagnostic agreement.

METHODS: Ninety patients who had PAN and PAR (XMind DC, Satelec Acteon, France; 70kVp, 8mA, 0.32 s) including all or part of the maxillary premolar teeth were included. The maxillary posterior crown region was masked on the panoramic radiography to avoid bias. 2 observers were asked to score the maxillary premolar teeth on radiographs as no lesion (0), lesion present (1), and no tooth (2). Observers were asked to evaluate PANs and classify them according to the diagnostic quality. Intra-observer and interobserver agreement were statistically evaluated using Cohen's kappa test.

RESULTS: The sensitivity, precision, and F1 score for interobserver agreement regarding the presence of a lesion (score 1) in the first premolar were lower in PAN compared to PAR. Additionally, the sensitivity, precision, and F1 score for lesions in all premolars were lower in the low PAN quality group compared to the high PAN quality group.

CONCLUSION: PAN quality can have an impact on the diagnostic accuracy of apical radiolucent lesions in the maxillary premolars.

Keywords: *Dental granuloma, Dental radiography, Panoramic radiography, Periapical granuloma, Premolar*

ÖZ

GİRİŞ ve AMAÇ: Amaç, maksiller premolarlardaki apikal radyolusent lezyonların panoramik radyografi (PAN) ile periapikal radyografi (PAR) arasındaki tanı uyumunu değerlendirmek ve PAN görüntü kalitesinin tanı uyumuna olan etkisini incelemektir.

YÖNTEM ve GEREÇLER: Çalışmaya, maksiller premolar dişlerinin tamamını veya bir kısmını içeren PAN (73 kVp, 10 mA, 13.5s tarama süresi; PCH 2500, Vatech, South Korea) ve PAR'a (XMind DC, Satelec Acteon, France; 70kVp, 8mA, 0.32 s) sahip 90 hasta dahil edildi. Önyargıdan kaçınmak için maksiller posterior kron bölgesi PAN'da sansürlendi. 2 gözlemciden radyografilerde maksiller premolar dişleri lezyon yok (0), lezyon mevcut (1) ve diş yok (2) olarak puanlamaları istendi. PAN kalitesi dört grupta sınıflandırıldı: ideal görüntü (seviye 1; 81-100), yeterli görüntü (seviye 2; 61-80), zayıf ancak tanısal görüntü (seviye 3; 41-60) ve tanı için çok zayıf ve tekrarlanması önerilen görüntü (seviye 4; 0-40). Gözlemcilerden PAN'ları değerlendirmeleri ve bunları tanı kalitesine göre sınıflandırmaları istendi. Gözlemci içi ve gözlemciler arası uyum, istatistiksel olarak Cohen'in kappa testi ile değerlendirildi.

BULGULAR: PAN'da birinci premolarda lezyonun (skor 1) varlığı için gözlemciler arası uyumun duyarlılığı, kesinliği ve F1 skoru PAR'dan daha düşüktü. Düşük PAN kalitesine sahip gruptaki tüm premolarlarda skor 1 için duyarlılık, kesinlik ve F1 skoru yüksek PAN kalitesine sahip gruptan daha düşüktü.

SONUÇ: PAN kalitesi, maksiller premolarlardaki apikal radyolusent lezyonların tanısal doğruluğunu etkileyebilir.

Anahtar Kelimeler: *Dental granülom, Dental radyografi, Panoramik radyografi, Periapikal granülom, Premolar*

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Received Date: 20.09.2024
Accepted Date: 13.02.2025

INTRODUCTION

Intraoral radiographs (IO) are considered superior to panoramic radiography (PAN) in diagnosing minor pathologies such as approximal caries and apical lesions.[1-5] In order to increase the proximal caries diagnostic accuracy of PAN, bite-wing radiography feature is added to digital PAN device software or tomosynthesis is utilized.[2,6] The failure of PAN compared to periapical radiography (PAR) in the diagnosis of apical lesions, especially in the maxillary posterior teeth, is associated with the superposition of anatomical structures in the maxilla.[7] On the other hand, it is stated that PAN is more successful than PAR in imaging the apical position of maxillary second and third molars,[8] and there may not be a significant difference between PAN and PAR in the diagnosis of periapical pathologies,[9] depending on the observer. In addition, although it is superior to PAN, it is noted that IO is not sensitive enough to detect associated lesions at an early stage.[6,10]

PAN has the important advantage of showing both jaws, TMJ, maxillary sinus and all teeth in the dental arch with a single image and is therefore routinely used in today's dental practice.[3,5] PAN is used in the detection of many pathologies and anatomical landmarks especially in artificial intelligence (AI)-based diagnostic applications, which have recently become widespread, as it provides a very large area to be displayed for the maxillofacial region.[11-13]

In the last few years, it is seen that the diagnostic accuracy is at a high level in AI-based diagnostic applications with PAN. However, emphasis is placed on standardizing the data used to increase diagnostic accuracy.[11,14] A study showing that the diagnostic accuracy decreases when deep learning models obtained from dental radiological data of different institutions are tested with each other, supports the idea that the databases that form the basis of AI applications should be standardized.[15] Observer interpretation plays a crucial role in standardizing PAN data quality. In addition, it can be said that one of the first and most important steps in PAN standardization is PAN image quality.[2,11,16]

There are scales developed to assess whether PANs are adequate for diagnosis.[16] In this way, it is tried to be a guide in which PANs meet the standard conditions in terms of diagnostic image quality and when imaging should be repeated. The main reasons that reduce the diagnostic quality in PAN are motion artifact, presence of metallic foreign objects, patient positioning errors, certain landmarks not in the correct localization in PAN, and the focal trough not compatible with the dental arch.[16]

Effect of PAN image quality on the diagnostic accuracy in the detection of various pathologies has gained importance especially with the increase in AI applications. This retrospective study aimed to assess the diagnostic agreement of PAN and PAR for detecting apical radiolucent lesions in maxillary premolars and to evaluate how PAN image quality impacts diagnostic accuracy.

MATERIALS AND METHODS

Ethics committee approval was received for this study from Karamanoglu Mehmetbey University Faculty of Medicine Clinical Research Ethics Committee (03-2023/14). Written consent was obtained from the patients whose retrospective data were included in the study, that their data could be used on condition that their identities and personal data remain confidential.

Sample Size

The sample size calculation aimed to ensure adequate power to assess observer agreement. Based on McHugh's classification,[17] a sample size of 70 was required to achieve 80% power (K0 = 0.80, K1 = 0.60, $\alpha = 0.05$). With 90 patients included, the achieved power for the study was 87.49% (two-sided hypothesis).[18] Power analyses were performed using PASS 11 software (NCSS, LLC., USA).

Patient selection

Patients who applied to Karamanoglu Mehmetbey University Faculty of Dentistry between December 2021 and December 2022 over 18 years of age and have taken on the same day both PAN (90 patients; 46 female, 44 male; mean age: 42.2, age range: 18-75) and PAR (189 teeth; 91 first premolars, 98 second premolars; 10 patients 37 teeth bilateral, 80 patients 152 teeth unilateral) were included in the study. Those with orthodontic brackets, implants in the maxillary posterior region, impacted teeth, or those with a specific lesion/condition (such as odontoma, non-odontogenic cyst, sinus lifting graft) were not included in the study as it may cause bias in the observers. Since it is the main subject of the study, no elimination criteria were applied for situations that could negatively affect the PAN image quality.

PAN assessment

PANs (73 kVp, 10 mA, 13.5s scan time; *PCH 2500, Vatech*, South Korea) were evaluated in a standard observation room by observing 30 cm from the WLCD screen (*HP Pavilion 2211x Monitor*, 21.5-inch screen size and 1920 × 1080 resolution). To prevent cognitive bias, the crowns of maxillary posterior teeth were masked using Windows Paint (*Microsoft*, USA) before assessment (Figure 1a-2a-3a). In each PAN, a total of 4 maxillary premolar teeth were scored as no lesion (score 0), radiolucent lesion present (score 1), and no tooth (score 2).

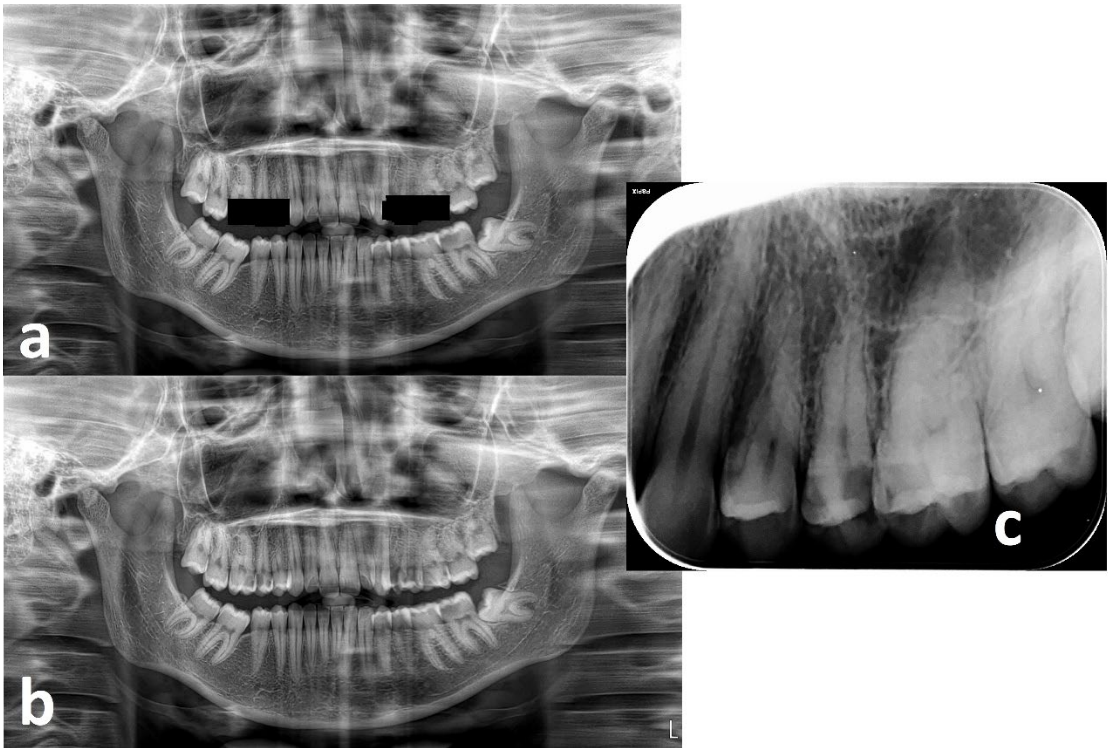

Figure 1. A 22-year-old female patient. Left maxillary first premolar scored 2 in one observation with PAN (a). For the same tooth, 0 was scored in all 4 observations with PAR. Note the radiolucent region on the mesial root surface in the PAR of this tooth (c). Observers included the unmasked version of this PAN in Level 3 in terms of image quality. Note the motion artifact on the left side (b).

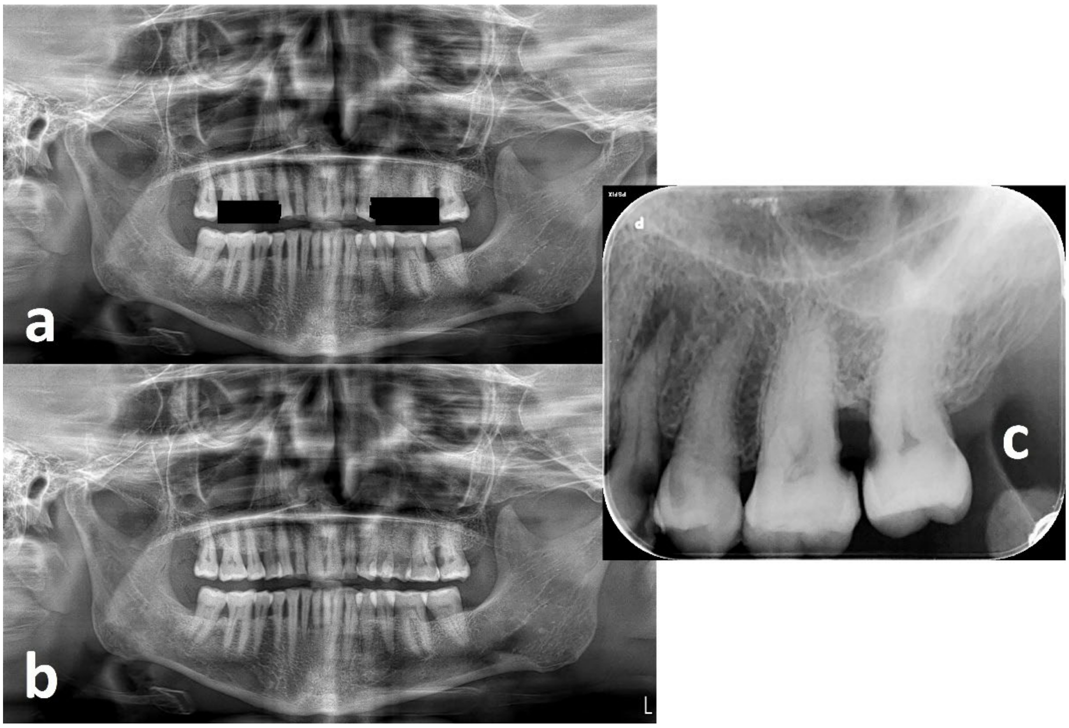

Figure 2. 56-year-old female patient. Left maxillary second premolar scored 2 in two observations with PAN (a). For the same tooth, 0 was scored in all 4 observations with PAR. While the left maxillary first premolar was scored as 0 in 4 observations with PAN, the score was 1 in 4 observations with PAR (c). Observers included the unmasked version of this PAN in Level 3 in terms of image quality. Note that the left ramus appears wider due to the midline positioning error (b).

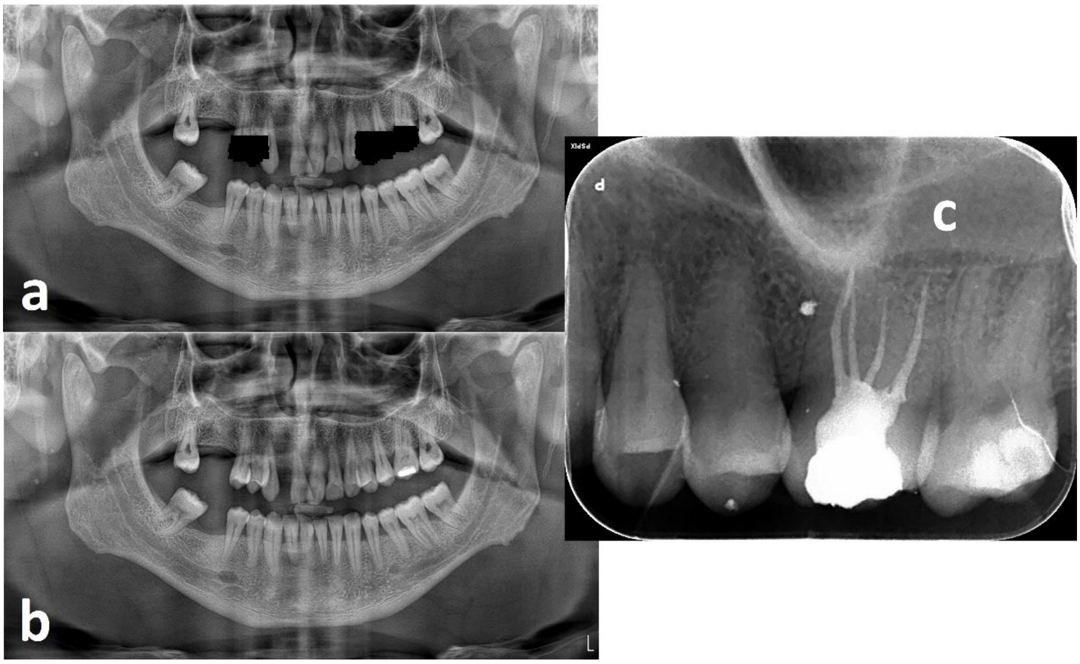

Figure 3. 41-year-old male patient. Left maxillary first premolar scored 2 in one observation with PAN (a). For the same tooth, 0 was scored in all 4 observations with PAR. PAR was taken due to root canal treatment of the left maxillary first molar. Both left premolars were only visible on the final radiography (c). Observers included the unmasked version of this PAN in Level 2 in terms of image quality (b).

PAR assessment

The PAR assessment was performed after the PAN assessment. PARs were taken by radiology technician (8 years' experience in oral radiology) with a wall-mounted periapical device (*XMind DC, Satelec Acteon*, France; 70kVp, 8mA, 0.32 s) and a phosphor plate (*Dürr Dental*, Germany) and visualized with a phosphor plate scanner (*VistaScan, Dürr Dental*, Germany). The same screen, the same distance and the same standard observation room were selected as in the PAN assessment. Each PAR was scored as no lesion (score 0), radiolucent lesion present (score 1), and no tooth (score 2), while premolars that did not imaged into the PAR region were not included in the study data. No classification for apical radiolucent lesion size was used. Observers were informed that the apical enlargement of the periodontal ligament should be evaluated as a score of 0.

PAN quality classification

The study of Choi et al. in 2012 was based on the PAN quality classification.[16] According to this classification, each PAN is scored between 0 and 100 (0 worst, 100 perfect). Of the total score, 8 are identification/information (gender, age, right/left marker, date), 6 are artifact/shadow (jewelry, dental prosthesis, unidentified foreign body), 8 are coverage (location and visibility of condyles, orbital inferior, and mandible inferior), 30 are patient position (midline location, occlusal plane location, artifact from patient movement, superposition of hyoid bone with mandible, anteroposterior location associated with bite plane), 38 are image properties (resolution, brightness, density and contrast) and 6 are overall image quality scoring (ideal, acceptable, poor but acceptable, very poor). According to the total score obtained, PAN quality is classified into four groups: ideal image (level 1; 81-100), adequate image (level 2; 61-80), poor but diagnostic image (level 3; 41-60), and very weak to diagnosis and recommended to be repeated image (level 4; 0-40).

Observers & the observation process

Two observers (SCO, 7 years' experience in oral radiology; SS, 6 years' experience in oral radiology) were designated for the PAN and PAR assessment and PAN quality classification. Both PAN and PAR assessments were made blindly and in an irregular order with observers independent of each other. Observers made their scoring twice, repeating all of them one month interval. One month after all scoring was completed, two observers evaluated the unmasked PANs together and determined the PAN image quality by consensus.

Statistical analysis

Statistical analyzes were evaluated using the IBM Statistical Package for Social Sciences 25.0 (*SPSS*, Chicago, IL) program. Descriptive statistics for continuous variables are presented as means (±standard deviation) or medians (Q1-Q3). Normality was assessed with the Shapiro-Wilk test, and parametric or non-parametric tests were applied accordingly. Interobserver agreement was determined by Cohen's Kappa Test. McHugh's classification was used to determine the Cohen's Kappa Test compliance levels.[17] In addition, multiclass confusion matrix values (sensitivity, specificity, precision, F1 score, etc.) were used to detail the interobserver agreement. Relationships and comparisons between categorical variables were calculated by chi-square analysis. Due to the minimum expected frequency percentage in PAN quality grouping, appropriate group aggregation (level 1+2 and level 3+4) was made. Correlation heatmap plots were created using the Python 3.7.9 (Delaware, USA) software program. Statistical significance level was accepted as $p<0.05$.

RESULTS

Interobserver agreement of the first and second premolars separately is shown in Table 2. In the first premolars for PAN, the score 1 kappa coefficient was 0.59-0.60 for sensitivity, precision and F1 score, with poor-moderate agreement, 0.95-0.96 for specificity, with almost perfect agreement. For PAN, the score 1 kappa coefficient in second premolars was 0.64-0.69, 0.67-0.73 and 0.65-0.71 for sensitivity, precision and F1 score, respectively, with moderate agreement. All score kappa coefficients for the first premolars for PAR were 0.97-1.00, 0.73-1.00, 0.79-1.00 and 0.84-1.00 for sensitivity, precision, specificity and F1 score, respectively, with a strong-almost perfect agreement. In the second premolars for PAR, all score kappa coefficients for sensitivity, precision, specificity and F1 score were between 0.81-1.00, 0.60-1.00, 0.75-1.00 and 0.72-1.00, respectively, with strong agreement.

Intra-observer agreement for PAN and PAR is shown in Table 1. Kappa values between 0.84-1.00 and 0.76-1.00 were obtained for sensitivity and specificity, respectively. Overall accuracy was found to be between 93-95%. A strong level of agreement was found with the Cohen's Kappa coefficient between 0.83-0.86.

Interobserver agreement of all premolars is shown in Table 3. Overall accuracy for PAN is between 90-92% and for PAR it is 94-95%. Kappa coefficients were 0.76-0.80 (strong agreement) and 0.83-0.86 (strong agreement) for PAN and PAR, respectively.

Table 4 presents diagnostic accuracy comparisons based on PAN image quality. For cases with poor image quality, score 1 yielded a Kappa coefficient of 0.55 (sensitivity), 0.44 (precision), and 0.49 (F1 score), indicating poor agreement, with specificity at 0.97 (almost perfect agreement).

Table 1. Interobserver agreement (first and second premolars separately) for PAN and PAR

First Premolar	PAN						PAR					
	Time 1			Time 2			Time 1			Time 2		
	0	1	2	0	1	2	0	1	2	0	1	2
TP	129	12	20	133	10	21	76	10	3	77	8	3
TN	32	152	157	31	156	157	13	79	88	11	80	88
FP	8	8	3	9	7	0	2	0	0	3	0	0
FN	11	8	0	7	7	2	0	2	0	0	3	0
Sensitivity	0,94	0,60	0,87	0,94	0,59	1,00	0,97	1,00	1,00	0,96	1,00	1,00
Precision	0,92	0,60	1,0	0,95	0,59	0,91	1,00	0,83	1,00	1,00	0,73	1,00
Specificity	0,80	0,95	0,98	0,78	0,96	1,00	0,87	1,00	1,00	0,79	1,00	1,00
F1 Score	0,93	0,60	0,93	0,94	0,59	0,95	0,99	0,91	1,00	0,98	0,84	1,00
Overall Accuracy	89,44%			91,11%			97,80%			96,70%		
Cohen's Kappa coefficient	0,723***			0,755***			0,918***			0,865***		
Second Premolar	**PAN**						**PAR**					
	Time 1			**Time 2**			**Time 1**			**Time 2**		
	0	**1**	**2**	**0**	**1**	**2**	**0**	**1**	**2**	**0**	**1**	**2**
TP	124	14	26	132	11	26	69	13	9	73	9	9
TN	40	151	153	37	160	152	22	78	89	18	82	89
FP	8	8	0	4	5	2	4	3	0	6	1	0
FN	8	7	1	7	4	0	3	4	0	1	6	0
Sensitivity	0,94	0,64	1,00	0,97	0,69	0,93	0,95	0,81	1,00	0,92	0,90	1,00
Precision	0,94	0,67	0,96	0,95	0,73	1,00	0,96	0,76	1,00	0,99	0,60	1,00
Specificity	0,83	0,94	1,00	0,90	0,97	0,99	0,85	0,96	1,00	0,75	0,99	1,00
F1 Score	0,94	0,65	0,98	0,96	0,71	0,96	0,95	0,79	1,00	0,95	0,72	1,00
Overall Accuracy	91,11%			93,89%			92,86%			92,86%		
Cohen's Kappa coefficient	0,791***			0,842***			0,828***			0,806***		

*TP: True Positive; TN: True Negative; FP: False Positive; FN: False Negative; Overall Accuracy; PAN: Panoramic Radiography; PAR: Periapical Radiography; Score 0: No lesion; Score 1: Radiolusent lesion; Score 2: No tooth; *** p<0,001 (Cohen's Kappa coefficient)*

Table 2. Intra-observer agreement (inter-time) for PAN and PAR

All Teeth	PAN						PAR					
	Observer SS			Observer SCO			Observer SS			Observer SCO		
	0	1	2	0	1	2	0	1	2	0	1	2
TP	264	27	46	263	30	46	145	23	12	150	17	12
TN	73	314	310	76	315	308	35	157	177	29	162	177
FP	15	5	3	15	3	3	6	3	0	9	1	0
FN	8	14	1	6	12	3	3	6	0	1	9	0
Sensitivity	0,95	0,84	0,94	0,95	0,91	0,94	0,96	0,88	1,00	0,94	0,94	1,00
Precision	0,97	0,66	0,98	0,98	0,71	0,94	0,98	0,79	1,00	0,99	0,65	1,00
Specificity	0,83	0,98	0,99	0,84	0,99	0,99	0,85	0,98	1,00	0,76	0,99	1,00
F1 Score	0,96	0,74	0,96	0,96	0,80	0,94	0,97	0,84	1,00	0,97	0,77	1,00
Overall Accuracy	93,61%			94,17%			95,24%			94,71%		
Cohen's Kappa coefficient	0,835***			0,852***			0,864***			0,830***		

*TP: True Positive; TN: True Negative; FP: False Positive; FN: False Negative; Overall Accuracy; PAN: Panoramic Radiography; PAR: Periapical Radiography; Score 0: No lesion; Score 1: Radiolusent lesion; Score 2: No tooth; *** p<0,001 (Cohen's Kappa coefficient)*

Table 3. Interobserver agreement (all teeth together) for PAN and PAR

All Teeth	PAN						PAR					
	Time 1			Time 2			Time 1			Time 2		
	0	1	2	0	1	2	0	1	2	0	1	2
TP	253	26	46	265	21	47	145	23	12	150	17	12
TN	72	303	310	68	316	309	35	157	177	29	162	177
FP	16	16	3	13	12	2	6	3	0	9	1	0
FN	19	15	1	14	11	2	3	6	0	1	9	0
Sensitivity	0,94	0,62	0,94	0,95	0,64	0,96	0,96	0,88	1,00	0,94	0,94	1,00
Precision	0,93	0,63	0,98	0,95	0,66	0,96	0,98	0,79	1,00	0,99	0,65	1,00
Specificity	0,82	0,95	0,99	0,84	0,96	0,99	0,85	0,98	1,00	0,76	0,99	1,00
F1 Score	0,94	0,63	0,96	0,95	0,65	0,96	0,97	0,84	1,00	0,97	0,77	1,00
Overall Accuracy	90,28%			92,5%			95,24%			94,71%		
Cohen's Kappa coefficient	0,760***			0,800***			0,864***			0,830***		

*TP: True Positive; TN: True Negative; FP: False Positive; FN: False Negative; Overall Accuracy; PAN: Panoramic Radiography; PAR: Periapical Radiography; Score 0: No lesion; Score 1: Radiolusent lesion; Score 2: No tooth; *** p<0,001 (Cohen's Kappa coefficient)*

DISCUSSION

The low interobserver agreement and low sensitivity for PAN in the presence of lesions (score 1) indicates that PAN is less successful in diagnosing apical radiolucent lesions in the maxilla premolars than PAR (Table 1 and 3). In the present study, it was found that sensitivity was lower than specificity in the diagnosis of apical lesions with both PAN and PAR, which is consistent with the literature.[7,8,10,19,20] In the diagnosis of radiolucent lesion with PAR, the sensitivity for the second premolar was lower than for the first premolar (Table 1). This may be because the second premolars are more likely to be in superposition with anatomical landmarks and in close proximity to the maxillary sinus.[7,8] In a diagnostic study with PAN with eye tracking, it was stated that lesions localized in the maxillary sinus were more frequently missed.[21] It is also stated that the diagnosis with PAR may be restricted when the lesion size is small.[10] In this retrospective study, a classification related to lesion size was not used for PAR and the lesion sizes of the first and second premolars were not standardized. Therefore, in the scenario where the lesions on the first premolars were larger in size, they might have been detected by the observers with higher agreement. Although it was not statistically significant in the diagnosis of radiolucent lesion with PAN, the sensitivity of the first premolars was lower than the second premolars. This may be since the first premolars are more closely related to the fossa canina than the second premolars and are more likely to be out of the focal trough.

It is seen that in most of the studies in which PAN is used for AI applications, no information is given about the image quality of the PAN included in the study for modeling,[7,22,23] or that insufficient and non-standardized criteria (such as good visualization, clear image) are used.[5,13,24,25] This situation suggests that although the necessity of PAN standardization for deep learning models has been emphasized in some studies,[26,27] the issue of PAN image quality, which should be standardized first, has been ignored. As a first step to achieve PAN standardization, it can be planned to classify PAN image quality and to include PANs that can meet a certain quality level in AI models. The results of in the present study showed that the statistical diagnostic accuracy of maxillary premolar apical radiolucent lesions in PANs with high image quality is slightly higher than in PANs with low image quality. In addition, it was determined that sensitivity, precision and F1 scores were lower in PANs with low image quality compared to PANs with high image quality, especially in score 1 (Table 4). There was not statistically and clinically significant difference in diagnostic agreement between groups separated by PAN image quality.

Table 4. Interobserver agreement in the effect of PAR image quality on diagnostic accuracy

Time 1	Panoramic Radiography Image Quality					
	High			Low		
	0	1	2	0	1	2
TP	159	20	18	94	6	28
TN	38	180	195	34	123	115
FP	7	9	3	9	7	0
FN	12	7	0	7	8	1
Sensitivity	0,96	0,69	0,86	0,91	0,46	1,00
Precision	0,93	0,74	1,00	0,93	0,43	0,97
Specificity	0,84	0,95	0,98	0,79	0,95	1,00
F1 Score	0,94	0,71	0,92	0,92	0,44	0,98
Overall Accuracy	91,20%			88,89%		
Cohen's Kappa coefficient	0,760***			0,753***		
Time 2	**Panoramic Radiography Image Quality**					
	High			**Low**		
	0	**1**	**2**	**0**	**1**	**2**
TP	165	16	19	100	5	28
TN	35	185	196	33	131	113
FP	6	10	0	7	2	2
FN	10	5	1	4	6	1
Sensitivity	0,96	0,62	1,00	0,93	0,71	0,93
Precision	0,94	0,76	0,95	0,96	0,45	0,97
Specificity	0,85	0,95	1,00	0,83	0,98	0,98
F1 Score	0,95	0,68	0,97	0,95	0,56	0,95
Overall Accuracy	92,59%			92,36%		
Cohen's Kappa coefficient	0,781***			0,817***		
All Teeth	**Panoramic Radiography Image Quality**					
	High			**Low**		
	0	**1**	**2**	**0**	**1**	**2**
TP	324	36	37	194	11	56
TN	73	365	391	67	254	228
FP	13	19	3	16	9	2
FN	22	12	1	11	14	2
Sensitivity	0,96	0,65	0,93	0,92	0,55	0,97
Precision	0,94	0,75	0,97	0,95	0,44	0,97
Specificity	0,85	0,95	0,99	0,81	0,97	0,99
F1 Score	0,95	0,70	0,95	0,93	0,49	0,97
Overall Accuracy	91,90%			90,63%		
Cohen's Kappa coefficient	0,770***			0,784***		

*TP: True Positive; TN: True Negative; FP: False Positive; FN: False Negative; Overall Accuracy; Score 0: No lesion; Score 1: Radiolusent lesion; Score 2: No tooth; *** p<0,001 (Cohen's Kappa coefficient)*

In studies comparing the diagnostic accuracy of radiographic techniques, the number and competence (such as being an oral radiologist and experience) of observers is an important indicator for the reliability of the findings. The use of one,[6,28] two,[7,29] three[2,26] or more[20,30] observers to provide a criterion close to the gold standard in diagnostic accuracy studies like present study shows that there is no standard in the number of observers and that the researchers determine the number of observers in accordance with their own conditions. The results of present study are compatible with the literature. Therefore, it can be said that the fact that only two observers were used in present study did not adversely affect the reliability of the study data. Despite her/his expertise in oral radiology and many years of experience, it should not be denied that there are many factors that influence an observer's diagnostic decisions. Therefore, it can be predicted that in the future, new criteria aiming to optimize visual perception (such as eye rest time and mood markers) may be added to the observer competences (such as number, expertise, and experience) determined in studies planned to increase the diagnostic accuracy. Therefore, in addition to numerical criteria such as years of experience and number of observers, qualitative criteria such as instantaneous performance measurements also affect the results, and qualitative performance criteria need to be standardized.

The most important limitation of present study is that histopathology was not used as the gold standard. This limitation can be excused due to the nature of the cases where the biological objects used in retrospective studies are not converted into ex-vivo material.[14,31] Another limitation of the inability to use histopathology as the gold standard was that only premolar teeth were included in the study. Molar teeth may be in close proximity to radiopaque anatomical landmarks such as the zygomatic arch and the floor of the maxillary sinus. Only premolars were included in this study since the superposition of their roots in the buccolingual direction is more confusing and the study[8] in the literature claiming that PAN may be superior to PAR in the diagnosis accuracy of apical radiolucent lesions in maxillary second and third molars. Since it is a retrospective study, the fact that the observers did not have information about the clinical history of the patients whose radiographs were used can be shown as a limitation. However, this turned into an advantage in present study as it prevented the bias of the observers. Because the aim of this study was to observe how observers make decisions when comparing different radiography techniques by simply making observations. It can be said that observer agreement is used as the gold standard, as in similar studies in the literature.[2,20,26] The compatibility of our findings with the literature in line with the expectations suggests that the subjective decisions of the observers can be trusted. Nevertheless, as the gold standard, histopathology is a more realistic and appropriate choice than observers regardless of number.

The classification model used for image quality in present study presents four different subgroups for PAN.[16] Since the data included in the study were concentrated under two subgroups (scores 2 and 3) according to the PAN quality classification, they had to be grouped under two groups as high and low classification. Further studies can be planned to include more PANs to reveal how diagnostic accuracy is affected for each sub-heading of the present classification. It can be predicted that the findings obtained from the two main subgroups formed in present study on diagnostic accuracy will contribute to the literature and similar studies to be planned in the future. Finally, the effect of only maxillary premolar apical radiolucent lesions on diagnostic accuracy was evaluated using the PAN image quality classification. In a study on the effect of patient positioning on the visualization of landmarks in cone-beam computed tomography (CBCT), it was mentioned that positioning by focusing on the cause of CBCT may adversely affect the imaging of other anatomical and pathological conditions.[32] The PAN image quality classification we used in present study[16] is not standardized for any lesion or anatomical landmark and aims to optimize the image quality of the entire region that can be imaged with PAN. It is possible that studies that can be created by different PAN quality classification methods and testing different pathological/anatomical structures will contribute to both the literature.

CONCLUSION

The statistical diagnostic accuracy of maxillary premolar apical radiolucent lesions in PANs with high image quality is slightly higher than in PANs with low image quality. It should not be overlooked that it would be a good idea to evaluate with PAR to detect possible residual roots in the maxillary premolar region, which is thought to be edentulous after imaging with PAN. These findings suggest the importance of considering both imaging techniques for comprehensive evaluation and emphasize the need for standardizing image quality to optimize diagnostic outcomes in clinical practice.

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Evaluation of Anxiety Levels and Ethical Opinions on Artificial Intelligence among Dental Students and Academicians : A Pilot Study

Diş Hekimliği Fakültesi Öğrencilerinin ve Akademisyenlerin Yapay Zeka Uygulamalarına İlişkin Kaygı Düzeyinin ve Yapay Zeka Etiği Hakkındaki Görüşlerinin Değerlendirilmesi: Bir Pilot Çalışma

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Citation: Kalaoğlu E E, Yeğin E. Evaluation of Anxiety Levels and Ethical Opinions on Artificial Intelligence among Dental Students and Academicians : A Pilot Study.*Int Arc Dent Sci*. 2025;46(1):51-58.

ABSTRACT

INTRODUCTION: To evaluate the concerns regarding artificial intelligence(AI) applications and the opinions on AI ethics among students of Istanbul Gelişim and Istanbul Medeniyet University Faculty of Dentistry, as well as among academics in dentistry faculties across Turkey.

METHODS: Google Forms-an online survey was created and shared with participants. The survey consists of three sections including participants' demographics, concerns about the use of AI in dentistry, and thoughts on ethics. Mann-Whitney U Test and Spearman Rho Correlation Analyses were employed to examine the relationship between professional experience/class and levels of concern.

RESULTS: A total of 315 individuals participated in the survey, with 85% being dentistry students. AI concern scores of dentistry students (7.49±4.51) were found to be similar to those of academics (8.47±4.34). As the students' class levels increased, their levels of concern increased (p=0.05, r=0.11). Conversely, as academics' professional experience increased, their levels of concern decreased significantly (p=0.02, r=-0.37). The general consensus regarding the ethical acceptability of AI applications was 55%, suggesting acceptance with education and oversight. However, the majority (61%) believed that the use of AI applications in dentistry education should be important but limited.

CONCLUSION: Both dental students and academicians were concerned about AI applications. They emphasize the importance of education and supervision for ethical usage.

Keywords: *Artificial intelligence, ethics, dental students, academicians*

ÖZ

GİRİŞ ve AMAÇ: İstanbul Gelişim Üniversitesi ve İstanbul Medeniyet Üniversitesi Diş Hekimliği Fakültesi öğrencileri ile Türkiye'deki diş hekimliği fakültelerindeki akademisyenlerin yapay zeka uygulamalarına ilişkin kaygılarını, yapay zeka etiği konusundaki görüşlerini değerlendirmektir.

YÖNTEM ve GEREÇLER: Google forms üzerinde online bir anket oluşturularak katılımcılar ile paylaşılmıştır. Anket; katılımcıların demografik bilgileri, yapay zekanın diş hekimliği uygulamalarında kullanılmasına ilişkin endişelerini ve yapay zeka etiği ile ilgili düşüncelerini içeren üç bölümden oluşmaktadır. Mesleki deneyim/sınıf ve kaygı düzeyleri arasındaki ilişkiyi incelemek için Mann-Whitney U Testi ve Spearman Rho Korelasyon Analizleri kullanılmıştır.

BULGULAR: Ankete toplam 315 kişi (180 kadın, %57; 135 erkek, %43; ortalama yaş=22,45±2,97) katılmış olup katılımcıların %85'i diş hekimliği öğrencileridir. Diş hekimliği öğrencilerinin yapay zeka kaygısı puanı (7.49±4.51) akademisyenler (8.47±4.34) ile benzer bulunmuştur. Öğrencilerin sınıf seviyeleri arttıkça kaygı düzeyleri de artmıştır (p= 0.05, r=0.11). Akademisyenlerin ise mesleki deneyimleri arttıkça kaygı düzeyleri azalmıştır (p= 0.02, r=-0.37). Yapay zeka uygulamalarının etik olarak kabul edilebilir kullanımıyla ilgili genel görüş (%55), eğitim ve denetim ile kabul edilebilir olduğu yönündedir. Ancak, yapay zeka uygulamalarının diş hekimliği eğitiminde kullanımına ilişkin çoğunluk (%61), önemli ancak sınırlı olmalıdır görüşündedir.

SONUÇ: Hem diş hekimliği öğrencileri hem de akademisyenler yapay zeka uygulamalarıyla ilgili kaygılıdır. Etik kullanımı için eğitim ve denetim önemlidir görüşündedir.

Anahtar Kelimeler: *Yapay zeka, etik, diş hekimliği öğrencileri, akademisyenler*

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Received Date: 03.03.2024
Accepted Date: 20.09.2024

INTRODUCTION

Artificial intelligence (AI) is the simulation, imitation, or replication of human intelligence, created by the fields of engineering and science, and expressed through technological devices. It involves the ability to think, learn, solve problems, and make decisions.[1] The use of AI in healthcare has led to significant advancements by enabling the rapid analysis of collected data, utilizing databases, considering patient-specific factors, facilitating workflows, and enhancing the productivity of healthcare professionals.[2] In dentistry, AI aims to assist practitioners in providing better patient care, reducing treatment duration and costs, and minimizing decision-making errors.[3] AI supports dentists in a range of tasks, from fundamental duties such as recording a patient's medical history to more complex processes, including analyzing acquired information for accurate diagnosis, identifying potential treatment options, and predicting prognoses. It is also used in conjunction with diagnostic tools such as radiographs to enhance the accuracy and speed of diagnoses.[4] Although the adoption of AI in various subfields of dentistry has been somewhat delayed, its increasing accessibility causes a significant interest in recent years. Notable progress has been made in different areas of dentistry, including disease diagnosis, localization, classification, prognosis prediction, and risk assessment.[5] Similar to other fields, dentistry is transitioning toward a new era of data-driven medicine, supported by robotics. Robotic dental assistance has the potential to be applied in various specialties, including prosthodontics, implantology and orthodontics.[5] Clinicians can leverage augmented reality to help patients visualize expected treatment outcomes before undergoing procedures. Additionally, augmented and virtual reality technologies can enhance dental education by improving students' learning experiences during preclinical training.[6]

As AI transforms or eliminates existing professions while creating new ones, automation and computerization will inevitably reshape the nature of work. McKinsey Global Institute (2017) suggested that, depending on the pace of AI adoption, between 75 million and 375 million workers may need to change occupations and/or upgrade their skills by 2030.[7] Studies on AI-related anxiety in the literature trace back to the first generation of computers, when researchers identified widespread concerns about computers threatening the essence of what it means to be "human." However, traditional measures of computer anxiety, internet anxiety, and robot anxiety are considered insufficient when applied to AI technologies and products. AI-related anxiety may stem from misconceptions about technological advancements, confusion regarding autonomy, and socio-technical blindness.[8]

Currently, AI is being increasingly utilized in dentistry for applications such as image and radiographic analysis, contributing to a more predictive approach to oral healthcare. However, this also raises critical ethical concerns and societal challenges. The advancement of technology necessitates a focus on AI ethics in dentistry.[9] While many dentists anticipate the integration of AI systems into diagnostics, prognosis assessment, and treatment planning, the expanding adoption of AI in dentistry has heightened concerns regarding the legal and ethical dilemmas associated with its use.[10] AI technology has already begun impacting the education sector, as demonstrated during the COVID-19 pandemic, where it facilitated personalized learning through interactive experiences.[11] However, many educational institutions encounter difficulties in effectively integrating AI into teaching procedure due to several factors such as lack of AI training for educators, the high cost of AI software, and ethical concerns.[6] The recent introduction of the powerful AI-driven language model ChatGPT-4 has immediately demonstrated its potential to help students grasp even complex scientific concepts, while simultaneously raising numerous legal and ethical concerns.[12]

A review of the existing literature revealed no studies examining AI-related anxiety among dental students and academicians. Our study is the first to explore AI ethics in this context and to gather the perspectives of both dental students and faculty members. Considering that adaptation to technology and ethical considerations may be influenced by age, our study also evaluates and compares the views and concerns of academicians and students.

MATERIALS AND METHODS

This study was conducted using a cross-sectional research design to evaluate and compare the concerns, perspectives on artificial intelligence (AI) ethics, and awareness levels of students and academicians from the Faculty of Dentistry at Istanbul Gelişim University and Istanbul Medeniyet University. Ethical approval for the study was obtained from the Ethics Committee of the Faculty of Dentistry at Istanbul Gelişim University (Date: October 24, 2023, No: 28). Informed consent was obtained from participants who agreed to take part in the study, and the study was conducted in accordance with the principles of the Declaration of Helsinki.

Sample and Power Analysis

The study included students from two dental faculties in Istanbul (one private and one public) and academic staff from eight different universities across Turkey. While the selection of two universities provided an initial basis for examining students' concerns and ethical perspectives on AI applications, the inclusion of academicians from multiple institutions ensured a broader perspective.

As this study was designed as a pilot study to determine the concerns and ethical viewpoints of students from two newly established dental faculties and academicians across Turkey regarding AI applications, no power analysis was conducted. Therefore, the study did not aim to establish a sample representative of the entire Turkish population. Despite the limited sample size (267 students and 48 academicians), this pilot study serves as a foundation for larger and more comprehensive research. Future studies are recommended to include a larger sample size and a greater number of universities.

Participants

The participants of this study consisted of students enrolled in the Faculty of Dentistry at Istanbul GelişimUniversity and Medeniyet University, as well as academicians working at various dental faculties across Turkey. Participation was voluntary, and an online survey link was distributed via email to invite potential participants to take part in the study.

Survey Development Process:

The survey used in this study was generated with the assistance of artificial intelligence (ChatGPT-3). During the survey development process, specific keywords and explanatory information were provided to the AI system. The AI was instructed to create five questions assessing concern levels and five questions related to AI ethics for the study titled "Evaluation of Dentistry Faculty Students' and Academicians' Levels of Anxiety Regarding Artificial Intelligence Applications and Their Opinions on Artificial Intelligence Ethics: A Pilot Study”. Each question was designed to include five response options.

Information Provided to AI

The AI was supplied with the following keywords and explanatory details:

- AI applications in dentistry
- Concern levels of students and academicians
- General concepts related to AI ethics

Based on these inputs, the AI was asked to generate questions categorized under these topics.

Question Development Process

The AI was instructed to create a total of ten multiple-choice questions (five related to anxiety levels and five related to AI ethics), each with five response options, ensuring that they aligned with the study's objectives and were comprehensible to participants.

Survey Review and Finalization

The AI-generated survey questions were carefully reviewed by the authors to assess their relevance and clarity. Necessary revisions and additions were made to refine the questionnaire, ensuring that it met the study’s objectives before final implementation.

Data Collection Tools

The data were collected using an online survey form called Google Forms. The survey consists of three sections. The first section includes the demographic information of the participants. This information includes age, gender, whether the participant is a dental student or an academician, the class information if the participant is a student, and professional experience for the academicians. The second section of the survey is designed to measure the participants' anxiety about artificial intelligence applications. This section contains 5 multiple-choice questions. It is specified that each question can have multiple answers, and the participant can select more than one option based on their subjective evaluation. The options A, B, C, and D for each question are worth 1 point. The E option represents "I have no concerns about this issue" and is worth 0 points. Each individual’s score is calculated in this way, and the scores were not scaled or grouped. The maximum anxiety score that can be obtained from this section is 20, and the minimum anxiety score is 0. The anxiety scores obtained from the second section were compared between dental students and academicians. Dental students were categorized by class level as preclinical (1st and 2nd years) and clinical (3rd, 4th, and 5th years). The anxiety level of academicians was compared based on their professional experience (0-5 years, 6-10 years, and 11 years or more). The third section of the survey contains questions related to AI ethics. These questions concern the ethical acceptability of AI applications in dentistry, privacy and data security in AI applications, responsibility for potential errors in AI applications, the importance of AI applications in dental education, and the training related to ethical rules provided to dental students regarding AI. Participants were asked to select only one option, and their responses were given as percentages. There is no scoring system in this section.

Data Collection

The research began in October 2023 and was completed in December 2023. Participants were sent an explanatory text and a survey link via email. They completed the survey at their convenience and using their preferred devices. The anonymity and confidentiality of the participants were ensured, and the data were accessible only to the researchers.

Data Analysis

Data analysis was performed using IBM SPSS Statistics 22 (SPSS IBM, Turkey). The normality of the parameters was evaluated using the Shapiro-Wilk test. In addition to descriptive statistical methods, the Kruskal-Wallis test was used for comparing quantitative data with non-normal distribution. The Mann-Whitney U test was preferred for comparing non-normally distributed parameters between two groups. Spearman's rho correlation analysis was used to examine relationships between non-normally distributed parameters. A significance level of $p<0.05$ was considered.

RESULTS

A total of 315 participants took part in the study (180 women, 57%; 135 men, 43%; mean age = 22.45, SD = 2.97) (Table 1.). 85% of the participants were dental students from Istanbul Gelişim University Faculty of Dentistry or Istanbul Medeniyet University Faculty of Dentistry. The remaining 15% were academicians from the following universities: Istanbul Gelisim University, Istanbul Medeniyet University, Marmara University, Inonu University, Ataturk University, Istanbul University Cerrahpasa, Cukurova, Akdeniz, Igdir, Sakarya, Bolu Abant Izzet Baysal, Istanbul Atlas University, and Istanbul Aydin University Faculty of Dentistry.

When the anxiety regarding the use of artificial intelligence (AI) in dentistry were examined, nearly half of the participants (47.3%) expressed concern about the possibility of AI making incorrect diagnoses or treatments. Regarding ethical concerns, the highest response rate (54.6%) was for the option "Failure to establish the doctor-patient relationship (lack of emotional connection/personal touch, etc.)", followed by "Uncertainty about the responsibility in the decision-making process of AI" (45.1%). Regarding privacy and data security, more than half of the participants (59%) indicated concerns about the risk of "hacking or misuse of AI algorithms". The common opinion regarding the potential conflict of AI use with ethical principles in dental practice (59.4%) was "Human doctors must maintain their position in important decisions and evaluations." When concerns about the potential impact of AI on dental education or practice were examined, the highest rate (53.7%) expressed concern about "the risk of dental students not being able to adequately develop their practical skills" (Table 2.). The mean AI anxiety score for dental students was 7.49±4.51, while for academicians, it was 8.47±4.34. Although academicians had higher anxiety levels, there was no statistically significant difference between the anxiety levels of students and academicians. As students' academic levels increased, their anxiety levels also increased, and a borderline significant correlation was found ($p=0.05$, $r=0.11$) (Table 3.). However, as academicians' years of experience increased, their anxiety levels decreased significantly ($p=0.02$, $r=-0.37$) (Table 4.).

Table 1. Demographic data of the participants

		Min-Max	Mean±SD
Age		17-65	22,45±2,97
		n	**%**
Gender	**men**	135	43
	women	180	57
Student		267	85
Academician		48	15
Student years	**1st year**	99	31,4
	2nd year	64	20,3
	3rd year	54	17,1
	4th year	39	12,4
	5th year	11	3,5
Group	**Preclinical (1,2)**	163	61
	Clinical (3,4,5)	104	39
Academicians' years of professional experience	**1-5**	28	8,9
	6-10	7	2,2
	11 years or more	8	2,5

Table 2. Distribution of Participants' Responses Regarding Concerns About AI Applications in Dentistry

Questions	Answers	n	%
What are your concerns regarding the use of AI in dental applications?	The inadequacy of AI in terms of accuracy and reliability	100	31.7
	The replacement of human doctors by AI	102	32.4
	The risk of AI violating patient privacy	73	23.2
	The possibility of AI making incorrect diagnoses or treatments	149	47.3
	I have no concern	54	17.1
What are your ethical concerns regarding the use of AI-assisted dental applications?	The inability to establish a patient-doctor relationship (lack of emotional connection/personal touch, etc.)	172	54.6
	The use of AI without obtaining a patient consent	66	21
	The ambiguity of responsibility in the AI decision-making process	142	45.1
	The unfair use of AI or the risk of discrimination	77	24.4
	I have no concern	56	17.8
What are your concerns regarding privacy and data security in relation to AI?	The risk of unauthorized access to personal health data	126	40
	The risk of AI algorithms being hacked or misused	186	59
	The inadequacy of data security standards	91	28.9
	The possibility of AI using health data for commercial purposes	141	44.8
	I have no concern	54	17.1
What are your thoughts on the possibility of AI use conflicting with ethical principles in dental practice?	There may be difficulties in protecting patient confidentiality.	120	38.1
	Obtaining informed consent may be challenging.	60	19
	Ensuring that AI algorithms are fair and unbiased can be difficult.	77	24.4
	Human doctors should maintain their role in important decisions and evaluations.	187	59.4
	I have no concern	48	15.2
What are your concerns about the potential impacts of AI on dental education or practice?	The risk of dental students not developing practical skills adequately	169	53.7
	The risk of dental students not reinforcing their theoretical knowledge sufficiently	82	26
	The risk of AI reducing the professional autonomy of dentists	135	42.9
	The risk of unemployment for dentists and auxiliary staff	135	42.9
	I have no concern	48	15.2

Table 3. Spearman rho correlation table between anxiety score and student class

	Anxiety Score	Student Class
Anxiety Score	1.00	0.11
p-value (two-tailed)		0.05*
Student Class	0.11	1.00
p-value (two-tailed)	0.05	

*Note: The result is significant at the two-tailed significance level with p=0.049 ($p < 0.05$).

Table 4. Spearman rho correlation table between anxiety score and academic experience

	Anxiety Score	Academic Experience (Years)
Anxiety Score	1.00	-0.37
p-value (two-tailed)		0.02*
Academic Experience (Years)	-0.37	1.00
p-value (two-tailed)	0.02	

*Note: The result is significant at the two-tailed significance level with p=0.02 ($p < 0.05$).

Regarding the distribution of thoughts on AI ethics in dentistry, the prevailing opinion on the ethical use of AI applications in dentistry was that it should be acceptable with proper education and supervision. More than half of the participants (55%) shared this view. Regarding privacy and data security in AI applications, the most common responses were "It is very important, strict measures must be taken" and "It is important, but data sharing may be acceptable in certain situations". The common concern regarding privacy and data security was "the risk of AI algorithms being hacked or misused". The responsibility for potential errors in AI applications was generally attributed to both the AI system manufacturers and the dentists and healthcare staff. It was emphasized that AI should have an important but limited role in dental education. Regarding the education of dental students on AI ethical rules, it was observed that both students and academicians did not have a clear opinion. After those who answered "Insufficient training is provided, it should be given," the "Undecided" option and "No training is provided, it should be given" response were marked (Table 5).

Table 5. Distribution of thoughts on AI ethics in dentistry

Questions	Answers	n	%
What is your opinion on the ethically acceptable use of AI applications in dentistry?	Definitely acceptable	10	3.2
	Acceptable with education and supervision	176	55.9
	Undecided	77	24.4
	Mostly unacceptable	43	13.7
	Definitely unacceptable	9	2.9
What is your opinion on privacy and data security in AI applications?	A very important issue, strict measures should be taken	143	43.4
	Important, but data sharing may be acceptable in some cases	102	32.4
	Undecided	37	11.7
	Should be considered, but flexibility in practices may be allowed	29	9.2
	Data protection is not important to me	4	1.3
What is your opinion on the responsibility for mistakes in AI applications?	The manufacturers and providers of AI systems are responsible	103	32.7
	The dentist and healthcare professionals are responsible	20	6.3
	Both the manufacturers and providers of AI systems and the dentist and healthcare professionals are responsible	146	46.3
	Undecided	39	12.4
	None of the above	7	2.2
What is your opinion on the importance of using AI applications in dental education?	Very important, should be widely used in education	47	14.9
	Important, but should be used in a limited way	192	61
	Undecided	49	15.6
	Not very important, traditional methods are more effective but can be used	25	7.9
	Not important at all	2	0.6

DISCUSSION

Artificial intelligence (AI) offers many benefits at every stage of the healthcare system, starting with education.[13] However, the need to adapt to this technology in a changing world is a factor that increases the level of anxiety. AI anxiety is defined as a state of panic and fear arising from the unknown aspects of this technology and its products.[8] At the same time, there are concerns that medical AI technology may blunt doctors' diagnostic expertise and critical thinking skills, or make doctors unemployed.[14] With increasing concerns about AI, an appropriate scale has been developed to measure AI anxiety.[15] Terzi adapted this AI anxiety scale to Turkish and conducted a validity and reliability study in 2020.[16] Yüzbaşıoğlu designed a web-based electronic questionnaire to acquire information about dental students' knowledge and attitudes towards AI and its possible applications in dentistry, with the participation of 9 dental faculties and 1103 dental students in Turkey. In this study, the knowledge and attitude questionnaire was self-developed as a result of literature review.[17] In the present study, in order to emphasize the development of AI, the survey questions were prepared using Chat GPT-3, an AI application frequently used by students. Then, the questions were edited by two researchers and necessary corrections were made.

In the present study, approximately one-third of the participants were concerned about "The replacement of human doctors by AI." Although the options in the studies by Karan-Romero et al.[18] and Yüzbaşıoğlu[17] were structured differently, the rate of those who agreed with this opinion was approximately 1 in 3 in both studies (34% and 28.60%). Also, 54.6% of the participants of the present study were concerned about" The inability to establish a patient-doctor relationship" in the use of AI-assisted dentistry applications. This result proves the concern that AI will replace human doctors is high. In contrast, 73% of participants of Sadeep's study believed that AI will improve the patient-doctor relationship.[19] The inadequate and non-standardized level of education on the use of AI in dentistry leads to these contradictory results.

In evaluating concerns about the potential impact of AI applications on dental education or practice, the high rate of concern about "the risk of unemployment for dentists and auxiliary staff" (42.9%) reinforces "The replacement of human doctors by AI" opinion. The high rate (59.4%) of belief that human doctors should retain their position in important decisions and evaluations if the use of AI conflicts with ethical principles in dental practice, originates from the similar concern. This also indirectly emphasizes that the use of AI as an auxiliary tool is more accurate.

Although the current technology is helpful in improving the clinical skills of doctors by providing advice rather than replacing their positions[14], its use as a tool in diagnosis and treatment is also seen as a concern. Because, 31.7% of participants were concerned that AI is not accurate or reliable enough. In accordance with this, around half of participants believed in "The possibility of AI making incorrect diagnoses or treatments". Similarly, 41% of participants in Sadeep's study said that "AI cannot make a definitive diagnosis".[19]

As society becomes more technology-dependent, information security becomes more critical.[20] Because throughout the process of data collection and transfer, there is a risk of data leakage and confidentiality.[21] The current study supports this with a high level of anxiety about privacy and data security related to AI, which also remains one of the biggest drawbacks of technological advances.

The dental curriculum includes both practical and theoretical training.[22] Uncertainty about the integration of AI into practical training led to a high level of concern about "the risk of dental students not developing their practical skills adequately" (53.7%). Although responses to the question of whether dental students should be educated on AI ethics varied, most participants agreed that education should be provided. Similarly, 61% of participants thought that the use of AI applications in education was important, but that it should be used in a limited way. All these results support the need for detailed and comprehensive curriculum that define the limits of AI applications.

In the question about responsibility for errors that may occur in AI applications, most participants said that "both the manufacturers and providers of AI systems and the dentist and healthcare professionals are responsible", but the number of those who thought that "the manufacturers and providers of AI systems are responsible" was also high. Although studies also report that awareness of AI is high[18,19], the ethical rules and responsibility limits of these applications should be well defined. This is because the dental curriculum should include the ethical applications of AI, including its risks and limitations, and should not only teach students how to use these programs, but also encourage critical thinking towards correct interpretation. The curriculum should also include issues such as data protection, privacy and potential interference by third parties.[23]

While Terzi reported no relationship between the AI anxiety levels of teachers and the years of professional experience[16], the present study stated that anxiety levels decreased as the years of professional experience increased. This difference can be explained by the fact that the other study included general questions, while the current study included profession-specific questions and the small number of participants. In the student participants, the anxiety level increased with advancing grade level. This may be related to increasing professional knowledge and the clinical practice. In some SCI and SCIE journals affiliated with Elsevier, authors are asked to explain the use of AI and AI-enabled technologies in the writing process under the title 'Declaration of productive AI in scientific articles'. It also states that AI and AI-enabled technologies should not be listed as authors, co-authors or cited as authors.[24]

In the present study, the authors declare that the Chat GPT-3 programme was used to prepare the survey questions. Then, the authors carefully reviewed and edited the questions and are fully responsible for the content of the publication. The use of AI (Chat GPT-3) is limited to the preparation of the survey and the article was written entirely by the authors. The use of technology in dentistry, as in any area of science, should be under human supervision and control. Scientists should carefully review and edit the results, as AI can produce results that appear reliable but may be incomplete, incorrect or biased. According to the results of the present study, both dental students and academicians were concerned about the applications of AI. The general view on the ethically acceptable use of AI applications in dentistry is that they can be used under education and supervision guidance.

CONCLUSION

Both dental students and academicians were concerned about AI applications. While the students' anxiety level was increased with advancing grade level, that of academicians' decreased as their professional experience increased. They believed that education and supervision were important for ethical use. They should be considered in the design of educational programs in order to contribute to the more effective and safe use of AI technologies in dentistry.

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Artificial Intelligence in Pediatric Dentistry

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Citation: Ghabchi B, Uzel İ, Çoğulu D. Artificial Intelligence in Pediatric Dentistry. *Int Arc Dent Sci*. 2025;46(1):59-63.

ABSTRACT

Artificial intelligence (AI) has become a transformative tool in various fields. This comprehensive review examines the innovative applications of AI in pediatric dentistry, emphasizing its potential to enhance patient care, facilitate accurate diagnosis, optimize treatment planning, and advance dental education.

Furthermore, the integration of virtual reality (VR) and augmented reality (AR) technologies offers immersive educational experiences that not only aid in educating children about dental procedures but also play a crucial role in reducing dental anxiety.

Keywords: *Artificial Intelligence, Pediatric Dentistry, Virtual Reality*

ÖZ

Yapay zeka (YZ), farklı alanlarda dönüştürücü bir araç olarak dikkati çekmektedir. Bu derleme makalesi, yapay zekanın çocuk diş hekimliğinde yenilikçi uygulamalarını sunmakta ve yapay zekanın hasta bakımı, tanı, tedavi planlaması ve eğitimde yerini vurgulamaktadır.

Sanal gerçeklik (SG) ve artırılmış gerçeklik (AG) uygulamaları, sürdürülebilir eğitim deneyimleri sunarak çocuklarda diş hekimliği uygulamalarının kabul edilebilir hale gelmesine ve kaygının azalmasına yardımcı olmaktadır.

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Received Date: 13.02.2024
Accepted Date: 13.06.2024

INTRODUCTION

The field of Artificial Intelligence (AI) is a relatively recent development in both engineering and science, concerned with the imitation of intelligent behaviour and the creation of artefacts that replicate such behaviour.[1-6] The integration of AI into diverse sectors has been a subject of considerable interest. Information technology (IT) in the field of dentistry has undergone significant expansion over the past 25 years, contributing to a reduction in costs, time, reliance on human expertise, and medical errors. As a subfield of computer science, AI encompasses hardware and software capable of perceiving its environment and taking actions that maximize its chances of successfully achieving its goals. The integration of AI into the dental field has the potential to enhance patient health outcomes while reducing costs, thereby facilitating the delivery of personalized, preventative, and predictive dentistry services that can be made universally accessible. The potential of AI to enhance dental care is evident in its capacity to refine diagnostic accuracy and efficacy, generate more precise visualizations for treatment, simulate outcomes, and predict oral diseases and health.[7-10]

Pediatric dentistry is a field that constantly seeks innovative ways to provide the best care for children's oral health. With the rapid advancement of technology, AI has emerged as a promising tool to enhance various aspects of pediatric dental care. From the initial diagnosis to the formulation of treatment plans and the education of patients, AI is profoundly transforming the manner in which dentists approach the field of pediatric oral health.[3,8,9]

Artificial intelligence holds immense promises for pediatric dentistry, offering opportunities to improve diagnostics, treatment planning, patient experience, and practice management. As research and development in this field continue to advance, clinicians, researchers, and administrators need to collaborate in harnessing the full potential of AI while addressing associated challenges to ensure equitable access and ethical use in pediatric dental care. With its ability to process vast amounts of data, recognize patterns, and make predictions, AI is revolutionizing oral healthcare in numerous ways. This review explores the applications of AI in dentistry, its benefits, challenges, and prospects.[11-17]

The Use of AI in Pediatric Dentistry

The use of AI in Pediatric Dentistry is quite relevant because it not only requires skill to perform procedures but also requires proper behavior guidance skills.[11-13] Innovations in pediatric dentistry are being introduced with the aim of facilitating the identification of patients' behavioural patterns, as well as the management of their anxiety, the management of data, investigations, diagnosis, treatment planning, prognosis and patient education. It benefits clinicians with high-quality patient care and simplifies complicated protocols by providing a predictable outcome.[11-17]

Early Detection, Diagnosis, and Treatment Planning

One of the most significant contributions of AI in pediatric dentistry is its ability to aid in the early detection and diagnosis of dental issues. AI-based image recognition systems can analyze dental images, such as X-rays and intraoral scans, with remarkable accuracy. These systems can detect dental caries, developmental abnormalities, and other oral health problems at their earliest stages, allowing for timely intervention and prevention of further complications. This aids in early diagnosis and precise treatment planning.[13-16]

AI algorithms can analyze vast amounts of patient data, including medical history, dental records, and diagnostic images, to develop personalized treatment plans for pediatric patients. By considering individual factors such as age, oral hygiene habits, and risk factors, AI can recommend the most appropriate interventions, such as topical fluoride applications, sealants, or orthodontic procedures, tailored to each child's unique needs.[9,14]

Chronological Age Assessment

It has been focused on producing a new method for detecting the chronological age using digital panoramic radiographs. This method is simpler, has near-perfect accuracy, and was one of the first to use radiographs for metric age assessment.[13,14,18]

Virtual Simulation and Education

Virtual reality (VR) and augmented reality (AR) technologies powered by AI are transforming the way children learn about oral hygiene and dental procedures. Interactive VR simulations allow young patients to explore virtual dental environments, familiarizing them with dental instruments and procedures in a fun and engaging way. AR applications can also educate children about proper brushing techniques and oral hygiene practices, encouraging them to develop lifelong habits for optimal oral health.[2,9,11]

Predictive Analytics and Preventive Care

AI-based predictive analytics can forecast future dental issues based on historical data and risk factors, enabling dentists to implement preventive measures before problems arise. By identifying high-risk patients and recommending targeted preventive interventions, such as dietary modifications or fluoride supplementation, AI helps mitigate the risk of dental caries and other common pediatric dental problems.[3,8,15,19-21]

Local Anesthesia

The new, better path to injection-free pediatric dentistry practice is pain control with AI-based devices. In children, anesthetic nanorobots if introduced in a suspension into the quadrant of interest, will reach the pulp via the gingival sulcus, lamina propria, and the dentinal tubules and block the action potentials in the sensory nerves upon activation by the dentist until decided by the dentist when he/she can command the robots to deactivate.[6,8]

Restorative Dentistry

AI-based restorative dentistry with computer-aided design and computer-aided manufacturing technology is well-established, and it would be a time and aesthetic benefit for pediatric restorations.[22-30]

Endodontics

Real-time information presented three-dimensionally on the patient's body is more efficient and avoids confusion in comparison to being presented on a separate screen. This allows the dentist to obtain critical information such as the complex anatomy of root canals while maintaining focus on the operating field in contrast to the conventional systems.[31-33]

Orthodontics and Prosthodontics

Orthodontic diagnosis, planning, and treatment monitoring are possible using AI. Analysis of radiographs and images taken by intraoral scanners and cameras can be used for diagnosis and treatment planning. Designing software has been a great aid to orthodontists in fabricating the best possible aesthetics for patients considering all the variables like measurements of the face, anthropological computation, and even the patient's desire.[7,8,34,35]

The computer-guided digital impression is another useful application of artificial intelligence. They are not only faster and more accurate but also laboratory procedures are eliminated, greatly reducing human mistakes.[2,36]

CAD/CAM technique helps to create three-dimensional models and aids in the manufacturing of inlays, onlays, crowns, and bridges. This technique has greatly reduced human efforts on time-consuming laboratory procedures, also reducing the errors in final prosthesis.[3,35,37]

Benefits of AI in Dentistry

Improved Accuracy: AI algorithms can analyze data with unparalleled precision, reducing diagnostic errors and ensuring optimal treatment outcomes.

Efficiency: The utilization of AI in the automation of routine tasks has been demonstrated to liberate time for dentists to concentrate on more complex cases and patient care, thus enhancing overall productivity.

Cost-effectiveness: AI-based preventive care can mitigate the need for expensive treatments by addressing dental issues at an early stage, reducing healthcare costs in a long-term period.

Enhanced Patient Experience: Personalized treatment plans and efficient appointment scheduling contribute to a more satisfying patient experience, fostering loyalty and trust.[3,8,9,20,38,39]

Challenges and Ethical Considerations

Despite its numerous benefits, the integration of AI in pediatric dentistry presents some challenges and considerations. Privacy and security concerns regarding the storage and handling of sensitive patient data must be addressed to ensure compliance with healthcare regulations. Additionally, there is a need for ongoing training and education to familiarize dental professionals with AI technologies and ensure their effective implementation in clinical practice.

Data Privacy: AI systems rely on vast amounts of patient data, raising concerns about privacy and security breaches.

Bias and Fairness: Biases in AI algorithms can lead to disparities in treatment recommendations and patient care, necessitating careful algorithm development and validation.

Regulatory Compliance: The integration of AI in dentistry requires adherence to regulatory standards and guidelines to ensure patient safety and ethical practice.[8,9,20,35,40]

Despite the promising results of the presented AI models, it is still necessary to verify their generalizability and reliability using appropriate external data obtained from patients or accumulated from other dental facilities. Future aims of AI research in dentistry include not only raising the performance of AI models to expert levels but also detecting early lesions that are invisible to humans.

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Intentional Replantation of a Mandibular First Molar with Post-Treatment Apical Periodontitis: A Case Report with 12-Month Follow-Up

Tedavi Sonrası Apikal Periodontitisli Mandibular Birinci Molarda Kasıtlı Replantasyon: 12 Aylık Vaka Takibi

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Citation: Ceylan A, Keskin M, Keskin C. Intentional Replantation of a Mandibular First Molar with Post-Treatment Apical Periodontitis: A Case Report with 12-Month Follow-Up. *Int Arc Dent Sci*. 2025;46(1):69-73.

ABSTRACT

Intentional replantation (IR) emerges as a critical intervention when non-surgical endodontic treatment fails, and anatomical limits rule out apicoectomy as a viable option. In cases where proximity to the inferior alveolar nerve, association with the maxillary sinus, or a thick buccal cortical plate prevents apicoectomy, IR becomes the preferred treatment method. A fifty-six-year-old female presented to the Ondokuz Mayıs University Department of Endodontics clinic with persistent discomfort and unresolved swelling in the left mandibular region following unsuccessful root canal treatment performed a year prior. Clinical examination revealed increased probing depths, a draining sinus tract, and localized swelling around tooth 36. A preoperative periapical radiograph confirmed post-treatment apical periodontitis, necessitating IR due to the thick buccal cortical plate. The tooth was atraumatically extracted, an extra-oral apicoectomy was executed, and the root end was prepared and sealed with mineral trioxide aggregate. Subsequently, the tooth was replanted and stabilized with sutures. A three-month follow-up demonstrated resolution of the sinus tract, with the tooth asymptomatic and fully functional at the one-year mark. Despite being overlooked by practitioners and often perceived as complex and unsafe, accumulating evidence supports its efficacy. Considering its cost-effectiveness to dental implants, clinicians should contemplate employing IR before opting for extraction.

Keywords: *Intentional replantation, mineral trioxide aggregate, conservative endodontics*

ÖZ

Kasıtlı replantasyon, cerrahi olmayan endodontik tedavi başarısız olduğunda ve anatomik sınırlar apikoektomiyi uygun bir seçenek olmaktan çıkardığında uygulanabilir. Inferior alveolar sinire yakınlık, maksiller sinüsle ilişki veya kalın bukkal kortikal plaka gibi durumlarda, kasıtlı replantasyon tercih edilebilir. Bu vaka raporunun amacı alt molar dişe yapılan kasıtlı replantasyon vakasının bir yıllık takibini sunmaktır. 56 yaşındaki kadın hasta, bir yıl önce uygulanan retreatment sonrası sol alt çenesinde rahatsızlık ve şişlik şikayetiyle Ondokuz Mayıs Üniversitesi Diş Hekimliği Fakültesi Endodonti kliniğine başvurdu. Klinik muayene, artmış sondalama derinliği, drene haldeki sinüs yolu ve 36 numaralı dişin fasiyal yüzündeki lokalize şişliği ortaya koydu. Periapikal radyografide periradiküler lezyon gözlendi ve tedavi sonrası apikal periodontitis teşhisi konuldu. Kalın bukkal kortikal kemik nedeniyle kasıtlı replantasyon kararı alındı. Diş atravmatik olarak çekildi, apikal rezeksiyon yapılıp kök ucu prepare edildikten sonra retrograd dolduruldu. Ekstraoral süre 5 dakika olarak kaydedildi. Diş replante edilip splintlendi. 3 aylık kontrolde sinüs yolunun kaybolduğu ve 1 yıllık kontrolde lezyonun tamamen iyileştiği, dişin semptomsuz ve fonksiyonel olduğu saptandı. Kasıtlı replantasyon, klinisyenler tarafından genelde göz ardı edilen bir tedavi seçeneğidir. Ancak, tedavinin başarılı olduğuna dair artan kanıtlar ve dental implantlara kıyasla maliyet etkinliği ile her klinisyenin değerlendirmesi gereken bir tedavidir.

Anahtar Kelimeler: *Kasıtlı replantasyon, mineral trioksit agregat, konservatif endodonti*

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Received Date: 27.01.2024
Accepted Date: 04.08.2024

INTRODUCTION

Endodontic treatment usually follows the order of less-invasive to invasive, such as pulp capping, amputation, root canal treatment, and retreatment. With the intention of minimal healthy tissue removal and avoidance of overtreatment, less invasive procedures are preferred. In this line of reasoning, when retreatment fails for some reason, we consider the possibility of an apicoectomy. Still, if the condition of the tooth is not viable for the procedure, most typically, Intentional replantation should be preferred to apicoectomy, in such cases as in mandibular molars because of the thick buccal cortical plate causing substantial bone removal to access to roots and post-op complications such as altered sensation[1] and in cases where maxillary premolar/molars are related with maxillary sinus and apicoectomy might damage the Schneiderian membrane.

Historically, intentional replantation has been practiced as early as the 18th and 19th centuries with the purpose of pain alleviation and abscess drainage.[2] Throughout the history of dental practice, the conduction of such treatment has progressed, and several successful case reports and studies have been made. Modern endodontics uses intentional replantation to treat many conditions, including maxillary sinusitis, vertical root, cases that are nonresponsive to non-surgical root canal treatment, or external root resorption.[3] Multiple meta-analyses finding the success rate 88% to 89.1%.[4] This case report aimed to present post-treatment apical periodontitis related to a mandibular first molar with fused roots and C-shape canals that were treated with hydraulic cement (AGM MTA, Andishe Gostar Masoud Co., Isfahan, Iran) intentional replantation in a female patient.

CASE REPORT

A 56-year-old female patient was referred to the clinic of the Endodontics Department at Ondokuz Mayıs University with complaints consisting of unresolved swelling on the left mandibular region, pain, and discomfort. Clinical examination confirmed a localized buccal swelling and a draining sinus tract in the facial region of tooth #36. The tooth was sensitive to palpation. Periodontal probing was 4 mm in the mesial, and the distal crown showed no sign of any crack. Restoration margins were appropriate. A periapical radiograph was taken, revealing a periapical lesion and a diagnosis of post-treatment apical periodontitis was made. After a thorough discussion with the patient about possible risks and complications, the patient consented to an intentional replantation procedure. The tooth was extracted as atraumatically as possible, purulent drainage was present and aspirated with a surgical suction until drainage was finished. The socket was free of any granulation tissue; to prevent damage to the periodontal ligament, no curettage was performed. The tooth was held by its crown with a sterile saline-soaked gauze by the operator. 3 mm of the apex was removed at 0° bevel angle from the root axis, and a C-shaped canal configuration was observed. Canals were retro-prepped 3mms with a high-speed rotary diamond round bur (FG Diamond, Adia abrasive Technologies, Istanbul, Türkiye) during copious sterile saline irrigation, and an AGM MTA (Andishe Gostar Masoud Co., Isfahan, Iran) retrograde filling was placed in the apices. After the root-end preparation was completed, the tooth was replanted, and A total of 4.5 minutes of extra-oral time was spent out of the socket. Afterward, the tooth was secured to its socket with a non-resorbable cruciate suture for one week. The tooth was reduced from the active occlusion, and 100 mg a day of doxycycline was prescribed for one week post-operatively. Three months of follow-up showed resolution of the apical radiolucency and swelling. In a one-year follow-up, the tooth was completely asymptomatic and in total recovery.

Figure 1. Periapical radiograph illustrating a sizeable periapical radiolucency associated with the apex of tooth #36.

Figure 2. Periapical radiograph of tooth #36 immediately after replantation.

Figure 3. Three-month postoperative periapical radiograph revealing osseous healing of the periapical radiolucency.

Figure 4. One-year postoperative periapical radiograph revealing complete osseous healing of the periapical radiolucency

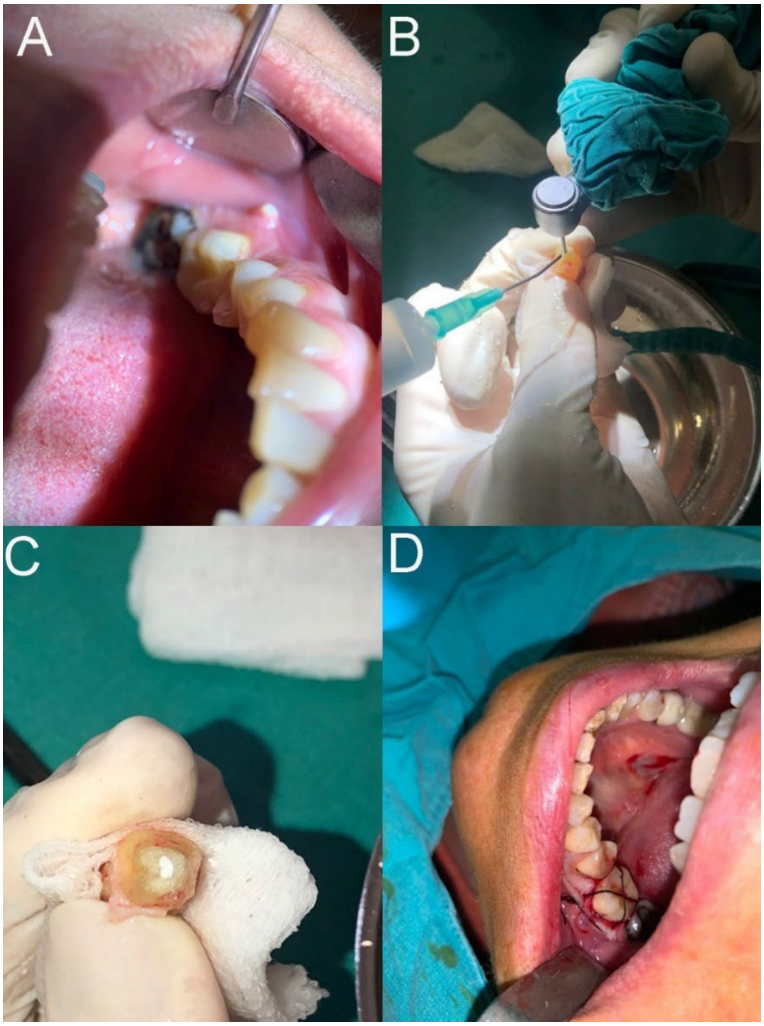

Figure 5-A. A preoperative clinical photograph with a mandibular occlusal view shows the symptomatic tooth #36 with a sinus tract, **5-B**. Photograph illustrating the apical retropreparation of the canals of tooth #36, **5-C** Photograph illustrating the retrograde filling with AGM MTA, **5-D** Photograph showing after replantation and splinting.

DISCUSSION

Nonsurgical root canal retreatment can be considered when the initial root canal procedure is unsuccessful. Although the success rate of retreatment is high, the inability to remove separated instruments in the apical zone, apical transportations, and zip perforations are some limitations to the retreatment procedure. These clinical scenarios may require surgical interventions. Proximity to anatomical landmarks such as the inferior alveolar nerve and maxillary sinus may be a contraindication to surgical approaches.

Apicoectomy and implant surgery are more complex and time-consuming operations than Intentional replantation since they require flap surgery, hemostasis, removal of the bone to some degree, and multiple sessions in implant surgery, making Intentional replantation relatively feasible to perform. Since intentional replantation does not require any flap operation, the surgical part only consists of atraumatic extraction and replantation, which requires little time. Even though dental implants have a high chance of survival compared to intentionally replanted teeth, Intentional replantation is a cost-effective option to single-tooth implants, even if a post-core is needed. The survival rate of intentional replantation must decrease to 54% to lose its cost-effectiveness against dental implants.[4]

Studies have confirmed the importance of intactness of cementum and periodontal ligament during extraction and during the extraoral environment; specimens showed external root resorption in areas with defective cementum and impaired periodontal ligament. Also, preservation of the tooth in a humid environment is critical to the treatment outcome, and studies conclude that 15 minutes or less should favor the prognosis since it also affects the chance of resorption[5] and dehydration of the periodontal ligament.

Although there has yet to be a consensus on the length and type of root-end preparation, multiple authors describe the amount between 2 mm to 4 mm or even one-third of the root length. 3 mm apical resections should be sufficient since 98% of anatomical ramifications and 93% of lateral canals are present within the apical 3mm from the apex.[6]

It has been suggested that the use of ProRoot MTA as a retro-filling material negatively affects the treatment outcome in teeth with C-shaped canal anatomy[7] for MTA's long setting time, resulting in its deterioration and an unfavorable diagnosis. However, new-generation hydraulic cements with a high concentration of larger d90 particles have a decreased setting time[8]; use of a hydraulic material with larger particle size and with a maximum of 15 minutes of setting time should favor the prognosis of intentional replantation.

Literature shows that splinting after replantation is still controversial. Although the literature indicates that The lack of splinting may expedite damage resulting from trauma and instability during the healing process, many materials have been used to splint teeth, such as orthodontic wire, sutures, and acrylic.[9] Kratchmen[10] states that rigid splinting may harbor bacteria, and studies state that suture splinting might facilitate periodontal healing.[9]

CONCLUSION

With the increasing number of successful long-term reports, intentional replantation should be considered before extracting a retreated or a "hopeless" tooth. Even considering its cost-effectiveness, minimal time requirement, and feasibility to dental implants, intentional replantation might be an option before a dental implant insertion.

DECLARATION

Conflicts of Interest: The author declares no potential conflicts of interest concerning this article's research, authorship, and publication.

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Regenerative Surgery of Residual Defect After Non-Surgical Periodontal Treatment in a Patient with Advanced Periodontitis

İleri Periodontitis Hastasının Cerrahisiz Periodontal Tedavi Sonrası Rezidüel Defektin Rejeneratif Cerrahisi

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Citation: Okandan H, Özçaka Yüksel Ö. Regenerative Surgery of Residual Defect After Non-Surgical Periodontal Treatment in a Patient with Advanced Periodontitis. *Int Arc Dent Sci*. 2025;46(1):71-76.

ABSTRACT

Periodontitis is a chronic inflammatory disease with destruction of tooth supporting tissues. There are multiple factors that affect the rate and pattern of destruction of this disease. Depending on the type of defect, various resective and regenerative surgical methods can be applied. In our case, regenerative surgery was performed on the tooth with a residual 2-walled defect after initial periodontal treatment. The platelet-rich fibrin membrane obtained from the patient's blood together with the bovine-derived granular bone graft was used in the operation area. The case, whose clinical and radiological results were successful in 6 months, showed that it can be beneficial to use these sources in combination.

Keywords: *Periodontitis, Regenerative periodontal surgery, Gingival recession, Platelet-rich fibrin, Acrylic temporary prosthesis*

ÖZ

Periodontitis diş destek dokularında yıkımla giden kronik enflamatuar bir hastalıktır. Bu hastalığın yıkım hızını, paternini etkileyen birden fazla faktör vardır. Defektin tipine göre çeşitli rezektif ve rejeneratif cerrahi yöntemler uygulanabilir. Olgumuzda başlangıç periodontal tedavi sonrası kalan rezidüel 2 duvarlı defekti bulunan dişin rejeneratif cerrahisi yapılmıştır. Sığır kaynaklı granüler kemik grefti ile beraber hasta kanından elde edilen trombositten zengin fibrin membran haline getirilerek operasyon alanında kullanılmıştır. 6 aylık sonucu klinik ve radyolojik sonucu başarılı olan vaka, bu kaynakların kombine olarak kullanılmasının faydalı olabileceğini göstermiştir.

Anahtar Kelimeler: *Periodontitis, Rejeneratif periodontal cerrahi, Dişeti çekilmesi, Plateletten zengin fibrin, Akrilik geçici protez*

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Received Date: 01.12.2022
Accepted Date: 01.07.2024

INTRODUCTION

Periodontitis is a chronic inflammatory disease that affects the supporting structures of the teeth, including the gingiva, periodontal ligament, alveolar bone, and cementum. The etiology of periodontitis involves multiple groups of bacteria. The destruction process begins with the induction of the host's immune response by pathogenic bacteria found in dental plaque, leading to irreversible damage in the surrounding tissues. Due to its chronic nature, this condition often begins and progresses without pain, making it difficult for patients to notice. Typically, patients seek clinical attention due to acute conditions such as periodontal abscesses.[1]

The severity of periodontitis varies from person to person, across different regions of the same individual and at different times in the same region.[2] Studies have shown that in areas where periodontal disease is active, there is a higher accumulation of plaque, and its removal becomes increasingly difficult. The effectiveness of the host's defense system is one of the main factors influencing the course and severity of the disease. While bacterial plaque is the primary factor in the development of periodontitis, local factors such as maladaptive restorations, tooth anatomy, the presence of caries, and root resorption facilitate plaque accumulation or exacerbate its effects, thus playing a secondary role in periodontal disease. Additionally, systemic factors, including smoking, genetic factors, stress, and dietary habits, are known to be risk factors for the initiation and progression of periodontal disease.[3,4]

The primary goals of periodontal treatment are the elimination of pathogenic microflora to prevent periodontal infections and the treatment of defects caused by active periodontitis. In defects resulting from destruction, the regeneration of the lost tissue can be achieved through guided bone regeneration.[5] The main aim of guided bone regeneration is to restore the supportive tissue lost due to disease and prevent early epithelial migration to ensure healing does not occur via repair. Bone grafts used for this purpose can be applied both independently and in combination with other regenerative materials.[3]

Bone defects, which arise in various types and widths in the alveolar bone due to periodontal disease, have been classified into three main categories based on morphological criteria to assist clinicians in diagnosis, treatment, and prognosis: 1. Suprabony defects, 2. Infrabony defects, a. Intrabony defects, b. Craters, 3. Interradicular defects (Furcation defects).[6] Clinically, the diagnosis of periodontal defects is made by measuring clinical attachment levels and radiographic evaluation. Due to the superimposition in radiographic evaluation and the limited information provided by two-dimensional images, it is essential to support the findings with clinical data.[7]

CASE PRESENTATION

A 34-year-old systemically healthy, non-smoking male patient presented to the Periodontology Department of Ege University Faculty of Dentistry with complaints of gingival hyperplasia, mobility, and pain in his teeth. Clinical and radiological examinations revealed widespread attachment loss in the maxillary anterior teeth, periodontal abscess, and malposition of the teeth. The clinical diagnosis of the case was stage 4 periodontitis with bone loss extending to the apical third of the root and grade C due to the progression of destruction. (Figures 1, 2)

The initial periodontal treatment of the patient began with tooth surface cleaning. Subsequently, following the extraction of teeth #21 and #23, which had Miller Class 3 mobility, and after the healing of the extraction sites, the periodontal treatment was completed without surgery. This included root surface planing at each session for one half of the arch, along with antibiotic support (Tetracycline 500 mg tablet, twice daily for 8 days). The probing depths at the beginning of treatment and at the second-month follow-up are shown in the table. (Table 1)

On a percentage basis, the area with a probing depth of 7 mm or greater, initially 14%, reduced to 2% following the extraction of hopeless teeth and periodontal therapy of the remaining teeth. The area with probing depths between 4 to 6 mm decreased from 10% to 4%.

At the 2-month follow-up after non-surgical periodontal treatment, probing depths in tooth #13, which showed insufficient reduction, were measured as mesial 6.5 mm, distal 7.2 mm, buccal 7.5 mm, and palatal 4 mm. The presence of healthy tissue on adjacent teeth suggested a possible intrabony defect topology, leading to the planning of periodontal regenerative surgery. (Figure 3)

For the regeneration of the intrabony defect in tooth #13, along with the closure of the buccal surface gingival recession, a coronally positioned flap technique was chosen.8 (Figure 4). To avoid creating a second surgical site, Platelet-Rich Fibrin (PRF) was selected as an alternative to connective tissue grafts for covering the root surface.[9]

Figure 1.

Figure 1, 2: Photographs and radiographs taken at the time of the patient's first visit to the clinic.

Table 1. Periodontal measurements of the patient before and after treatment.

	Initial			**Post operative**		
Probing depth	**Mean (mm)**	**Number of sites**	**%**	**Mean (mm)**	**Number of sites**	**%**
Full mouth (mean)	3,5	168	100	2,9	150	100
0-3	2,6	128	76	2,7	141	94
4-6	5,1	16	10	4,3	6	4
≥7	7,2	24	14	7,1	3	2
Bleeding of probing			83			6

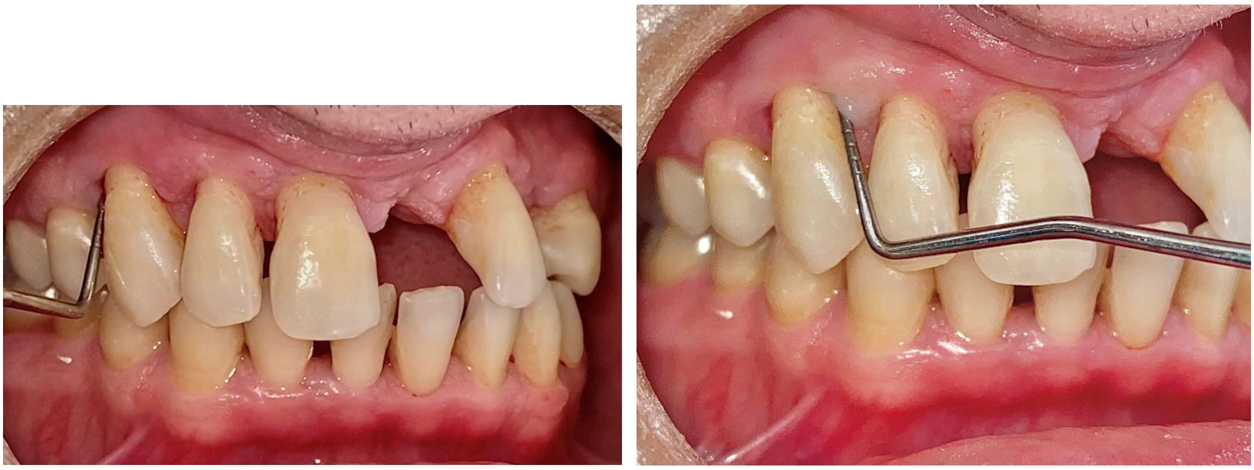

Figure 3. Clinical appearance after non-surgical periodontal treatment.

The flap was elevated, and granulation tissue was cleaned. During the same session, a blood sample was collected from the patient in a non-coagulant, glass-coated 10 ml plastic tube. The blood samples were centrifuged at 2700 rpm for 12 minutes. The prepared PRF membrane was compressed in the PRF BOX (Kruger, Istanbul, Turkey). A fine granular bone graft (Cerabone Botiss, Berlin, Germany), hydrated with the plasma exudate, was applied along the borders of the intrabony defect.1 The prepared membrane was placed over the graft, and the flap was released and repositioned coronally to cover the defect and close the recession. The wound was closed with 5-0 and 6-0 polypropylene sutures. (Figures 3,4)

No complications were observed post-surgery. Sutures were removed on the 10th day. The patient was recalled for follow-up visits at 1, 2, 3, and 6 months, and the case was evaluated both clinically and radiographically. (Figures 5,6)

Pre-surgical probing depth in the affected tooth was 7.3 mm, and at the 6-month follow-up, it measured 4.2 mm. The average clinical attachment level, initially 8.8 mm, reduced to 3.4 mm. The mobility, initially classified as Miller Class 1, was reduced to 0, and the vestibular gingival recession, initially 3 mm, was reduced to 0.25 mm. The root coverage achieved was approximately 91%.

Due to aesthetic concerns arising from the loss of teeth #21 and #23 for periodontal reasons, a temporary acrylic palatal prosthesis was fabricated. (Figure 7)

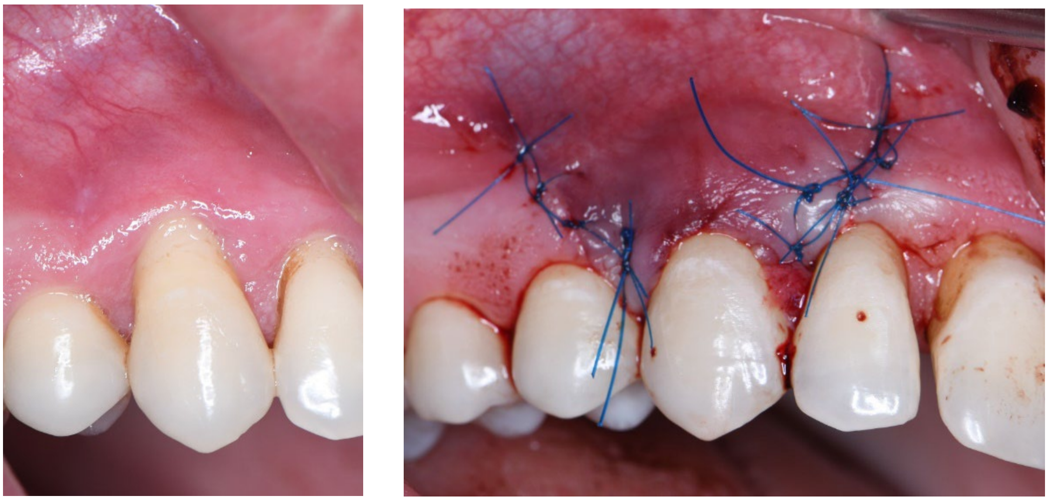

Figure 4. Pre-operative and post-operative photographs.

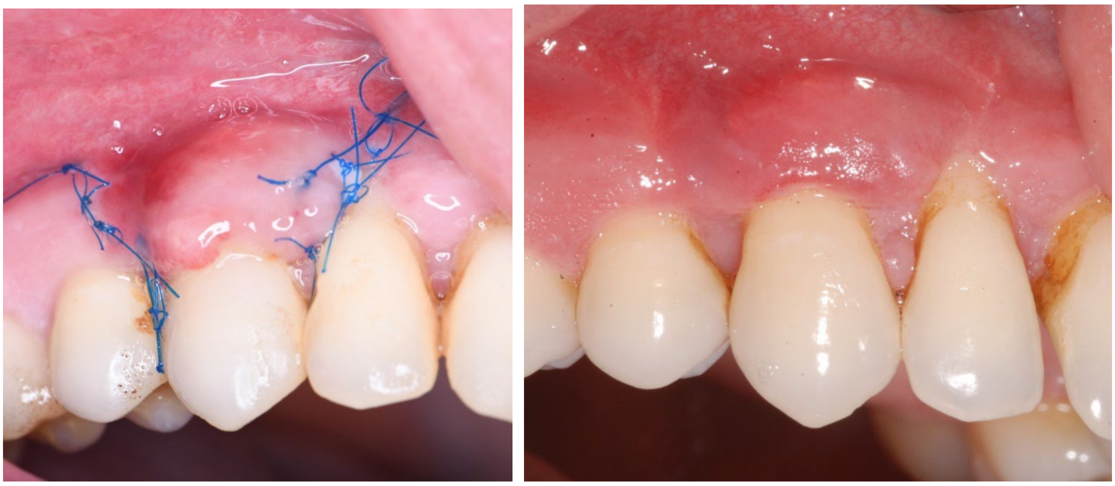

Figure 5. Photographs taken on the 10th day and at the 6-month follow-up after the surgery.

Figure 6. Radiographs taken at the beginning of treatment and at the 6-month follow-up.

Figure 7. Temporary prosthesis.

DISCUSSION

One of the main aesthetic concerns following periodontal regenerative surgery is the occurrence of gingival recession in the soft tissues. Although minimal invasive surgical techniques aim to reduce this issue, it remains a potential problem. The use of connective tissue grafts during surgery has been shown to yield more aesthetic results.8 In our study, the goal was to achieve root surface coverage along with periodontal regeneration; however, we aimed to utilize Platelet-Rich Fibrin (PRF), an alternative to connective tissue, for this purpose.[9]

In the early stages of healing in periodontal regeneration, stabilization of the blood clot in the defect site is crucial for the success of regeneration. After the preparation of PRF, its hemostatic effect, which helps stabilize the bone graft and clot in the defect site, contributes to improved wound healing. Additionally, PRF application prevents epithelial cell migration by inhibiting the adherence of the clot to the tooth structure. Literature indicates that there is an increase in clinical attachment gain and bone filling in direct proportion to the depth of the intrabony defect treated with regenerative therapy.[4]

Aroca et al. compared the use of a coronally advanced flap combined with a PRF membrane to a coronally advanced flap alone in the treatment of gingival recession. They reported that while the addition of PRF did not have a positive effect on root surface coverage, it did increase gingival thickness.[10] While subepithelial connective tissue grafts are more successful for root surface coverage, PRF can be used as an alternative.[9]

CONCLUSION

Within the limitations of our study, the coronally advanced flap technique, combined with PRF membranes as an alternative to connective tissue grafts, can be used for the treatment of intrabony defects with the aim of achieving root surface coverage. Further clinical controlled studies on more patients are needed to support these preliminary findings.

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