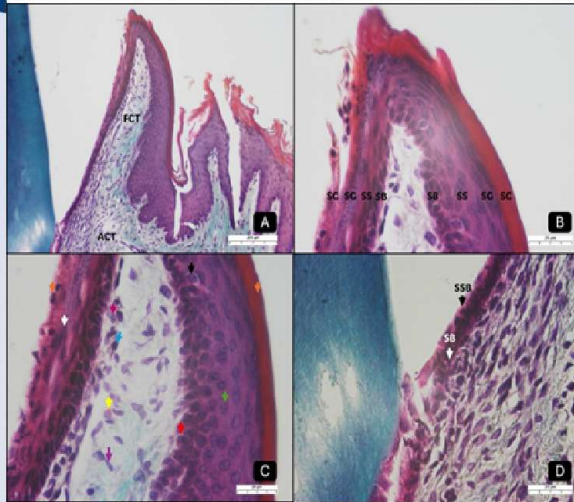




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Cumhuriyet Dental Journal (CDJ) is an international journal dedicated to the latest advancement of dentistry. The aim of this journal is to provide a platform for scientists and academicians all over the world to promote, share, and discuss various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

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



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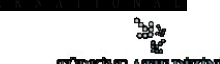
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Evaluation of the Effects of a Mobile Application on Oral Hygiene Motivation and Compliance with Fixed Orthodontic Patients

Hikmet Guliyev^{1,a}, Barış Başer^{1,b,*}

¹Department of Orthodontics, Faculty of Dentistry, Karadeniz Technical University, Trabzon, Turkey
*Corresponding author

Research Article

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ABSTRACT

Objectives: The aim of this study is to evaluate the effects of a uniquely developed mobile app on oral hygiene motivation and treatment compliance in patients undergoing fixed orthodontic treatment in comparison to traditional oral hygiene instructions.

Materials and Methods: In this prospective, controlled clinical trial, 50 orthodontic patients having fixed treatment were equally divided into two groups: a mobile app (e-tel (ortomobil)) and a control group. The control group received only traditional communication, consisting of verbal and written instructions at the start of treatment. Patients assigned to the mobile app group were provided with the ability to reschedule their appointments via the app, engage in direct chat with their orthodontist, and receive periodic notifications to remind them of oral hygiene motivation in addition to standardized hygiene instructions. Periodontal scores were obtained at 4 week intervals during three appointments (T1-T3) using the gingival index (GI), bleeding index (BI), and planimetric plaque quantification (PI) on photographs. Student's t-test and Mann Whitney U test were used for intergroup comparisons and evaluation of repeated measurements ($p < 0.05$).

Results: GI and BI scores were significantly lower in the mobil app group than in the control group at T3 ($p = 0.001$, $p < 0.01$). The PI scores did not show a statistically significant result at the end of the third month ($p > 0.05$). The use of mobile app increased patients' compliance.

Conclusions: A uniquely developed mobile app effectively maintained the oral hygiene motivation of patients undergoing fixed orthodontic treatment and contributed to an improvement in their treatment compliance.

Keywords: Orthodontic treatment, oral hygiene motivation, smartphone application.

Sabit Ortodontik Tedavi Gören Hastalarda Bir Mobil Uygulamanın Ağız Hijyeni Motivasyonu ve Uyum Üzerindeki Etkilerinin Değerlendirilmesi

Araştırma Makalesi

Süreç

Geliş: 23/10/2024
Kabul: 22/03/2025

ÖZET

Amaç: Bu çalışmanın amacı, özgün olarak geliştirilen bir mobil uygulamanın sabit ortodontik tedavi gören hastalarda ağız hijyeni motivasyonu ve tedavi uyumu üzerindeki etkilerini geleneksel ağız hijyeni talimatlarıyla karşılaştırarak değerlendirmektir.

Materyal ve Metot: Bu prospektif, kontrollü klinik çalışmada, 50 sabit ortodontik tedavi hastası eşit şekilde mobil uygulama (Ortomobil (e-tel)) ve kontrol grubu olmak üzere ikiye ayrıldı. Kontrol grubu, tedavinin başlangıcında sadece sözlü ve yazılı talimatlardan oluşan geleneksel iletişim aldı. Mobil uygulama grubuna atanan hastalara, randevularını uygulama üzerinden yeniden planlama, ortodontistleriyle doğrudan iletişimde olabilmek ve standart hijyen talimatlarına ek olarak ağız hijyeni motivasyonunu belirli aralıklarla hatırlatan bildirimler alma imkanı sağlandı. Periodontal skorlar, 4 haftalık aralıklarla, ardışık üç randevu (T1-T3) sırasında gingival indeks (GI), kanama indeksi (BI) ve fotoğraflardan elde edilen planimetrik plak miktarı (PI) ölçülerek elde edildi. Gruplar arası karşılaştırmalar ve tekrarlanan ölçümlerin değerlendirilmesi için Student's t-testi ve Mann Whitney U testi kullanıldı ($p < 0,05$).

Bulgular: Mobil uygulama grubundaki GI ve BI skorları, kontrol grubuna göre T3'te ($p = 0,001$, $p < 0,01$) anlamlı şekilde daha düşük bulundu. Üçüncü ayın sonunda PI skorları istatistiksel olarak anlamlı bir sonuç göstermedi ($p > 0,05$). Mobil uygulamanın kullanımı hastaların tedavi uyumunu artırdı.

Sonuç: Özgün olarak geliştirilen bir mobil uygulama, sabit ortodontik tedavi gören hastaların ağız hijyeni motivasyonunu etkili bir şekilde sürdürebilmesine ve tedavi uyumlarının artmasına katkıda bulundu.

Anahtar Kelimeler: Ortodontik tedavi, ağız hijyeni motivasyonu, akıllı telefon uygulaması.

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Introduction

Maintaining proper oral hygiene is essential for patients throughout the orthodontic treatment process.¹ Oral hygiene can rapidly deteriorate immediately after bracket application.² Compliance with hygiene protocols tends to decline to its lowest levels during long-term orthodontic treatment, highlighting the difficulty and importance of maintaining consistent and adequate oral hygiene throughout the treatment period.³ The most critical factor preventing gingivitis and pathological hard tissue loss is the control of microbial plaque.⁴ Both mechanical and chemical approaches can be used to combat the formation of microbial plaque.⁴ The use of interdental brushes and dental floss is a mechanical plaque control method; however, agents such as antiseptics, antibiotics, and enzymes that reduce plaque activity are used for chemical plaque control.⁵

Patient compliance, which is a crucial component of orthodontic treatment, is defined as regular attendance at appointments, adhering to oral hygiene instructions, using elastics and other orthodontic appliances correctly, and avoiding hard and sticky foods that can damage the brackets and orthodontic appliances.⁶ When patient compliance, which is essential for successful treatment, is not achieved, treatment success is compromised.⁷ Studies have shown that effective communication with patients promotes more successful treatment outcomes.⁸⁻¹³ Patients' willingness to undergo treatment and effective dialogue with their parents are highlighted as significant factors that enhance patient compliance.^{9,14}

The methods orthodontists use to communicate with patients are a crucial part of the information delivery process, as patients need to clearly understand what is expected of them to remain compliant and motivated during the treatment process.^{11,15} Previous studies have shown that presenting information to orthodontic patients in a visual format can effectively enhance information retention.^{16,17} In recent years, technological innovations have made dental health services more effective, faster, and comfortable.¹⁸ Among these developments, teledentistry combines telecommunications and dental practices to facilitate the exchange of clinical information and images over long distances for dental consultations and treatment planning.¹⁹ With technological advancements, new opportunities for teledentistry have emerged, reshaping existing business models and altering the dynamics of dental treatment services.²⁰ Teledentistry offers the ability to remotely monitor recorded data rapidly, enables simultaneous communication with multiple individuals, reduces hospital costs and patient waiting times, and contributes to lowering long-term treatment costs.²¹ Marino et al. reported in their study on teleorthodontics that orthodontists could effectively assess the need for early orthodontic treatment in pediatric patients through digital methods via teleconsultation.²² Among these

innovative developments, smartphone applications offer various advantages, particularly for young patients undergoing fixed orthodontic treatment.²³ A 2019 study revealed that there were 612 mobile applications related to oral health, highlighting the high level of interest and need for maintaining oral health.²⁴ Another study reported that mobile health applications could be used as additional tools to manage periodontal inflammation and enhance oral health knowledge.²⁵

Considering this information, this study aimed to examine the potential effects of a uniquely designed mobile application on oral hygiene motivation and behavioral changes in patients undergoing fixed orthodontic treatment.

Materials and Methods

This study included 50 patients aged ≥ 13 years who were scheduled at the Department of Orthodontics, Karadeniz Technical University Faculty of Dentistry. The sample size calculation was based on the study by Scheerman et al.²⁶ (alpha error = 0.05, beta error = 0.20, effect size = 0.55). All patients and their parents provided informed consent after receiving information on the purpose of the study. Ethical approval was obtained from the Karadeniz Technical University Ethics Committee (Date: December 30, 2021; Protocol no: 24237859-8).

The study included patients with Class 1 malocclusion who had mild-to-moderate crowding that did not require tooth extraction and who owned a smartphone. Patients requiring orthognathic surgery, those with any motor function disorder or physical or mental disability that would impede tooth brushing, patients with congenital tooth absence or missing teeth before treatment, patients with impacted teeth, patients with supernumerary teeth, and patients with tooth shape anomalies were excluded from the study.

Development of the Mobile Application

In this study, a smartphone application (Figure 1) named e-tel (Ortomobil) was developed and licensed in collaboration with a technology company (Turcasoft Software, Samsun, Turkey) to examine its effects on the oral hygiene motivation of the study group. This application, with distinct patient and orthodontist modules, allows written and visual messaging between the patient and orthodontist (Figure 2). Additionally, the application allows the patient or orthodontist to reschedule or cancel appointments. With additional software, the application allows for recording patient compliance with appointments, changes in periodontal values, and bracket detachment scores. The application ensures that data tracking remains confidential upon entering the identities of the orthodontists and patients. The mobile application was uploaded to digital markets (App Store and Google Play Store) and installed on the smartphones of the patients in the study group.

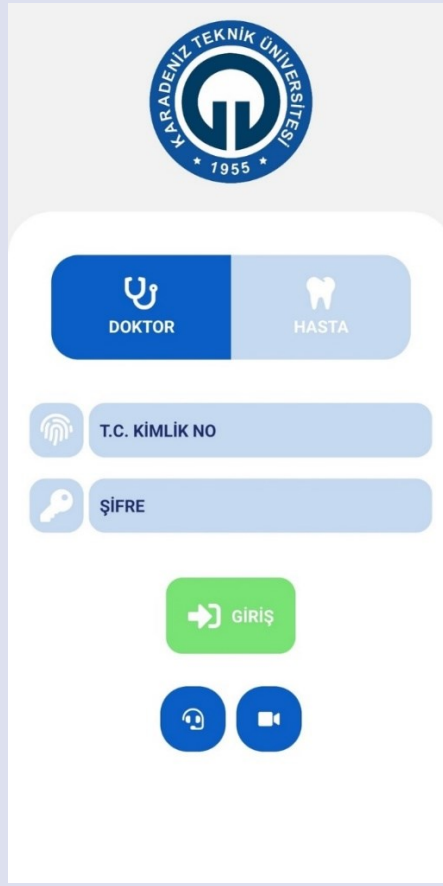


Figure 1. Ortomobil application

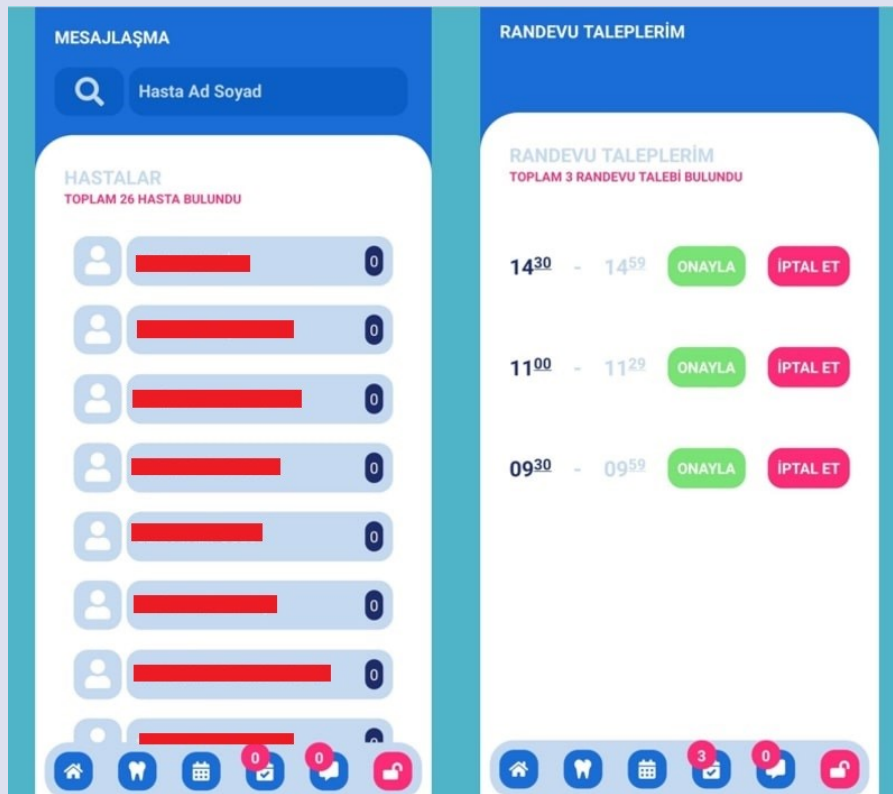


Figure 2. Ortomobil interface

All patients in the control group ($n = 25$) and the study group ($n = 25$) received 0.022 slot Roth system stainless steel brackets and tubes (Discovery® Smart; Dentaurum, Ispringen, Germany). The same bonding protocol and adhesive (3M Transbond XT) were used for all patients. After the bonding procedure, all participating patients were provided with oral hygiene instructions through videos and hands-on training using models, and it was explained that oral care should be performed at least twice a day. In addition to standard hands-on hygiene instructions, patients in the mobile application group (study group) received appointment reminder notifications, hygiene motivation reminders through visual aids, and direct messaging opportunities with the orthodontist through the mobile application. No additional motivational interventions were provided to patients in the control group beyond the standard instructions provided at the start of treatment.

After the removal of archwires during orthodontic control sessions held at 4-week intervals, changes in oral hygiene and the periodontal status of the teeth were assessed using the Bleeding Index (BI), Gingival Index (GI), and Plaque Index (PI).²⁷⁻²⁹ Plaque staining was performed on teeth 12, 22, 13, 23, 33, and 43.³⁰ Measurements were performed by photographing the teeth and analyzing the

images digitally using the Digimizer 6.3.0 (MedCalc Software Ltd., Belgium) software for planimetric analysis (Figure 3). The stained areas in the measurements were quantified in square millimetres and expressed as a percentage of the total tooth areas. The initial oral hygiene measurement was designated as T0, and sequential measurements were made during the first three orthodontic sessions (T1, T2, and T3). Data were recorded by a single researcher after each measurement.

To examine the effects of the mobile application on behavioral changes in patients between the study and control groups, a patient cooperation form³¹ was developed, and the responses were recorded.

Statistical analyses were conducted using the *Statistical Package for the Social Sciences* (SPSS 27) software. Student's *t*-test and Mann-Whitney *U* test were used for intergroup comparisons. For intragroup comparisons of quantitative variables, repeated measures ANOVA and Friedman test were employed, whereas Bonferroni-corrected pairwise comparisons and Dunn test were used for evaluating binary comparisons. Pearson chi-squared test was used to compare qualitative data. A *p*-value <0.05 was considered statistically significant in all analyses.

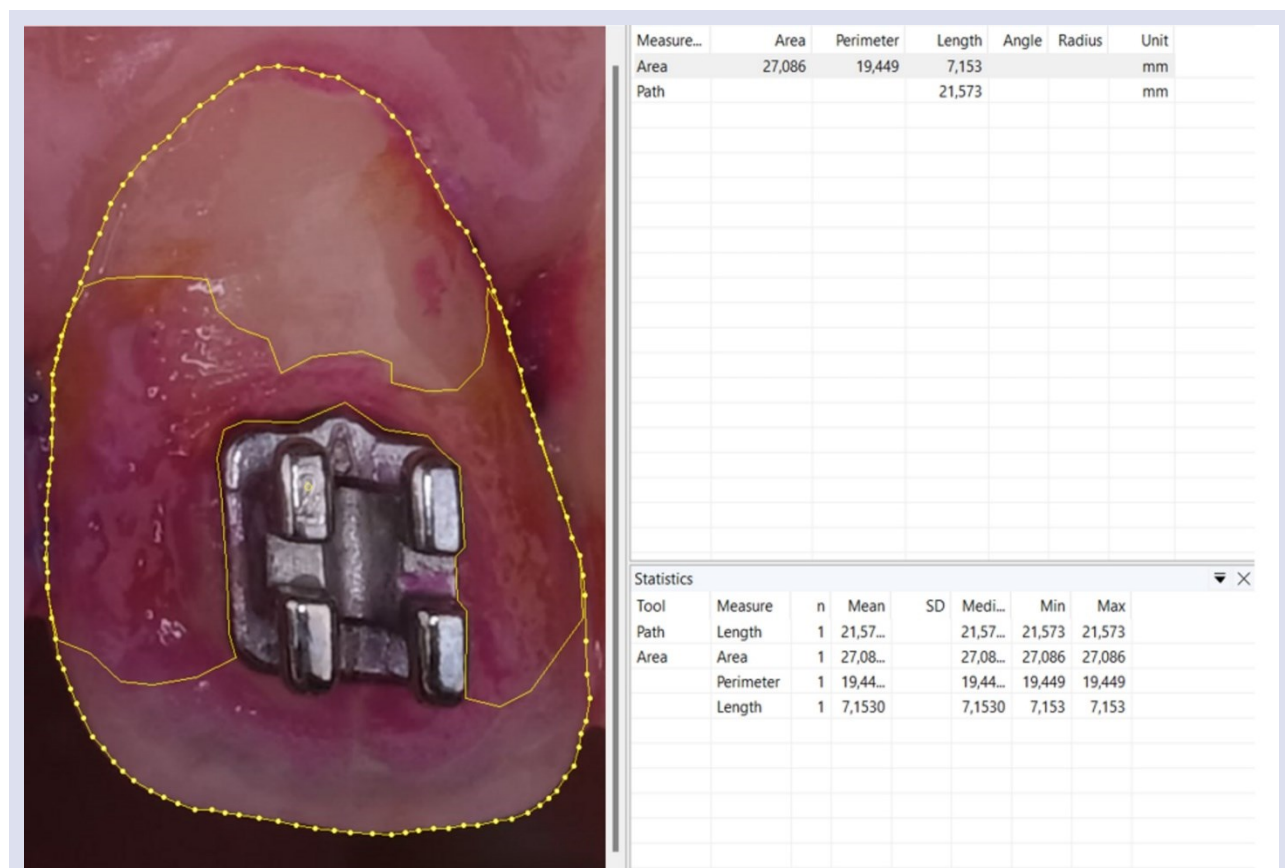


Figure 3: Digimizer software

Results

The study was conducted with a total of 50 participants, consisting of 64% (n = 32) female and 36% (n = 18) male participants. The ages of the participants ranged from 13 to 21 years, with a mean age of 15.96 ± 1.73 years. The descriptive characteristics of the study and control groups are shown in Table 1.

According to the cooperation form, the scores for “Number of broken or damaged brackets noticed at patient appointments,” did not show significant differences at all measurement periods in study and control groups ($p > 0.05$). The scores for “Patient adherence to appointments” did not show significant differences at T1 and T2 ($p > 0.05$), but at T3, the scores for the mobile application group were significantly lower

($p = 0.010$; $p < 0.05$). The scores for “Patient is enthusiastic about their treatment” did not show significant differences at T1 and T2 ($p > 0.05$), but at T3, the mobile application group also had significantly lower scores ($p = 0.009$; $p < 0.05$). The scores of patient cooperation form are presented in Table 2.

Upon analysing the study and control groups individually, significant increases in gingival index (GI) values were noted following three consecutive orthodontic sessions (T1–T3) ($p = 0.001$; $p < 0.01$). When comparing the study and control group patients, the GI values at T1 and T2 did not differ significantly ($p > 0.05$). However, the GI value for the study group at T3 was significantly lower than that of the control group ($p = 0.001$; $p < 0.01$). The mean GI values and a comparison of the groups are presented in Table 3.

Table 1. Distribution of descriptive characteristics by groups

		Group			Test Value
Age	Mean±Sd	Control	Experimental	Total	p
	Median (Min-Max)	15.64±1.50 16 (13-18)	16.28±1.90 16 (13-21)	15.96±1.73 16 (13-21)	t:-1.321 ^a 0.193
Gender	Female	15 (60.0)	17 (68.0)	32 (64.0)	χ^2 :0.347 ^b 0.556
	Male	10 (40.0)	8 (32.0)	18 (36.0)	

^aStudent-t Test ^bPearson Chi-Square Test

Table 2. Statistical analyses of scores of the patient's cooperation

			Group			
			Control (n=25)	Experimental (n=25)	Total (n=50)	p
Compliance to appointments	T1	Mean±Sd	2±0.87	1.8±0.71	1.9±0.79	Z:-0.760
		Median (Min-Max)	2 (1-4)	2 (1-3)	2 (1-4)	^a 0.447
	T2	Mean±Sd	1.8±0.71	1.64±0.57	1.72±0.64	Z:-0.713
		Median (Min-Max)	2 (1-4)	2 (1-3)	2 (1-4)	^a 0.476
	T3	Mean±Sd	2.84±0.69	2.28±0.79	2.56±0.79	Z:-2.592
		Median (Min-Max)	3 (1-4)	2 (1-4)	3 (1-4)	^a 0.010*
Breakage of braces	T1	Mean±Sd	2.4±0.5	2.36±0.49	2.38±0.49	Z:-0.288
		Median (Min-Max)	2 (2-3)	2 (2-3)	2 (2-3)	^a 0.773
	T2	Mean±Sd	2.36±0.49	2.28±0.61	2.32±0.55	Z:-0.361
		Median (Min-Max)	2 (2-3)	2 (1-3)	2 (1-3)	^a 0.718
	T3	Mean±Sd	2.08±0.57	1.8±0.58	1.94±0.59	Z:-1.690
		Median (Min-Max)	2 (1-3)	2 (1-3)	2 (1-3)	^a 0.091
Attention to treatment	T1	Mean±Sd	1.6±0.5	1.52±0.51	1.56±0.5	Z:-0.564
		Median (Min-Max)	2 (1-2)	2 (1-2)	2 (1-2)	^a 0.573
	T2	Mean±Sd	1.92±0.86	1.8±0.65	1.86±0.76	Z:-0.337
		Median (Min-Max)	2 (1-4)	2 (1-3)	2 (1-4)	^a 0.736
	T3	Mean±Sd	2.88±0.67	2.4±0.5	2.64±0.63	Z:-2.597
		Median (Min-Max)	3 (2-4)	2 (2-3)	3 (2-4)	^a 0.009**

^aMann Whitney U Test

* $p < 0.05$

** $p < 0.01$

Table 3. Comparison of gingival index (GI) values by groups

			Group			
Gingival Index	T0	Mean±Sd	Control (n=25)	Experimental (n=25)	Total (n=50)	p
		Median (Min-Max)	0	0	0	-
	T1	Mean±Sd	0.88±0.23	0.95±0.4	0.92±0.32	t:-0.702
		Median (Min-Max)	0.9 (0.5-1.4)	1 (0.3-1.8)	1 (0.3-1.8)	^a 0.487
	T2	Mean±Sd	0.95±0.24	0.98±0.38	0.96±0.32	t:-0.233
		Median (Min-Max)	1 (0.5-1.4)	1 (0.4-1.9)	1 (0.4-1.9)	^a 0.817
	T3	Mean±Sd	1.76±0.19	1.28±0.3	1.52±0.35	t:6.664
		Median (Min-Max)	1.8 (1.4-2)	1.2 (0.9-2)	1.6 (0.9-2)	^a 0.001**
			F:651.017	F:220.464		
		p	^d 0.001**	^d 0.001**		
	T0 - T1		0.88±0.23	0.95±0.40		t:-0.702
		p	0.019*	0.003**		^a 0.487
	T0 - T2		0.95±0.24	0.98±0.38		t:-0.233
		p	0.001**	0.001**		^a 0.817
	T0 - T3		1.76±0.19	1.28±0.30		t:6.664
		p	0.001**	0.001**		^a 0.001**
	T1 - T2		0.07±0.05	0.03±0.06		Z:-2.305
		p	0.129	0.835		^c 0.021*
	T1 - T3		0.87±0.23	0.33±0.18		t:9.349
		p	0.001**	0.001**		^a 0.001**
	T2 - T3		0.80±0.24	0.30±0.16		t:8.800
		p	0.019*	0.011*		^a 0.001**

^aStudent-t Test^cMann Whitney U Test^dFriedman Test&post hoc Dunn test

*p<0.05 **p<0.01

Table 4: Comparison of bleeding index (BI) values by groups

			Group			
Bleeding Index	T0	Mean±Sd	Control (n=25)	Experimental (n=25)	Total (n=50)	p
		Median (Min-Max)	0	0	0	-
	T1	Mean±Sd	0.26±0.12	0.3±0.14	0.28±0.13	Z:-0.824
		Median (Min-Max)	0.3 (0-0.4)	0.3 (0-0.5)	0.3 (0-0.5)	^a 0.410
	T2	Mean±Sd	0.44±0.11	0.37±0.16	0.4±0.14	t:1.847
		Median (Min-Max)	0.4 (0.2-0.7)	0.3 (0-0.8)	0.4 (0-0.8)	^a 0.071
	T3	Mean±Sd	0.65±0.12	0.4±0.18	0.53±0.2	t:5.930
		Median (Min-Max)	0.6 (0.5-1)	0.3 (0.2-1)	0.5 (0.2-1)	^a 0.001**
			χ ² :72.024	χ ² :53.094		
		p	^d 0.001**	^d 0.001**		
	T0 - T1		0.26±0.12	0.3±0.14		Z:-0.824
		p	0.051	0.001**		^a 0.410
	T0 - T2		0.44±0.11	0.37±0.16		t:1.847
		p	0.001**	0.001**		^a 0.071
	T0 - T3		0.65±0.12	0.4±0.18		t:5.930
		p	0.001**	0.001**		^a 0.001**
	T1 - T2		0.18±0.12	0.07±0.15		Z:-2.776
		p	0.037*	0.331		^c 0.005**
	T1 - T3		0.40±0.16	0.10±0.17		Z:-4.867
		p	0.001**	0.026*		^c 0.001**
	T2 - T3		0.22±0.15	0.03±0.11		Z:-4.213
		p	0.051	1.000		^c 0.001**

^aStudent-t Test^cMann Whitney U Test^dFriedman's Test&Post hoc Dunn test

*p<0.05 **p<0.01

Table 5. Comparison of Plaque Index (PI) values by group

			Group			p
Plaque Index	T0	Mean±Sd	Control (n=25)	Experimental (n=25)	Total (n=50)	
		Median (Min-Max)	0	0	0	-
	T1	Mean±Sd	47.41±10.21	49.86±9	48.64±9.61	t:-0.899
		Median (Min-Max)	43.8 (33.2-65.9)	51.1 (33.5-67.3)	48.9 (33.2-67.3)	^a 0.373
	T2	Mean±Sd	48.17±10.14	50.66±8.97	49.41±9.56	t:-0.920
		Median (Min-Max)	44.8 (34-66.5)	51.8 (34.4-68.2)	49.7 (34-68.2)	^a 0.362
	T3	Mean±Sd	51.11±10.15	51.44±8.47	51.28±9.25	t:-0.125
		Median (Min-Max)	48.2 (36.3-69.3)	52.2 (36.3-69.9)	51.8 (36.3-69.9)	^a 0.901
	Total	Mean±Sd	283.17±24.82	275.45±23.74	279.31±24.35	t:1.124
		Median (Min-Max)	289.2 (228-321.3)	275.4 (231.3-311.6)	286.2 (228-321.3)	^a 0.267
			χ ² :73.848	χ ² :69.336		
		p	^a 0.001**	^a 0.001**		
	T0 - T1		47.41±10.21	49.86±9.00		t:-0.899
		p	0.026*	0.019*		^a 0.373
	T0 - T2		48.17±10.14	50.66±8.97		t:-0.920
		p	0.001**	0.001**		^a 0.362
	T0 - T3		51.11±10.15	51.44±8.47		t:-0.125
		p	0.001**	0.001**		^a 0.901
	T1 - T2		0.76±0.38	0.80±0.34		Z:-0.349
		p	0.071	0.051		^a 0.727
	T1 - T3		3.70±0.93	1.58±1.03		Z:-5.549
		p	0.001**	0.001**		^a 0.001**
	T2 - T3		2.94±0.78	0.78±1.03		Z:-5.792
		p	0.026*	0.129		^a 0.001**

^aStudent-t Test^cMann Whitney U Test^dFriedman's Test&Post hoc Dunn test

BI values showed significant increase in both groups after three orthodontic appointments ($p = 0.001$; $p < 0.01$). However, when comparing the study and control groups, no significant differences were observed in BI values during the first 2 months after the start of treatment (T1 and T2), similar to the GI values ($p > 0.05$). In contrast, the BI value for the study group at T3 (measurement during the third orthodontic session) was significantly lower than that of the control group ($p = 0.001$). The mean BI values and a comparison of the groups are presented in Table 4.

Plaque staining values also showed significant increase in both groups after three orthodontic sessions ($p = 0.001$; $p < 0.01$). When examining the study and control groups separately, the measurement values at T1, T2, and T3 did not significantly differ ($p > 0.05$). The mean plaque staining values and comparison of the groups are presented in Table 5.

Discussion

Technological advancements have made healthcare systems more accessible than ever before.³² Significant developments and the rapid proliferation of smartphones in recent years have enabled mobile applications to provide comprehensive health information to a broader audience.³³ These applications have motivated users to improve their oral hygiene.³³ The primitive form of these technologies, the short message service (SMS), was initially tested on patients. SMS reminders significantly reduced periodontal scores at specific intervals for patients undergoing fixed orthodontic treatment.^{1,34,35} In another study that examined the course of BI, Modified

Gingival Index (MGI), PI, and white spot lesions over time, SMS reminders resulted in significantly lower average BI, MGI, and PI scores after approximately 5 months.¹ In contrast, previous studies have shown that providing audiovisual information to orthodontic patients via the internet significantly enhances their knowledge.³⁶ In the present study, considering the ages of patients undergoing orthodontic treatment, the usage habits of this generation, and the prevalence of smartphone use, a unique and user-friendly mobile application was designed and used instead of applications lacking visual elements like SMS.

Previous studies, reviews and meta-analysis have examined the effects of mobile applications (WhiteTeeth and WeChat), digital innovations and smartphone-based telemonitoring on the hygiene motivation of orthodontic patients.^{26,37-43} Although these applications generally focus on oral hygiene motivation, the mobile application used in the present study offers a more interactive interface. This approach promotes periodontal motivation and facilitates appointment adherence, proper use of orthodontic appliances, and direct access in acute situations. In addition, while other applications typically offer chat rooms and networking services, the e-tel (Ortomobil) application allows individual use. This allows patients to feel more comfortable during treatment and avoids the secondary effects of group communication. Other applications in previous studies and the mobile application used in the present study showed that sending reminders to patients, communicating with them, and raising awareness during treatment increased knowledge

levels and improved or maintained periodontal values in patients undergoing fixed orthodontic treatment. The significant results obtained in this study can be attributed to the unique, multifaceted, and interactive mobile application interface.

In a study using the “Brush DJ” application, a mobile health technology to manage the frequency and duration of oral care in patients undergoing orthodontic treatment, significant reductions in GI and PI were observed at the start, fourth week, eighth week, and twelfth week of treatment compared with those using traditional methods.²⁹ In the present study, the decreases in the GI and BI values in the mobile application group observed at the third month of treatment were consistent with the results of this study.²⁹ When comparative findings were examined, no significant difference was found in the GI and BI values at T1 and T2 measurements. According to social psychology studies, it takes 2–3 months for a behavior to become a habit.⁴⁴ This may explain the effects of the mobile application on the GI and BI values after the second measurement. When the mobile application and standard oral hygiene education groups were analyzed separately, significant increases in plaque staining values were observed in both groups ($p = 0.001$; $p < 0.01$). A 2017 study reported that at least 354 applications related to orthodontics were registered in Android and Apple application stores.⁴⁵ Although these orthodontic applications have improved oral health, oral hygiene has not yet reached an optimal level, and patients’ plaque levels remain high after treatment.²⁶ In line with previous studies, plaque levels remained high in both groups in the present study.

Consistent with digital developments in orthodontics, a recent systematic review noted that social media is crucial in the dissemination of information on psychosocial factors related to orthodontic patients.⁴⁰ The data obtained from the patient cooperation forms evaluated in the present study showed that there were significant changes in “patient adherence with appointments” and “enthusiasm toward their treatment” at the end of 3 months. These results demonstrate that mobile applications can promote certain behavioral changes similar to social media applications.

In general dental practice, it is challenging for professional dentists to educate patients about the importance of oral hygiene.³⁸ Because esthetic concerns affect the appearance and function of orthodontic appliances, motivation and compliance during treatment are key to its success.³⁸ Therefore, educating patients about the benefits of treatment is crucial for successful orthodontic therapy.³⁷ Medium- and long-term studies (6–12 months) have shown that as patient interest and motivation decrease over time, the effectiveness of smartphone applications in treatment diminishes, leading to deterioration in oral health.³⁹ Therefore, the present study was designed as a short-term study to mitigate the natural decline in patient interest and motivation.

The results of the present study suggest that maintaining communication with patients through a

mobile application yields better outcomes than traditional motivation methods. However, this improvement may be due to the additional attention given to the patients in the study group. Installing an application on patients’ phones may have served as a reminder of their involvement in the study and could have helped keep their hygiene motivation active. Therefore, future studies should examine whether the additional attention given to the study group is a causal factor in improving oral hygiene compliance. Additionally, it is not definitively known whether the patients who participated in the study used professional oral care treatments, ozone, laser, or probiotic treatments during the first three sessions, which could potentially have biased the periodontal values. Moreover, since patients’ preference for oral hygiene tools other than the standard ones recommended at the beginning of treatment may influence the results so future studies should consider this factor. Previous studies have indicated that these treatments can affect periodontal values.¹⁴ Therefore, further studies on this topic are needed. This study was designed as a short-term intervention to mitigate the natural decline in patient motivation; thus, there is a need for long-term studies that also examine pathological hard tissue loss. Although fixed orthodontic treatments are widely used today, examining the effectiveness of similar applications on hygiene motivation among patients undergoing treatment with clear aligners is also beneficial.

Conclusions

This study demonstrated that direct communication with patients and reminding oral hygiene instructions through e-tel (Ortomobil) increased their motivation to practice oral hygiene and resulted in positive behavioral changes in patients. Therefore, it would be beneficial for orthodontists to take an interest in and actively use such mobile applications as they can help ensure adequate oral hygiene and compliance among patients.

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Conflicts of Interest statement

No conflicts of interest.

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Evaluating the Use of Large Language Models in Radiology and Histopathology Reporting: Expert-Based Assessment of Diagnostic Support and Patient-Oriented Simplification

Sümeyye Çelik^{1,a,*}, Alican Kuran^{1,b}, Oğuz Baysal^{1,c}, Umut Seki^{1,d}, Merve Soluk Tekkesin^{2,e}, Enver Alper Sinanoğlu^{1,f}

¹Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Kocaeli University, Kocaeli, Türkiye.

²Department of Oral Pathology, Faculty of Dentistry, İstanbul University, İstanbul, Türkiye.

*Corresponding author

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ABSTRACT

Objectives: The aim of this study was to evaluate the effectiveness of two different versions of Chat-GPT, one of the large language models (LLMs), in the diagnosis and interpretation of cone beam computed tomography (CBCT) and histopathology reports.

Materials and Methods: In this study, Chat-GPT 3.5 and Chat-GPT 4 were tasked with generating preliminary diagnoses and differential diagnoses based on the findings from ten CBCT reports and ten histopathology reports. Additionally, both versions were asked to simplify these reports to a level understandable by patients. Dentomaxillofacial radiologists and pathologists, with varying levels of expertise, evaluated the responses of the LLMs and the performance of Chat-GPT 3.5 and Chat-GPT 4 in these tasks was subsequently compared based on these expert assessments.

Results: A comparison of diagnostic performance for radiology reports showed that Chat-GPT 4 was statistically superior to Chat-GPT 3.5 ($p < 0.001$), while no significant difference was observed between the two models in terms of report simplification scores ($P > 0.05$). In contrast, when evaluating histopathology reports, Chat-GPT 4 performed significantly better than Chat-GPT 3.5 in terms of both diagnostic accuracy and report simplification ($p < 0.05$).

Conclusions: The results demonstrated that Chat-GPT 4 achieved superior performance in the interpretation and evaluation of CBCT reports by LLMs. The strong performance of this latest version highlights the potential for LLMs to become valuable tools in the reporting processes of radiology and histopathology, as well as in numerous other fields, as advancements in technology continue to improve their capabilities.

Keywords: Large language models, Cone-Beam Computed Tomography, ChatGPT

Radyoloji ve Histopatoloji Raporlamasında Büyük Dil Modellerinin Performans Analizi: Tanı Desteğinden Hasta İletişimine

Araştırma Makalesi

Süreç

Geliş: 19/11/2024

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ÖZET

Amaç: Bu çalışmanın amacı, Chat-GPT'nin iki farklı sürümünün, büyük dil modellerinden biri olarak, konik ışınli bilgisayarlı tomografi (KİBT) ve histopatoloji raporlarının tanı ve yorumlanmasındaki etkinliğini değerlendirmektir.

Gereç ve Yöntemler: Bu çalışmada, Chat-GPT 3.5 ve Chat-GPT 4, on KİBT raporu ve on histopatoloji raporuna dayanarak ön tanı ve ayırıcı tanı üretmekle görevlendirilmiştir. Ek olarak, her iki sürümden de bu raporları hastaların anlayabileceği bir düzeye basitleştirmeleri istenmiştir. Farklı uzmanlık seviyelerine sahip ağız diş ve çene radyolojisi uzmanları ve oral patoloji uzmanları, Chat-GPT'nin yanıtlarını değerlendirmiş ve Chat-GPT 3.5 ile Chat-GPT 4'ün bu görevlerdeki performansı bu uzman değerlendirmelerine göre karşılaştırılmıştır.

Bulgular: Radyoloji raporlarına ilişkin tanısal performans karşılaştırması, Chat-GPT 4'ün Chat-GPT 3.5'e kıyasla istatistiksel olarak anlamlı şekilde üstün olduğunu göstermiştir ($p < 0,001$). Ancak, rapor basitleştirme puanları açısından iki model arasında anlamlı bir fark gözlemlenmemiştir ($P > 0,05$). Öte yandan, histopatoloji raporlarının değerlendirilmesinde, Chat-GPT 4 hem tanısal doğruluk hem de rapor basitleştirme açısından Chat-GPT 3.5'ten anlamlı derecede daha iyi performans göstermiştir ($p < 0,05$).

Sonuç: Sonuçlar, Chat-GPT 4'ün CBCT raporlarının yorumlanmasında ve değerlendirilmesinde eski versiyona kıyasla üstün performans gösterdiğini ortaya koymuştur. Bu son sürümün güçlü performansı, büyük dil modellerinin radyoloji ve histopatolojideki raporlama süreçlerinde ve teknolojik ilerlemelerle yeteneklerinin artmaya devam ettiği birçok başka alanda değerli araçlar haline gelebileceğini göstermektedir.

Anahtar Kelimeler: Büyük dil modelleri, Konik Işınli Bilgisayarlı Tomografi, ChatGPT.

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International License

^a smyycelik41@gmail.com

^c oguz_baysal@outlook.com

^e msoluk@istanbul.edu.tr

^b 0009-0003-0676-5098

^d 0009-0000-0360-0050

^f 0000-0002-7178-3335

^b alicankuran_15@hotmail.com

^d dtumut@outlook.com

^f alpersinanoglu@yahoo.com

^b 0000-0001-9677-8690

^d 0000-0002-0286-9792

^f 0000-0002-8349-3239

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Introduction

Artificial intelligence (AI) systems have the ability to interpret situations, events and objects and respond to them in a way that mimics human behaviour.¹ The recent developments in artificial intelligence technology have resulted in the introduction and extensive utilization of large language model-based (LLM) applications, which are readily accessible to the public. LLMs are artificial intelligence models that have been developed with the objective of understanding speech, responding accordingly and fulfilling the desired tasks. These models require large amounts of text data for training and can recognize the nuances of language using deep neural networks, through which they are also able to generate responses that mimic human interaction.²

In 2018, OpenAI (San Francisco, CA, USA) initiated the development of one of these LLM systems. The company released GPT, a generative pre-training transformer with a neural network comprising 1.5 billion parameters, trained on a dataset comprising 40 gigabytes of text. In 2022, an AI-based LLM, designated 'ChatGPT', was made available which had the ability to generate responses to text input comparable to human beings in terms of quality and sophistication. In 2023, a new version of the LLM, designated ChatGPT 4, was produced, which exhibited significantly enhanced capabilities in comparison to the previous version.³

Radiology and histopathology reports contribute significantly to the decision-making process of clinicians by providing a comprehensive evaluation of different diseases.⁴ However, the style and rules regarding the composition of reports may vary between institutions and according to the training received by the individual responsible for the report. This situation may cause confusion for patients who receive different explanations from multiple institutions, as well as limiting communication between physicians.⁵ Therefore, an effective and standardized approach to the formatting of radiological and histopathological reports is required.⁶⁻⁹

While artificial intelligence is currently employed primarily for image analysis in radiology and pathology studies, ChatGPT has yet to be fully investigated for its potential in reporting.^{10,11} In accordance with the radiologist's/pathologist's descriptions of findings in the report, ChatGPT has the capacity to perform preliminary diagnoses, differential diagnoses, and to elucidate the rationale behind its decisions. Furthermore, it has been proposed that ChatGPT could be employed to reduce the complexity of these reports, thereby facilitating patient comprehension.³ In recognition of this potential, the objective of the present study is to assess the capability of ChatGPT 3.5 and 4 to conduct preliminary and differential diagnoses based on data derived from radiology and histopathology reports, as well as their capacity to elucidate these reports to the patient.

Material and Methods

As this study was conducted in February 2024, the versions of Chat GPT that were active at that time were used. Approval for our study (project number 2024/112) was obtained from the Ethics Committee for Non-Interventional Clinical Research at Kocaeli University.

Study Design

In this retrospective study, radiology and histopathology reports written between 2020 and 2023, with the preliminary diagnosis sections deleted were uploaded to ChatGPT versions 3.5 and 4 in Turkish without translation into English and answers were requested in Turkish. The LLM was tasked with identifying a preliminary diagnosis and several differential diagnoses based on the findings presented in the reports. Subsequently, it was instructed to convey the report and diagnosis in a manner that would be readily comprehensible to the patient. The relative success of each version was evaluated by a group of experts in the field of dentomaxillofacial radiology and pathology, who were not aware of which version produced the answer. The workflow of the study is illustrated in Figure 1.

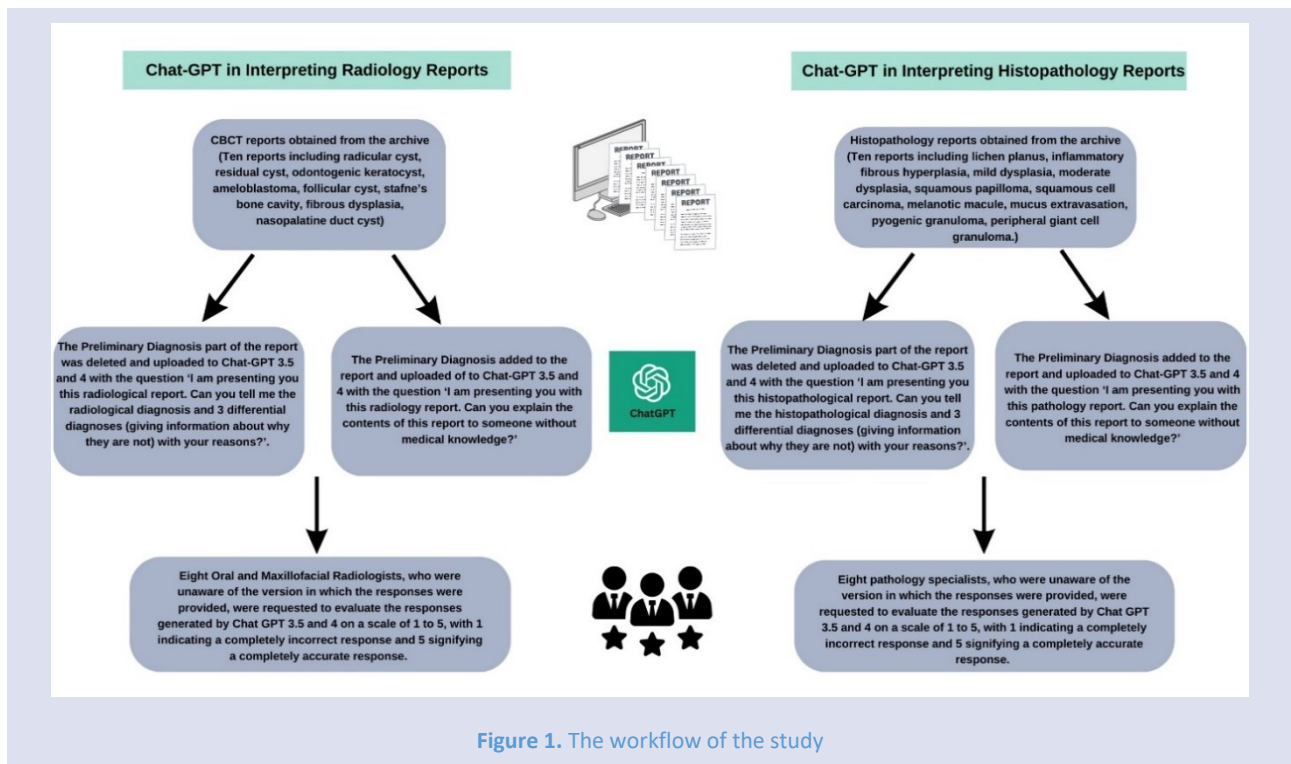


Figure 1. The workflow of the study

Radiographic Reports Data Set

Tomography reports written between 2020 and 2023 in the CBCT archive of the Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Kocaeli University, were retrospectively analysed. Reports were included only if they contained detailed information regarding the boundaries, shape, internal structure, and the lesion's relationship with adjacent anatomical structures. Reports that lacked any of these essential elements were excluded. To ensure diagnostic diversity and avoid overrepresentation, no more than two reports were included for each diagnosis. The reports included in the study consisted of 10 CBCT reports of radicular cyst, residual cyst, odontogenic keratocyst, ameloblastoma, follicular cyst, staphne bone cavity, fibrous dysplasia, nasopalatine duct cyst lesions.

Histopathology Reports Data Set

Histopathological reports written between 2020 and 2023 from İstanbul University, Faculty of Dentistry, Department of Oral Pathology were examined. Reports were selected based on the presence of comprehensive diagnostic information, including the type and structure of the affected tissue, cellular morphology, and the presence of inflammatory or vascular changes. Reports lacking

sufficient detail in these domains were excluded from the study. To maintain diagnostic variety and prevent bias, no more than two reports were included for each diagnosis. The histopathological reports included in the study consisted of 10 reports including lichen planus, inflammatory fibrous hyperplasia, mild dysplasia, moderate dysplasia, squamous papilloma, squamous cell carcinoma, melanotic macula, mucus extravasation, pyogenic granuloma, peripheral giant cell granuloma.

Uploading Reports to Chat-GPT

In the initial phase of report processing, the preliminary diagnosis sections, along with any personal information, were removed from the reports. Subsequently, Chat-GPT versions 3.5 and 4 were queried with the following question: "Could you please provide a preliminary diagnosis and differential diagnosis for the lesion described in this report, including your rationale?" The responses from both versions of the language model were documented for comparison (Table 1,2).

Table 1. Chat-GPT's responses to radiology reports

Radiological Preliminary Diagnosis	Radiology Report	Diagnosis		Report Simplification	
Radicular Cyst		ChatGPT 3.5 Preliminary Diagnosis:	ChatGPT 4 Preliminary Diagnosis:	ChatGPT 3.5	ChatGPT 4
	As a result of the evaluation, there is a cortical limited, unilocular, radiolucent lesion associated with the	Radicular Cyst Differential Diagnosis:	Radicular Cyst Differential Diagnosis:	The report contains the results of a detailed scan of your teeth and jaw. A significant issue has been found in one of your teeth, specifically tooth number 47,	This report explains some issues related to a lower right back tooth (tooth number 47). The top

	<p>roots of tooth 47 with excessive crown destruction. The lesion caused minimal expansion of the cortical bones but caused perforation of the cortical bone on the lingual side. No resorption was observed in the roots of the related tooth. In addition, the lesion is in close relationship with the right mandibular canal from the lingual side.</p>	<p>Dentigerous Cyst Odontogenic Keratocyst Ameloblastoma</p>	<p>Ameloblastoma Odontogenic Keratocyst Odontogenic Myxoma</p>	<p>with a type of cystic lesion associated with the roots. This cyst has caused the formation of hard bone surrounding the lesion within the bone structure. Additionally, the cyst has damaged the bones inside the mandible, but there has been no expansion beyond the bone. There is no damage to the roots of your tooth. Your doctor believes this cyst may be a type called a radicular cyst. Your doctor will provide you with appropriate treatment options for this condition. If you require further information or explanation, feel free to consult your doctor.</p>	<p>part of your tooth is severely damaged, and a small cyst (cavity) has formed at the tip of the roots in the jawbone. This cyst has caused a hole in the jawbone, but the bone itself has not expanded. The cyst may have originated from an infection starting in the tooth's root, and it is located near the main nerve canal in your jawbone. For a definitive diagnosis, a sample from the cyst will need to be examined in more detail.</p>
Radicular Cyst	<p>The evaluation revealed a 12x15x11 mm unilocular, cortically defined, circular radiolucent lesion associated with the roots of teeth numbered 11-12, which have undergone root canal treatment. The lesion has not caused any resorption in the affected teeth. However, it has perforated the buccal cortex and is near the incisive canal.</p>	<p>Preliminary Diagnosis: Periapical Radicular Cyst Differential Diagnosis: Periapical Granuloma Ameloblastoma Periapical Abscess</p>	<p>Preliminary Diagnosis: Radicular Cyst Differential Diagnosis: Dentigerous Cyst Odontogenic Keratocyst Ameloblastoma</p>	<p>A lesion related to the roots was detected after a previous root canal treatment on a tooth. This lesion has created a hole in the bone and is associated with the nerve canal of the front teeth. Doctors believe that this lesion is a type of cyst. The cyst is a fluid-filled sac that forms in the tissues around the tooth roots. The size and characteristics of the lesion support the likelihood of it being a cyst.</p>	<p>A cyst measuring approximately 12x15x11 mm has been detected next to the roots of two teeth in the upper jaw. These teeth have previously undergone root canal treatment. The cyst has penetrated one of the jaw bones and is in contact with a nerve canal. This type of cyst has been identified as a 'radicular cyst,' which typically results from infections in the tooth root. This is a condition concerning dental or jaw health, and it is necessary to consult a dentist for appropriate treatment.</p>
Stafne Bone Cavity	<p>As a result of the evaluation, it has been determined that the bone cavity observed in the left mandibular angle region is located inferior to the mandibular canal. The bone cavity has a concave shape, starting from the mandibular lingula. The boundaries of the bone cavity are surrounded by</p>	<p>Preliminary Diagnosis: Mandibular Osteomyelitis Differential Diagnoses: Mandibular Osteoma, Ameloblastoma, Cystic Lymphoma</p>	<p>Preliminary Diagnosis: Stafne Bone Cavity Differential Diagnoses: Ameloblastoma Odontogenic Cysts Existential Variations of the Mandibular Canal</p>	<p>According to the radiological report, a bone cavity has been detected in the left corner of the jaw. This cavity is located on the inner part of the jaw, beneath the teeth, and is surrounded by bone. The condition is referred to as a Stafne bone cavity. It is generally harmless and does not require treatment. However, it is important to follow your doctor's recommendations.</p>	<p>Of course, this report indicates that there is a small, stable cavity on the left side of your jaw, within the jawbone, which is present without causing harm. This cavity likely points to a Stafne Bone Cavity, a natural condition that is usually discovered incidentally and generally does not require treatment. It</p>

	cortical bone, and the integrity of the bone has been preserved				is most often a benign condition and has no negative impact on your health
Odontogenic Keratocyst	The evaluation revealed a unilocular, radiolucent lesion with sclerotic borders, measuring 14x26x22 mm, associated with the impacted tooth number 38, extending from the left mandibular molar region toward the ramus. The lesion has perforated the mandibular base and the medial surface of the ramus. The mandibular canal is within the lesion. The lesion has caused expansion in the buccal and lingual cortices, with sclerotic bone formation present on the buccal side.	Preliminary Diagnosis: Ameloblastoma Differential Diagnosis: Odontogenic Keratocyst Dentigerous Cyst Bone Cyst	Preliminary Diagnosis: Odontogenic Keratocyst Differential Diagnosis: Ameloblastoma Dentigerous Cyst Odontogenic myxoma	This report indicates that a lesion called an odontogenic keratocyst has been detected in the lower left jaw area, at the back of the lower jaw. This lesion has affected the surrounding tissues, causing expansion and hardening of the jawbones. Treatment will likely require surgical intervention.	A cyst about the size of a hazelnut has been found under your jawbone, next to an unerupted tooth. This cyst has caused some changes in the jawbone and is a condition that requires treatment. Doctors believe it is a specific type of cyst related to the tooth's development.
Fibrous Dysplasia	The evaluation revealed a radiopaque lesion, starting from the region of tooth number 48, involving the entire ramus, and extending towards the right condyle, giving a ground-glass appearance in the trabecular bone. The lesion has caused expansion in the condyle and ramus, resulting in asymmetry. Additionally, there is severe resorption on the superior surface of the left condyle.	Preliminary Diagnosis: Temporomandibular Joint (TMJ) tumor or lesion Differential Diagnoses: Ameloblastoma Fibrous Dysplasia Radiolucent Lesions (cystic lesions)	Preliminary Diagnosis: Fibrous Dysplasia Differential Diagnoses: Osteosarcoma, Paget's Disease, Osteomyelitis	According to this report, a ground-glass appearance lesion has been detected in the right jaw joint (condyle) region, starting from the area of tooth number 48. This lesion has caused growth in the jaw joint and jawbone, leading to facial asymmetry. Additionally, significant bone loss (resorption) has been identified on the left jaw joint. Based on the evaluation, the lesion is suspected to be a condition called fibrous dysplasia. Fibrous dysplasia is a condition that causes abnormal growth of bone tissue and often requires surgical treatment.	The report indicates that there is abnormal tissue growth (lesion) on the right side of the jaw. This growth has caused asymmetry (unevenness) and deformation in the jaw joint and jawbone. Additionally, bone loss has been detected on the left jaw joint. Doctors believe that this abnormal growth and changes are due to a condition called 'fibrous dysplasia.' Fibrous dysplasia is a rare disease where the normal structure of bones is disrupted, potentially affecting their function.
Ameloblastoma	The evaluation revealed a radiolucent lesion measuring 24x38x26 mm, extending from the left mandibular premolar region to	Preliminary Diagnosis: Ameloblastoma Differential Diagnoses: Ameloblastoma, Odontogenic Cyst, Osteosarcoma	Preliminary Diagnosis: Ameloblastoma Differential Diagnoses: Odontogenic Keratocyst,	Of course, the report mentions a lesion in the left lower jaw area that is growing and contains air spaces and flat septa. This lesion has caused expansion in the jawbone and affected the surrounding tissues. Additionally, it has damaged the roots of a	Doctors have found a large mass in your lower jaw, starting from the area where some of your teeth are located and extending toward the back of

the right mandibular angle. The lesion contains areas of air spaces and thin, flat septa. The lesion has caused severe expansion in the buccal and lingual cortices and has destroyed the apex of the alveolar ridge. There is a radiopaque band around the lesion, indicating a chronic process. The lesion has caused root resorption in tooth number 45. It has displaced the mandibular canal cortex buccally and superiorly. Within the lesion, tooth number 48 is located in an inverted position toward the mandibular ramus. The obtained images indicate that the observed lesion is of a chronic nature, but its severe expansion should be taken into account. Magnetic resonance imaging and histopathological examination are recommended for assessing soft tissue involvement and the contents of the lesion

Odontogenic Myxoma,
Central Giant Cell Granuloma

tooth and displaced the jaw canal. Imaging and biopsy are recommended for better evaluation of the lesion's contents. Doctors believe that this lesion could be a tumor called ameloblastoma.

the jaw. This mass has disrupted the normal structure of your jawbone and damaged some of your teeth. Additionally, this mass has caused swelling by expanding your jawbone. This condition is a type of tumor called 'ameloblastoma,' which is usually benign. This slow-growing tumor occupies space in the jawbone and can damage surrounding tissues if left untreated. Doctors have recommended additional tests to gather more information and determine the appropriate treatment. This is an important issue for your jaw health, and it is crucial to follow your doctor's advice and pursue treatment

Infected follicular cyst

The evaluation revealed that tooth number 38 is impacted in an oblique position and that there is a unilocular, radiolucent lesion around its crown. The lesion measures 25x38x29 mm. The lesion, which is in close proximity to tooth number 37, has not caused resorption in the roots. The mandibular canal passes through the

Preliminary Diagnosis: Dentigerous Cyst
Differential Diagnoses: Follicular Cyst, Ameloblastoma, Osteomyelitis

Preliminary Diagnosis: Ameloblastoma
Differential Diagnoses: Odontogenic Keratocyst, Dentigerous Cyst, Central Giant Cell Granuloma

The evaluation revealed that tooth number 38 is impacted in an oblique position and that there is a unilocular, radiolucent lesion around its crown. The lesion measures 25x38x29 mm. The lesion, which is in close proximity to tooth number 37, has not caused resorption in the roots. The mandibular canal passes through the lesion. The lesion has caused expansion in the mandible and has perforated the buccal and lingual cortices. Sclerotic structures have been identified in the bone surrounding the lesion. Based on the obtained information, it is thought that the relevant lesion is an infected follicular cyst

The report indicates that there is a misaligned tooth trapped in the jawbone beneath your mouth, which should normally have erupted, and a large cyst has formed around this tooth. This cyst has damaged the jawbone by causing expansion and has perforated both the outer surfaces of the jawbone and is close to an important nerve that runs through the

	<p>lesion. The lesion has caused expansion in the mandible and has perforated the buccal and lingual cortices. Sclerotic structures have been identified in the bone surrounding the lesion.</p>				<p>jawbone. The bone surrounding the cyst has hardened slightly. This indicates a problem in the jawbone that requires treatment.</p>
Nasopalatine Canal Cyst	<p>The evaluation revealed a unilocular, radiolucent lesion measuring 9x9x12 mm with cortical borders in the anterior maxillary region along the midline. The lesion is not associated with teeth numbers 11 and 21. The lesion shows continuity with the incisive canal and has caused expansion in the incisive canal. Additionally, the lesion has caused perforation in the palatal cortex</p>	<p>Preliminary Diagnosis: Odontogenic Keratocyst Differential Diagnoses: Dentigerous Cyst, Periapical Cyst, Ameloblastoma</p>	<p>Preliminary Diagnosis: Nasopalatine Canal Cyst Differential Diagnoses: Radicular Cyst, Odontogenic Keratocyst, Globulomaxillary Cyst</p>	<p>A small fluid-filled sac has been detected in the anterior upper jaw, just above the midline. This sac is not related to the teeth and is located near a structure called the nasopalatine canal. The sac has caused expansion within the canal and created a perforation in the inner part of the upper jawbone. Based on these findings, it is thought to be a nasopalatine canal cyst.</p>	<p>There is an approximately 1-centimeter hollow structure (cyst) in the upper jaw, not related to the teeth. This cyst has enlarged a canal in the front part of the jaw and has caused a perforation in the inner part of the jawbone. This condition is usually not serious but may sometimes require treatment</p>
Residual Cyst	<p>The evaluation revealed a round, unilocular, radiolucent lesion measuring 18x19x18 mm in the left maxillary molar region where a tooth extraction was previously performed. The lesion has extended into the left maxillary sinus but has not perforated the sinus. Additionally, the lesion has a cortical boundary. It has caused severe expansion with perforation in the buccal cortex</p>	<p>Preliminary Diagnosis: Fungal Sinusitis Differential Diagnoses: Dentigerous Cyst, Ameloblastoma, Odontogenic Keratocyst</p>	<p>Preliminary Diagnosis: Residual Cyst Differential Diagnoses: Dentigerous Cyst, Ameloblastoma, Odontogenic Keratocyst</p>	<p>According to the radiological report, a cyst measuring 18x19x18 mm was detected in the area of the extracted tooth in the left upper back tooth region of the jawbone. The cyst has grown towards the maxillary sinus but has not perforated its membrane. It has a cortical boundary and has caused significant expansion in the buccal cortex. It is thought to be a residual cyst, likely originating from the extracted tooth.</p>	<p>A walnut-sized cyst (cavity) has been found in the upper part of your mouth, on the left rear side, where a tooth was previously extracted. This cyst has grown towards an air-filled space inside your mouth called the sinus but has not damaged it. The cyst has pushed against the bone on the cheek side, causing expansion in the area. This type of cyst is called a 'residual cyst,' and it usually forms where teeth have been extracted. Your doctor will likely recommend surgery to remove the cyst</p>

In the second phase, the complete, unredacted versions of the reports, including the diagnosis sections, were provided to Chat-GPT versions 3.5 and 4. These versions were then asked the question: "I am presenting this radiology/pathology report to you. Can you explain its

contents in a way that someone without medical knowledge would understand?" The responses from both versions were similarly recorded for analysis (Table 1,2).

Table 2. Chat-GPT's responses to histopathology reports

Pathology result	Pathology Report	Diagnosis		Report Simplification	
Lichen Planus	Sample Area: Buccal Mucosa In the examined sections, the surface is covered by stratified squamous epithelium showing acanthosis and hyperorthokeratosis, with a distinct granular layer. Beneath the epithelium, there is band-like lymphocytic infiltration in the connective tissue. These lymphocytes have migrated into the epithelium in some areas	ChatGPT 3.5 Preliminary Diagnosis: Aphthous Mucositis Differential Diagnoses: Lupus Erythematosis, Pemphigus Vulgaris, Chronic Aphthous Stomatitis	ChatGPT 4 Preliminary Diagnosis: Lichen Planus Differential Diagnoses: Oral Lichenoid Reaction, Psoriasis, Squamous Cell Carcinoma	ChatGPT 3.5 The report states that a sample taken from the buccal tissue inside the mouth has been examined. It notes thickening in the tissue, accumulation of immune cells in the connective tissue, and migration of some cells into the tissue. As a result, a diagnosis of "Lichen Planus," an inflammatory condition, has been made.	ChatGPT 4 This report concerns the examination of a tissue sample taken from the inside of your mouth. Changes have been found in the tissue indicating thickening of the upper layer of the skin and the accumulation of dead cells. Additionally, white blood cells, which the body uses to fight infections, have been observed within this tissue and sometimes entering skin cells. Based on these findings, a diagnosis of "Lichen Planus" has been made, which is a chronic skin condition that often causes uncomfortable sores in the mouth. This condition is associated with the body's immune system mistakenly attacking its own tissues, and treatment is aimed at alleviating symptoms.
Inflammatory Fibrous Hyperplasia	Sample Area: Alveolar Mucosa The examined sections show a stratified squamous epithelium covered with parakeratosis and irregular acanthosis. Beneath this, there is dense connective tissue consisting of hyalinized collagen fibers, containing a patchy chronic inflammatory infiltrate. Inflammatory cells have occasionally migrated into the epithelium.	Histopathological Diagnosis: Chronic Ulcerative Mucositis Differential Diagnoses: Ulcerative Colitis, Hypersensitivity Reaction, Chronic Leukoplakia	Histopathological Diagnosis: Oral mucosal lesion consistent with chronic inflammation Differential Diagnoses: Lichen Planus, Squamous Cell Carcinoma, Aphthous Ulcer	The report indicates that there is chronic inflammation beneath the examined mucosa, resulting in thickening and densification of the tissue. This condition has been diagnosed as "inflammatory fibrous hyperplasia."	The report explains the result of examining a tissue from the oral cavity under a microscope and summarizes the following: The oral tissue (mucosa) is inflamed and thickened. There are hardened fibers and inflammatory cells within the tissue. This condition indicates that a fibrous (fibrous) growth has occurred in response to prolonged irritation or inflammation in the tissue. As a result, a condition known as "Inflammatory Fibrous Hyperplasia" has been identified, meaning there is excessive and abnormal growth associated with inflammation in the tissue. This signifies an issue in the oral cavity, suggesting that a specialist should be consulted for further evaluation and treatment.
Mild Dysplasia	Sample Area: Lateral Tongue Mucosa The examined serial sections show that the surface of the specimens is covered by multilayered squamous epithelium exhibiting parakeratosis, irregular acanthosis,	Histopathological Diagnosis: Mucosal Hyperplasia Differential Diagnoses: Lichen Planus, Leukoplakia, HPV Reaction	Histopathological Diagnosis: Oral Leukoplakia or Oral Epithelial Dysplasia Differential Diagnoses: Oral Candidiasis, Lichen Planus, Squamous Cell Carcinoma	The sample taken from the tongue mucosa was examined. The results showed mild cellular changes (dysplasia) on the mucosa. These changes were detected alongside some signs of	This report describes the results of a detailed examination conducted on a sample taken from your tongue. The examination revealed some abnormal changes in the tissue of your tongue. These changes indicate that the cells in certain areas of the tissue are growing irregularly and

	and areas of papillomatosis. In the basal layer of the epithelium, there is a localized increase in cell numbers and loss of polarity. The rete ridges display a thickened appearance resembling "fil" (foot) in certain areas. Below these structures, particularly in the superficial sections, chronic inflammatory cell infiltration is observed. In the deeper part of the larger specimen, a salivary gland lobe with dilated ducts can be seen			inflammation. Although the current risk of cancer is low, regular monitoring is recommended.	are inflamed. However, this condition is currently mild and does not indicate cancer. Nevertheless, such changes could potentially lead to more serious issues in the future, so your doctor will closely monitor the situation and may recommend treatment if necessary.
Moderate dysplasia + Proliferative verrucous leukoplakia	<p>Sample Area: Mucosa of the Floor of the Mouth</p> <p>In all sections, the covering stratified squamous epithelium shows advanced hyperkeratosis (hypergranulosis), acanthosis, and papillomatosis. In the areas identified as lesions, prominent finger-like projections extending towards the surface are observed. The rete ridges extend into the connective tissue and thicken as they merge. These changes gradually diminish toward the surgical margins, where the epithelium appears hyperkeratotic and smooth, with occasional areas of edema. Below these layers, there is connective tissue with superficial lymphocytic infiltration, followed by well-developed mature adipose tissue and deeper striated muscle tissue</p>	<p>Histopathological Diagnosis: Epithelial Dysplasia</p> <p>Differential Diagnoses: Aphthous Ulceration, Leukoplakia, Fibroma</p>	<p>Histopathological Diagnosis: Oral Lichen Planus or Oral Leukoplakia</p> <p>Differential Diagnoses: Oral Candidiasis, Squamous Cell Carcinoma, Erythroplakia</p>	The report indicates that there are some abnormal changes in the tissue at the floor of the mouth. These changes are characterized by thickening, protrusions, and cellular abnormalities in the surface of the tissue. These findings could be precancerous and may require appropriate treatment and monitoring	The report indicates that there are some abnormal changes in the tissue lining the inside of your mouth. These changes include: The top layer of tissue is thicker and harder than normal. There are irregular protrusions on the surface of the tissue. Signs of inflammation are present, with healthy fat and muscle tissue found beneath the affected area. The diagnosis suggests abnormal cell growth, and a condition known as Proliferative Verrucous Leukoplakia (PVL), which carries a risk of turning into cancer, has been identified. This indicates unhealthy changes in some areas of the tissue inside your mouth. It's important to discuss with your doctor what this means and what actions should be taken.
Squamous Cell Carcinoma	<p>Sample Area: Alveolar Mucosa</p> <p>In the examined sections, tumor islands are observed,</p>	<p>Histopathological Diagnosis: Squamous Cell Carcinoma</p>	<p>Histopathological Diagnosis: Squamous Cell Carcinoma</p>	Of course, I will try to understand. Samples taken from an area called the alveolar mucosa were	The report diagnoses a type of skin cancer called squamous cell carcinoma. This indicates the presence of abnormal (different in

	some of which are associated with the stratified squamous epithelium covering the fragments, while others are spread as separate masses within the connective tissue. The tumor islands consist of atypical squamous layer cells. Most of them show keratin plugs in their centers. Some tumor cells are distributed either individually or in smaller groups. A mild inflammatory reaction is noted surrounding the tumor.	Differential Diagnoses: Ameloblastoma, Papilloma, Adenocarcinoma	Differential Diagnoses: Verrucous Carcinoma, Basal Cell Carcinoma, Papilloma	examined. In some areas, there was normal tissue known as stratified squamous epithelium. In other areas, however, tumors with abnormal growths were found. These tumors contain cells that are normally not present, and some of them showed abnormalities. There is a mild inflammatory response around the tumors. All these findings indicate the presence of a type of cancer called "squamous cell carcinoma." Appropriate steps can be taken for treatment and monitoring.	structure and appearance from normal) and uncontrolled growth of cells grouped together in the skin or mucous membranes. Most of these cells show an accumulation of a protein called keratin, and a mild inflammatory response has been observed around them. In summary, cancerous cells have been found in the tissue samples, and they exhibit specific characteristics.
Mucous Extravasation	Sample Area: Lip Mucosa In the examined sections, the surface is covered by stratified squamous epithelium showing parakeratosis. Below this, expanded salivary gland ducts and mucus lakes are observed, spread over a wide area. Within and around these lakes, there is dense infiltration of lymphocytes, plasma cells, occasional neutrophils, and histiocytic cells.	Histopathological Diagnosis: Chronic lip mucosa inflammation Differential Diagnoses: Leukoplakia, Lichen Planus, Lip Cancer	Histopathological Diagnosis: Chronic Mucositis Differential Diagnoses: Sjögren's Syndrome, Acute Mucositis, Lichen Planus	Sure, the report examines a section of the inner surface of the lip. There is a layer called parakeratosis on top, beneath which are enlarged salivary gland ducts and mucus lakes. It is observed that immune cells have accumulated around these lakes, which may indicate a possible infection. As a result, increased secretion from the mucous glands and accumulation of immune cells have been detected.	This report describes some changes in the inner surface of your lips. There is a thickening in the cells that cover the inside of the lips, as well as an enlargement of some of the salivary glands in your lips. Additionally, mucus accumulations have been observed, which contain various immune cells in high density as a sign of inflammation. The diagnosis indicated is mucus extravasation, which shows that mucus is leaking into the tissues in an abnormal way. This is usually not a serious condition, but your doctor may provide recommendations for treatment or follow-up.
Pyogenic Granuloma	Sample Area: Gingival Mucosa The examined sections are covered by stratified squamous epithelium showing parakeratosis. In some areas, the epithelium has been lost, with exudate and debris present in these regions. Underneath, numerous lumens lined with young endothelial cells are observed. Some of	Histopathological Diagnosis: Chronic inflammatory changes Differential Diagnosis: Gingivitis, Periodontitis, Aphthous stomatitis	Histopathological Diagnosis: Periodontitis Differential Diagnosis: Lichen planus, Squamous cell carcinoma, Aphthous ulcer	The report indicates that a condition known as "pyogenic granuloma" has been identified in the gingival mucosa. This suggests a loss of the protective layer in the upper part of the mucosa, along with signs of infection and tissue damage. Surrounding it, there are various white blood cells involved in fighting the infection.	The report indicates the presence of a "pyogenic granuloma," which is an inflamed and rapidly growing benign tissue growth in the gums. The gum surface shows damage and inflammation in some areas. Surrounding it, there is a concentration of new blood vessels and white blood cells, which indicates inflammation. This condition usually arises as a result of oral irritation or injury and may require treatment.

Giant Cell Granuloma	<p>these lumens are unopened, while others are filled with erythrocytes. Surrounding them, infiltration composed of numerous polymorph neutrophils, lymphocytes, and plasma cells can be seen.</p> <p>Sample Area: Gingival Mucosa In the examined sections, the epithelium covering the areas has largely disappeared. Here, there is exudate and debris present. Underneath, a vascular-rich focal lesion is observed, consisting of mononuclear young mesenchymal cells and multinucleated osteoclastic giant cells. Additionally, there is a significant accumulation of hemosiderin and small areas of new bone formation scattered throughout.</p>	<p>Histopathological Diagnosis: Chronic Periodontitis</p> <p>Differential Diagnosis: Leukoplakia, Periodontal Abscess, Gingival Hyperplasia</p>	<p>Histopathological Diagnosis: Chronic Osteomyelitis</p> <p>Differential Diagnoses: Acute Osteomyelitis, Periapical Abscess, Paget's Disease</p>	<p>According to the report, there is a loss of epithelium in large areas of the gingival mucosa, with inflammation and debris present in these regions. Beneath this, a vascular-rich focal lesion has been observed, containing young mesenchymal cells and multinucleated giant cells. Additionally, there are deposits of hemosiderin and areas of new bone formation. The diagnosis has been made as "giant cell granuloma." This is typically a type of healing disorder that arises due to trauma or infection around the gums.</p>	<p>This report is the result of an examination conducted on a sample taken from the gums. The report indicates that the surface layer of the gums has been damaged and has disappeared in some areas. In these damaged regions, there is inflammation and remnants of necrotic tissue. Additionally, there are signs that the body is attempting to repair the damage: young cells coming in for repair and large cells facilitating bone destruction and remodeling are observed. The report also mentions damaged areas filled with blood vessels, iron deposits from old bleeding, and areas of new bone formation. In conclusion, this condition is defined as a "giant cell granuloma," which is typically characterized as a benign type of tumor. This indicates an inflammatory condition and the body's repair process. It is advisable to consult a specialist for treatment.</p>
Melanotic Macule	<p>Sample Area: Lip Mucosa The examined sections reveal a covering of parakeratotic stratified squamous epithelium. In the basal layer of the epithelium, there are areas with an increase in the number of melanocytes and basal cells containing melanin pigment. Additionally, melanin incontinence is observed in the superficial layers of the connective tissue.</p>	<p>Histopathological Diagnosis: Simple Lentigo</p> <p>Differential Diagnoses: Lentigo, Melanosis, Solar Lentigo</p>	<p>Histopathological Diagnosis: Melanotic macular pigmentation</p> <p>Differential Diagnoses: Melanoma, Nevus, Actinic Keratosis</p>	<p>The report examines a sample taken from the lip mucosa. There is an abnormal condition in the epithelial layer covering the inner surface of the lips. Some cells show an increase in melanin pigment, and there is an increase in the number of melanocytes. It is observed that the distribution of melanin pigment in the connective tissue is abnormal. This condition is referred to as "oral melanotic macule." It is generally benign and</p>	<p>Of course! The "oral melanotic macule" mentioned in the report is a harmless spot that forms due to the accumulation of melanin pigment, which determines skin color, in the lip tissue inside your mouth. An increase in melanin and its transport to certain cells (melanocytes) in the cells covering the inner surface of your lips has been observed. This is generally a change in color seen on the skin and may not indicate a serious condition. However, if you notice any changes, it is important to</p>

Squamous Papilloma	Sample Area: Buccal Mucosa The examined sections reveal a hyperparakeratotic stratified squamous epithelium covered by papillomatous and irregular acanthosis. Numerous small and large vascular sections are present between the papillaries. Koilocytic cells are particularly observed in the superficial regions of the epithelium.	Histopathological Diagnosis: Papillomatosis Differential Diagnoses: Candidiasis, Leukoplakia, Lichen Planus	Histopathological Diagnosis: Papillomatosis Differential Diagnoses: Verruca Vulgaris, Lichen Planus, Squamous Cell Carcinoma	usually does not require treatment. However, expert evaluation is important. This report summarizes the examination of samples taken from the oral mucosa. The results indicate that the surface of the mucosa is raised, the epithelial layer is abnormally thickened, and there are numerous blood vessel cross-sections present. Additionally, "koilocytic cells" have been detected in the superficial regions of the epithelial layer. These findings suggest a benign condition known as squamous papilloma. This is a common type of benign lesion in the oral cavity. It is important to consult your doctor for treatment and management.	The report indicates that there are some abnormal changes in the tissue covering the inner surface of the mouth (buccal mucosa). There is thickening of the tissue, excessive keratin production, and small protrusions present. Additionally, certain specific cells have been detected that may be indicative of an HPV infection. As a result, these findings suggest the presence of a "squamous papilloma," which is generally a benign and harmless tumor. While it may require treatment, it is usually not a serious condition.
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Experts' Evaluation

Eight expert oral and maxillofacial radiologists and eight expert pathologists, each with at least five years of clinical and academic experience in their respective fields, evaluated the responses generated by ChatGPT 3.5 and 4 using a questionnaire created on Google Forms. The evaluators were not informed of the version to which each response belonged. The questionnaire comprised 10 responses in which the LLMs interpreted the diagnosis from the radiology/pathology reports and 10 responses in which they simplified the radiology/pathology reports for the patient. In this evaluation phase, the experts were requested to rate the answers on a scale of 1 to 5, with 1 indicating a response that was 'completely wrong', 2 representing a response that was 'mostly wrong', 3 signifying an 'average' response, 4 indicating a response that was 'mostly correct', and 5 denoting a response that was 'completely correct'.

Statistical Analysis

Descriptive statistics were calculated to summarize the experts' evaluating scores. The Mann-Whitney U test was used to compare the differences in scores between Chat-GPT 3.5 and Chat-GPT 4 for both radiology and histopathology tasks. To assess inter-rater reliability among experts, the Intraclass Correlation Coefficient (ICC)

was computed. A p-value of <0.05 was considered statistically significant.

All statistical analyses were performed using IBM SPSS Statistics for Windows, version 20.0 (IBM Corp., Armonk, NY, USA)

Results

The mean number of years' experience of the eight dentomaxillofacial radiologists who evaluated the responses provided by the Chat-GPT versions was 6.87 years (minimum = 1, maximum = 17). The results of the ICC analysis, which was conducted to assess the compatibility of the scores provided by the radiology specialists, indicated a moderate statistically significant agreement between the experts regarding the scores assigned to the responses generated by Chat-GPT 3.5 ($r = 0.661$, $p < 0.001$). Similarly, for the responses generated by Chat-GPT 4, the experts demonstrated a moderately significant level of agreement ($r = 0.602$, $p < 0.001$).

The mean number of years' experience of the pathology experts who evaluated the responses of Chat-GPT on pathology reports was 13.87 (minimum = 6, maximum = 29). The ICC analysis, conducted to assess the inter-rater reliability of the pathology experts' evaluations, revealed a moderate statistically significant agreement between the experts in assessing the

responses generated by Chat-GPT 3.5 ($r = 0.545$, $p < 0.001$). Similarly, the evaluation of the responses provided by Chat-GPT 4 revealed a moderate statistically significant agreement between the experts ($r = 0.729$, $p < 0.001$).

The overall performance of Chat-GPT 3.5 and Chat-GPT 4 in diagnosing lesions based on CBCT reports and simplifying radiological findings for patient understanding was evaluated by dentomaxillofacial radiologists on a total of 50 points (10 questions with 5 points each). Each evaluator scored 10 distinct model responses for each task (diagnosis and simplification) using a 5-point Likert scale (1 = completely wrong, 5 = completely correct), resulting in a maximum possible score of 50 per category. Chat-GPT 3.5 scored an average of 23.87 ± 4.61

(minimum= 15 maximum= 30) for diagnostic accuracy, while Chat-GPT 4 achieved a significantly higher average score of 37.00 ± 3.33 (minimum= 32 maximum= 42). Comparison of diagnostic performance using the Mann-Whitney U test revealed that Chat-GPT 4 was statistically superior to Chat-GPT 3.5 ($U = 3.000$, $p < 0.001$). Regarding the ability to simplify radiological reports for patients, Chat-GPT 3.5 scored a mean of 35.12 ± 4.94 (minimum= 27 maximum= 44), while Chat-GPT 4 scored slightly higher with a mean of 37.75 ± 3.33 (minimum= 32 maximum= 42).

However, the comparison between the two versions for report simplification, as analyzed by the Mann-Whitney U test, did not show a statistically significant difference ($U = 30.500$, $p = 0.143$) (Table 3).

Table 3. Comparison of Chat-GPT 3.5 and 4 scores in diagnosis and report simplification

Task	LLM Version	Expert (n)	Mean (\pm SD)	Mean Rank	p
Lesion diagnosis from the radiology report	Chat-GPT 3.5	8	23.87 ± 4.61	5.80	$p < 0.001$
	Chat-GPT 4	8	37.00 ± 3.33	15.20	
Simplifying the radiology report for the patient	Chat-GPT 3.5	8	35.12 ± 4.94	8.15	$p > 0.05$
	Chat-GPT 4	8	37.75 ± 3.33	12.45	
Lesion diagnosis from the histopathology report	Chat-GPT 3.5	8	21.25 ± 3.91	7.65	$p < 0.05$
	Chat-GPT 4	8	30.62 ± 5.37	13.35	
Simplifying the histopathology report for the patient	Chat-GPT 3.5	8	30.87 ± 4.61	6.75	$p < 0.05$
	Chat-GPT 4	8	38.37 ± 7.15	14.25	

The overall performance of Chat-GPT 3.5 and Chat-GPT 4 in diagnosing lesions from pathology reports and simplifying pathology reports for patient understanding was evaluated by pathology experts, with scores given out of a total of 50 points. Chat-GPT 3.5 achieved a mean score of 21.25 ± 3.91 (minimum = 18, maximum = 29) for diagnostic accuracy, while Chat-GPT 4 achieved a higher mean score of 30.62 ± 5.37 (minimum = 19, maximum = 37). A comparison of the diagnostic performance of the two LLMs using the Mann-Whitney U test revealed that Chat-GPT 4 was statistically superior to Chat-GPT 3.5 ($U = 21.500$, $p = 0.029$). In terms of simplifying pathology reports for patient comprehension, Chat-GPT 3.5 received a mean score of 30.87 ± 4.61 (minimum = 23, maximum = 39), while Chat-GPT 4 scored higher with a mean of 38.37 ± 7.15 (minimum = 26, maximum = 47). The Mann-Whitney U test showed that Chat-GPT 4 was significantly more successful in simplifying reports compared to Chat-GPT 3.5 ($U = 12.500$, $p = 0.003$) (Table 3).

To evaluate whether Chat-GPT 3.5's performance in diagnosing lesions based on report findings and simplifying reports for patient understanding was more effective in radiology reports compared to pathology reports, the scores assigned by experts were analyzed using the Mann-Whitney U test. The results indicated that there was no statistically significant difference in Chat-GPT 3.5's ability to make a diagnosis from radiology reports versus pathology reports ($U = 18.500$, $p = 0.161$), nor in its ability to simplify the report for patient comprehension ($U = 16.000$, $p = 0.105$). In contrast, when Chat-GPT 4's performance was analyzed, the scores awarded by dentomaxillofacial radiologists for interpreting radiology reports were significantly higher than those given by pathology experts for interpreting pathology reports ($U = 8.500$, $p = 0.010$). However, no statistically significant difference was observed between radiology and pathology reports in Chat-GPT 4's ability to simplify reports for patients ($U = 29.000$, $p = 0.798$) (Table 4).

Table 4. Comparison of Chat-GPT's performance in radiology reports versus histopathology reports

LLM Version	Task	Expert (n)	Mean (\pm SD)	Mean Rank	p
Chat-GPT 3.5	Lesion diagnosis from the radiology report	8	23.87 ± 4.61	10.19	$p > 0.05$
	Lesion diagnosis from the histopathology report	8	21.25 ± 3.91	6.81	
	Simplifying the radiology report for the patient	8	35.12 ± 4.94	10.50	$p > 0.05$
	Simplifying the histopathology report for the patient	8	30.87 ± 4.61	6.50	
Chat-GPT 4	Lesion diagnosis from the radiology report	8	37.00 ± 3.33	11.44	$p = 0.010$

Lesion diagnosis from the histopathology report	8	30.62 ± 5.37	5.56	p>0.05
Simplifying the radiology report for the patient	8	37.75 ± 3.33	8.13	
Simplifying the histopathology report for the patient	8	38.37 ± 7.15	8.88	

Discussion

Chat-GPT, consisting of its basic chat-based interface, provides a user-friendly experience that is easily accessible even to individuals with no prior experience in AI technologies. Regarding its simple design and capacity to provide precise and contextually relevant replies, Chat-GPT has been increasingly adopted across a wide range of research disciplines.¹² Two areas of research that have garnered significant attention are the potential of this tool to enhance both research and clinical workflows in radiology and pathology.^{12,13} In both domains, studies have demonstrated that Chat-GPT and similar LLMs can be effectively utilized for various purposes, including the training of specialists, report generation, patient education, and aiding in the diagnosis and follow-up of diseases.^{2,14-19} The use of the complete capabilities of domain-specific LLMs and integrating these tools into academic and clinical settings could lead to substantial enhancements in efficiency, precision, and the advancement of scientific knowledge, which will help all those involved in the healthcare sector, from clinicians to patients.¹³ Considering this information, the present study investigated the diagnostic capabilities of various versions of Chat-GPT based on findings from radiology and histopathology reports, as well as their ability to present these reports in a manner comprehensible to patients.

The integration of ChatGPT and similar artificial intelligence models into radiology raises important ethical questions. First of all, clear rules on patient privacy and data security should be determined, and the use of artificial intelligence should be clearly communicated to patients and referring physicians. The contribution of AI to diagnostic processes may affect patients' trust in the quality of care and the healthcare system. Therefore, it should be emphasised that AI is only a supportive tool and the final decision should be made by expert radiologists. Furthermore, responsibility for diagnostic errors caused by AI should be clearly defined and accountability mechanisms should be established both legally and professionally. Potential biases in AI algorithms should be minimised by using diverse and inclusive training data, thus ensuring fair and reliable results. Finally, obtaining informed consent from patients regarding the use of AI will play a critical role in ensuring compliance with ethical standards by increasing transparency in the integration of technology into healthcare.²⁰

Many studies have been conducted to evaluate the accuracy of ChatGPT in reporting accurate radiology and general information about pathophysiology, and mostly positive results have been obtained. Bhayana et al. used 150 multiple-choice questions with similar style, content and difficulty level to the Royal College of Canada and

American Board of Radiology examinations between 25 February and 3 March 2023. The model performed well on low-level cognitive thinking (84%) and clinical management questions (89%), but poorly on higher-level thinking (60%), identification of imaging findings (61%), calculation and classification (25%). Physics questions (40%) were found to be less successful than clinical questions (73%). ChatGPT always used confident language, even when giving incorrect answers. The results suggest that the model may be helpful in radiology education but should be used with caution in clinical decision-making.²¹

Expert evaluations of Chat-GPT 4's performance in diagnosing lesions from radiology reports revealed a score of 37.00 ± 3.33 out of 50. This suggests that Chat-GPT 4 has the potential to assist clinicians during the preliminary diagnosis phase by interpreting findings from expert-written CBCT reports. However, this level of performance was not observed in Chat-GPT 3.5, which received a significantly lower score of 23.87 ± 4.61 out of 50 for its ability to make a preliminary diagnosis from CBCT reports. The performance disparity between Chat-GPT 3.5 and Chat-GPT 4, indicating that Chat-GPT 3.5 is substantially less reliable than Chat-GPT 4 for this specific task. Expert evaluations of Chat-GPT 4's performance in simplifying radiology reports for patient comprehension resulted in a score of 37.75 ± 3.33 out of 50. These findings indicate that Chat-GPT 4 is capable of effectively translating CBCT reports into a patient-friendly format, which could improve physician-patient communication and support patient education. While Chat-GPT 3.5 received a slightly lower score of 35.12 ± 4.94 , the performance difference between the two versions was not statistically significant. Therefore, Chat-GPT 3.5 also shows potential in making radiology reports more accessible to patients, though with somewhat lower effectiveness compared to Chat-GPT 4. This difference may be attributed to the enhanced language comprehension and instruction-following capabilities of Chat-GPT 4, which allow it to simplify technical medical content more effectively than Chat-GPT 3.5. In contrast, Chat-GPT 3.5 may struggle with nuanced expression or resort to terminology that is still overly technical for laypersons.

In the context of tasks involving histopathology reports, Chat-GPT 4 demonstrated significantly better performance in both areas evaluated. Specifically, Chat-GPT 4 received scores of 30.62 ± 5.37 and 38.37 ± 7.15 out of 50 for these tasks, indicating that it shows promise in simplifying histopathology reports for patient comprehension. However, the score of 30.62 ± 5.37 for making a preliminary diagnosis from histopathology reports is notably lower than the 37.00 ± 3.33 score

achieved for preliminary diagnosis from radiology reports. This suggests that while Chat-GPT 4 is effective in processing both types of reports, it is significantly more proficient in deriving preliminary diagnoses from radiology findings compared to histopathology findings. It is stated that ChatGPT 4 can solve complex problems with higher accuracy thanks to its improved reasoning ability and wider knowledge base.²² Chat-GPT 4 has a more advanced architecture and a more comprehensive training data. In this way, it can analyse medical terms, anatomical structures and findings in reports more accurately. Chat-GPT 3.5, on the other hand, is insufficient in synthesising information, especially in the clinical context, as it has a more limited understanding capacity.

This discrepancy may be explained by the nature of the content in histopathology reports, which often involve more complex terminology, abstract concepts, and context-dependent findings at the microscopic level. In contrast, radiology reports typically include more structured and standardized language describing macroscopic anatomical features. These differences may affect how well the model interprets and synthesizes information. Furthermore, it is possible that the training data used for Chat-GPT 4 included relatively fewer examples of histopathological language compared to radiological terminology, contributing to the observed performance gap.

In their systematic review on the application of Chat-GPT in radiology, Keshavarz et al. reported that across eleven studies in the field, researchers compared the performance of Chat-GPT 4 with that of Chat-GPT 3.5. In 90% of these studies, Chat-GPT 4 was found to outperform Chat-GPT 3.5, particularly in solving complex problems and demonstrating advanced reasoning skills.¹² In their study, Rao et al. evaluated the performance of ChatGPT-3.5 and GPT-4 in clinical decision support for radiology, focusing on two scenarios: breast cancer screening and breast pain. Using both open-ended and select-all-that-apply (SATA) prompts based on ACR Appropriateness Criteria, they found that GPT-4 significantly outperformed GPT-3.5. Specifically, GPT-4 achieved 98.4% accuracy in SATA prompts for breast cancer screening compared to 88.9% for GPT-3.5, and 77.7% versus 58.3% for breast pain scenarios. These results demonstrate GPT-4's improved contextual understanding and reasoning capabilities in complex clinical tasks.²³ Consistent with these findings, our study showed that Chat-GPT 4 was superior to Chat-GPT 3.5 in all tasks, except for simplifying radiology reports for patients. Similarly, Doshi et al. reported no significant difference between Chat-GPT 3.5 and Chat-GPT 4 in simplifying radiology reports, paralleling the results observed in our study. This suggests that software updates do not always lead to improved performance, particularly in tasks related to readability.²⁴

In a separate study, Hirosowa et al. compared the diagnostic and differential diagnosis capabilities of Chat-GPT 3 with those of physicians across various clinical scenarios. Although their findings indicated that

physicians' responses were significantly more accurate, they demonstrated that general AI chatbots, like Chat-GPT 3, were also capable of generating well-differentiated diagnostic lists for common chief complaints.²⁵ In the present study, while the diagnostic outputs of Chat-GPT were not directly compared with those of medical experts, the responses generated by the language models were evaluated by experts, revealing that Chat-GPT, particularly its latest version, can achieve high accuracy in deriving differential diagnoses and preliminary diagnoses from radiology and histopathology reports. Nevertheless, it is important to recognize that the generated diagnoses are not flawless, and large language models such as Chat-GPT are not intended to replace physicians, but rather to function as supportive tools within clinical workflows.

A key limitation of this study is the exclusive use of Chat-GPT among LLMs. Future research should adopt a more comprehensive approach, evaluating the performance of other LLMs in executing these specific tasks and conducting comparative analyses between them. Such an approach would offer more robust and reliable insights into the performance capabilities of various chatbots. Additionally, since the reports in this study were written in Turkish, both the input prompts and the generated responses were in Turkish, which may have influenced Chat-GPT's performance. Further studies could explore the impact of language on the accuracy and efficiency of LLMs.

Conclusions

Chat-GPT has the potential to serve as a valuable tool in supporting specialists by aiding in the preliminary diagnosis of radiology and histopathology reports, generating differential diagnoses, and providing explanations for these diagnostic possibilities. Additionally, it may prove beneficial in simplifying complex reports for patients, making them more accessible to those without specialized knowledge. However, it is crucial that the use of Chat-GPT or other LLMs for these purposes remains under the supervision of experts, with the final decisions and interpretations being made by qualified professionals.

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During the preparation of this work the author(s) used Chat-GPT in order to translate the histopathological/radiological reports and the answers given by Chat-GPT in the study into English for publication since they were in Turkish. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

The radiological data of this study was presented at the Genç ORAD Congress held in Adana between March

5–9, 2024, and was awarded first prize among the oral presentations.

Conflicts of Interest Statement

The authors declare no conflicts of interest. They have no financial, personal, or institutional relationships that could have influenced the work reported in this study.

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A Detailed Analysis of Oral Hygiene Habits of Patients with Cervical Dental Lesions

Iryna I. Zabolotna^{1,a,*}, Tatiana L. Bogdanova^{2,b}, Olena S. Genzytska^{1,c}

¹Department of Internship of Doctors-Dent, Educational and Scientific Institute of Postgraduate Education, Donetsk National Medical University, Lyman, Ukraine

²Department of Biomedical Sciences, Department of Biomedical Engineering, Faculty of Biomedical Engineering, Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute», Kyiv, Ukraine

*Corresponding author

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ABSTRACT

Objectives: Studying oral hygiene habits of patients with cervical dental lesions; identifying differences in dental health depending on characteristics of oral hygiene care.

Materials and Methods: The study enrolled 272 patients being fully examined to diagnose cervical dental lesions: I – with a wedge-shaped defect (WSD), II – with erosion, III – with cervical caries (CC), IV – with a combination of cervical dental lesions, V – without any cervical dental lesions. The patients filled in the survey/questionnaire with information about their hygienic care. We identified Decayed, Missing and Filled Teeth index (DMFT), Papillary bleeding index (PBI), papillary-marginal-alveolar index (PMA), Oral Hygiene Index Simplified (OHI-S), level of personal anxiety, presence of dentin hypersensitivity (DH), wear facets.

Results: When brushing teeth twice daily or more often, patients of Group I had less DMFT; OHI-S indicators were lower in mixed toothbrush motions; when using whitening toothpaste, probability of wear facets often ($p \leq 0.05$). Application of pressure to a toothbrush was associated with level of personal anxiety; contributed to WSD development and increase in their number and PBI indicators ($p < 0.05$). When brushing teeth after breakfast, the depth of lesions was less in patients of Group II ($p = 0.039$). Probability of development of wear facets increased in subjects of Group III when duration of tooth brushing was three minutes or longer and PBI indicators increased; when flossing and brushing teeth for three minutes or longer, DH was diagnosed more while PMA indicators decreased when brushing teeth three or more times daily ($p < 0.05$). Patients of Group IV flossed more aggressively and brushed in a circular motion less frequently than patients with CC ($p < 0.05$). Flossing reduced probability of CC; dominance of mixed or circular toothbrush motions reduced probability of CC and associated lesions ($p < 0.05$).

Conclusions: Identified differences in oral hygiene habits of patients with cervical dental lesions are recommended to take into account when planning preventive measures.

Keywords: dental caries, dentine hypersensitivity, erosion, non-carious cervical lesions

^a myhelp200@gmail.com
^c blacky3000@ukr.net

^{ib} 0000-0002-3284-0392
^{id} 0000-0002-4694-8679

^b bogdanovatyana2408@gmail.com

^{id} 0000-0001-5501-132X

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Introduction

Dental caries remains an actual problem of dental health despite modern scientific achievements.¹ Prevalence of its numerous forms varies from 67 to 100% among almost all age and sex groups of the population.² The World Health Organization (WHO) has recently classified dental caries as a non-infectious disease closely related to individual behavior and lifestyle.¹ Therefore, timely and effective comprehensive preventive measures, especially in cervical localization of the pathology, will contribute to a significant reduction in its prevalence, avoiding complications and development of periodontal diseases, gingival recession (GR) and dentin hypersensitivity (DH).²

Non-carious cervical lesions (NCCL) are the second most common reason for treatment of permanent teeth

after caries, especially among adults who are over 40 years of age. Their prevalence varies from 10 to 90% and increases with age.³ A further increase in this indicator is expected along with an increase in the period of functioning of the teeth due to an increase in life expectancy. This emphasizes the need for preventive measures at an earlier age to avoid invasive treatment in the future.⁴ In this regard, it is important to understand the causes of development, progression and combination of cervical dental lesions at the individual level.⁵ These days more and more attention is paid to social and behavioral determinants of oral health.⁶ Most modern researchers consider the etiology of cervical dental lesions to be multifactorial, completely unexplained and related to patients' habits including hygienic ones.^{3,4,7-13} Therefore, in addition to careful history taking, it is essential to analyze individual oral hygiene habits and

their correlations in order to change them, control such changes and improve the patient's quality of life.^{4,12,14}

Tooth brushing habit plays an important role in development, distribution and structure of cervical dental lesions.¹⁵ The pathological picture of NCCL differs from caries and is mainly associated with such processes as erosion and abrasion that is associated with chronic mechanical trauma being characteristic of tooth brushing.^{5,11} Abrasion with a toothbrush is also affected by the pressure with which the patient uses it, the duration and frequency of hygiene procedures.^{3,15,16} Tooth brushing technique and stiffness of toothbrush bristles, that are correlated with clinical development and severity of NCCL, are of great importance.¹⁷ The majority of patients with NCCL is known to use a horizontal tooth brushing technique.^{3,18} Horizontal and vertical scratches detected on the tooth surfaces with the help of scanning electron microscopy can be the result of appropriate motions of a toothbrush, and uneven scratches - the result of incorrect or circular motions of a toothbrush. It is possible that these defects are the result of long-term unidirectional abrasion.¹⁹ According to,^{3,7,20} excessive and horizontal tooth brushing technique can cause a wedge-shaped defect (WSD). Other researchers have linked susceptibility to erosion and abfraction to tissue destruction at the cemento-enamel junction due to such physiological activities as tooth brushing and chewing.²¹ The acid produced by dental plaque can also disrupt the mechanical properties of enamel and dentin in cemento-enamel junction area to such an extent that they will be susceptible to abrasion by a toothbrush that will subsequently lead to development of NCCL.²² In addition, tooth brushing, especially with application of pressure, may cause DH symptoms that are common in patients with NCCL.^{23,24} But there are also such known studies that did not confirm the existence of correlations between development and localization of erosive tooth wear and WSD and various hygienic factors.^{10,25} It is also possible that ordinary hygienic procedures by themselves do not cause significant wear of tooth enamel.¹⁶ This confirms the well-known fact that carious and non-carious dental lesions occur in people who have no access to hygienic means.²⁶

Thus, today there are opposite opinions and research results regarding the role of oral hygiene habits in the development of cervical dental lesions. In addition, most of available information is related to NCCL, often has a generalizing nature and is not specified for cervical caries (CC), WSD and erosion that is not sufficient for their practical application. So, it is important to identify each type of lesion during clinical examination in order to recognize individual etiological factors for prescribing effective preventive measures.^{9,13,27} In our opinion, special attention should be paid to young patients in whom exposure to potential etiological factors will help reduce the prevalence and progression of cervical dental lesions. The aim of the research is to study oral hygiene habits of young patients having cervical dental lesions; identifying

potential differences in their dental health depending on the characteristics of oral hygiene care.

Materials and Methods

Ethical Consideration

The research was carried out based on the principles of WMA Declaration of Helsinki Ethical Principles for Medical Research Involving Human Objects as amended in 2013, Order No. 690 of the Ministry of Health of Ukraine (dated September 23, 2009) and approved by the Bioethics Commission (No 43, dated January 21, 2021). All participants were given written informed consent before the study.

Participants and Study Design

The study enrolled 272 patients (174 women and 98 men) aged 18-44 years (average age 24.3±6.9 years). Based on the classification of the WHO (2016)²⁸ there were such qualifying criteria as young age, absence of harmful habits, pregnancy and lactation period; neoplasms.

A practitioner-dentist performed a clinical check-up of hard dental tissues for the presence of NCCL and CC. NCCL was classified under their morphology (WSD and erosion). We diagnosed WSD, erosion and occlusal/incisal wear facets according to the Tooth Wear Index (TWI) by B.G. Smith, J.K. Knight based on William's periodontal probe (Trinity®).⁴ The TWI uses a scale from 0 to 4, where 0 - no change in contour, 1 - minimal loss of contour, 2 - defect, 1 mm deep, 3 - depth of defect between 1 mm and 2 mm, and 4 - depth of defect 2 mm or exposure of secondary dentin or pulp.⁴ A caries marker Izumrud (Latus, Ukraine) was applied to diagnose CC.

Patients filled in the survey/questionnaire answering the questions about oral hygiene habits (frequency, duration, force, and tooth brushing technique; carrying out hygiene procedures in the morning depending on the meal, type of a toothbrush (manual or electric); use of whitening toothpaste and additional hygiene products (floss, brushes, irrigator, etc.). Dominant motions of a toothbrush mentioned in the survey/questionnaire were proven in front of a dentist during control tooth brushing. Tooth brushing was considered intensive, and the use of additional hygiene products was thought aggressive according to the patient's self-assessment that was confirmed by a change in the appearance of the working surface of a toothbrush (bristle condition) or the working part of additional hygiene products.

The survey/questionnaire form included both proposed answer options and own responses. The list of oral hygiene habits from the survey/questionnaire was related to subjects' area of residence and socio-economic characteristics. Patients were provided with explanations on any questions that arose during its filling.

The intensity of dental caries was identified according to Decayed, Missing and Filled Teeth index (DMFT), the severity of the inflammatory process in the periodontal tissues - according to the papillary-marginal-alveolar index (PMA) by S. Parma, bleeding gums - according to Papillary

Bleeding Index (PBI) by H.R. Mühlemann, GR - using William's periodontal probe (Trinity®).²⁹ The state of oral hygiene was assessed based on Oral Hygiene Index Simplified (OHI-S) by J. Greene, J. Vermillion.³⁰ We diagnosed DH carrying out probing tooth surfaces (tactile test) and air blast and cold water tests from a triple syringe.^{17,23} In order to make a diagnosis of the psycho-emotional state we identified personal anxiety with the help of Ch.D. Spielberger State-Trait-Anxiety-Inventory (STAI) in the adaptation of Y.L. Khanina.²³

Statistical Analysis

Statistical analysis was carried out with the help of the Statistica 12.0 computer program (3BA94C4ED07A) software for Windows (IBM corp., Armonk, NY, USA). By comparing average indicators in normally distributed populations, Student's t-test was calculated. The differences were thought to be statistically significant at $p \leq 0.05$. Nominal data were compared with the help of Pearson's χ^2 test. In cases where the number of expected trials was less than 5, Fisher's test was applied to evaluate the level of significance of differences. The relationship between indicators was calculated using non-parametric Spearman's rank coefficient (r).

Results

We made a diagnosis of cervical dental lesions in 43.4% of subjects: 72 women (41.4%) and 46 men (46.9%).²³ Taking into account the presence and type of cervical dental lesions patients' distribution is presented in Figure 1. All erosive defects were within the enamel. We revealed the combination of cervical dental lesions in 7 subjects: 5 cases - erosion with WSD, 2 cases - erosion with CC.²³ Taking into consideration the results of the clinical check-up, all patients were divided into five groups: I – with WSD, II – with erosion of enamel, III – with CC, IV – with a combination of cervical dental lesions, V – without any cervical dental lesions. We did not find any difference in patients' age depending on the study group ($p > 0.05$).²³ TWI indicators of teeth with WSD and occlusal/incisal wear corresponded to grades 1-3, teeth with erosion – grades 1-2. During previous studies, some indicators of dental health and the presence of complaints of feeling of bad breath in the mouth were determined in subjects.^{8,31}

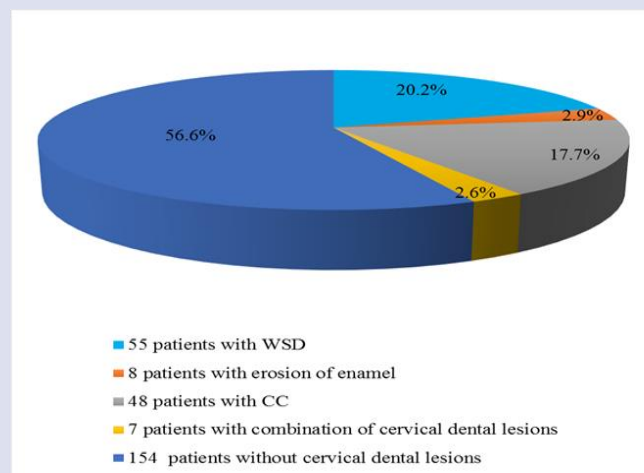


Figure 1. Patients' distribution based on the results of clinical check-up

Analysis of Oral Hygiene Habits

Common oral hygiene habits among subjects are shown in Table 1 and Figure 2. They do not present those oral hygiene habits that were episodic in nature or were present in a small number of patients, so they were not taken into account during the analysis. The studied oral hygiene habits did not depend on subjects' age ($p > 0.05$). Patients performed hygiene procedures before or after breakfast almost equally often. But under the condition of tooth brushing after eating, the degree of TWI was significantly lower in teeth with erosion ($\chi^2 = 4.286$, $p = 0.039$).

Subjects used whitening toothpaste, on average, for 0.40 ± 1.23 years. In patients with WSD, this period was longer (0.56 ± 1.49 years, $p > 0.05$), but significant differences were identified only between Group III (0.12 ± 0.38 years) and Group IV (0.01 ± 0.04 years), ($t = 1.97$, $p < 0.05$). Subjects flossed, on average, for 0.81 ± 2.13 years. Although there was no statistically

significant difference, patients in Group II flossed for a longer time (2.0 ± 5.3 years, $p > 0.05$). It was determined that women chose floss and whitening toothpaste as hygiene products significantly more often than men ($\chi^2 = 8.33$, $p = 0.003$ and $\chi^2 = 3.80$, $p = 0.05$, respectively).

When brushing their teeth, patients with WSD applied more pressure to a toothbrush than patients with CC and without cervical lesions ($\chi^2 = 4.716$, $p = 0.030$ and $\chi^2 = 8.176$, $p = 0.05$, respectively). Intensive tooth brushing influenced the development of WSD and an increase in their number ($\chi^2 = 7.281$, $p = 0.007$ and $\chi^2 = 9.045$, $p = 0.003$, respectively).

Subjects of Group III flossed more often as an additional hygiene product compared to the subjects of Group V ($\chi^2 = 4.147$, $p = 0.042$). It was determined that under the condition of flossing, probability of CC development decreased ($\chi^2 = 4.813$, $p = 0.029$). Patients with WSD and associated cervical dental lesions flossed

aggressively significantly more often compared to patients with CC ($\chi^2=4.365$, $p=0.037$ and $\chi^2=7.270$, $p=0.008$, respectively).

A greater number of subjects (68.8%) brushed their teeth twice daily (Table 2 and Figure 3) and used manual medium-hard toothbrushes for individual hygiene (87.9%), $p>0.05$ (Table 3 and Figure 4). Although there was no statistically significant difference, patients with clinical symptoms of DH also chose a toothbrush with medium-hard bristles more often ($p>0.05$).

The majority of patients (89.3%) indicated mixed motions of a toothbrush as the main technique for tooth brushing (Table 4 and Figure 5). Subjects with WSD made horizontal motions more often ($\chi^2=5.458$, $p=0.02$), but that did not affect their development ($\chi^2=0.051$, $p=0.822$). Significant differences in

tooth brushing technique were also observed between patients of Group III and Group IV as well as Group III and Group V. When brushing their teeth subjects with CC made circular movements with a brush more often than subjects with combined cervical dental lesions and without cervical dental lesions ($\chi^2=6.984$, $p=0.009$ and $\chi^2=3.976$, $p=0.047$, respectively). In case of dominance of mixed or circular motions, there was a lower probability of CC or combined forms of dental lesions ($\chi^2=4.130$, $p=0.043$ and $\chi^2=52.801$, $p<0.001$, respectively).

The average duration of tooth brushing was 2.64 ± 1.29 minutes. Although there was no statistically significant difference, its higher values (2.72 ± 1.37 minutes) were identified in subjects of Group V ($p>0.05$).

Table 1. Comparison of study groups by prevalence of oral hygiene habits

Oral hygiene habits	Sex	Total by sex (abs./% of the total number of patients of this sex)	Groups (abs./% of the total number of patients in the group)				
			I	II	III	IV	V
Tooth brushing before breakfast	m	52/53	14/25	2/25	9/19	0/0	27/18
	w	85/49	15/27	4/50	15/3	4/57	47/31
		p-value	$p_2=0.125$	$p_1=0.125$	$p_1=0.973$	$p_1=0.784$	$p_1=0.552$
			$p_3=0.973$	$p_3=0.317$	$p_2=0.317$	$p_2=0.666$	$p_2=0.138$
			$p_4=0.784$	$p_4=0.666$	$p_4=0.799$	$p_3=0.799$	$p_3=0.814$
Tooth brushing after breakfast	m	45/46	8/14	0/0	11/22	1/14	25/16
	w	90/52	18/32	2/25	13/27	2/28	55/35
		p-value	$p_2=0.223$	$p_1=0.223$	$p_1=0.408$	$p_1=0.192$	$p_1=0.552$
			$p_3=0.408$	$p_3=0.492$	$p_2=0.492$	$p_2=0.485$	$p_2=0.138$
			$p_4=0.192$	$p_4=0.485$	$p_4=0.291$	$p_3=0.291$	$p_3=0.814$
Application of pressure to a toothbrush	m	22/22	9/16	0/0	1/2	0/0	12/8
	w	31/18	10/18	2/25	5/10	1/14	13/8
		p-value	$p_2=0.375$	$p_1=0.375$	$p_1=0.030^*$	$p_1=0.342$	$p_1=0.005^*$
			$p_3=0.030^*$	$p_3=0.573$	$p_2=0.573$	$p_2=0.747$	$p_2=0.517$
			$p_4=0.342$	$p_4=0.747$	$p_4=0.984$	$p_3=0.984$	$p_3=0.531$
Use of whitening toothpaste	m	11/11	3/5	0/0	5/10	0/0	3/2
	w	36/21	8/15	1/13	1/2	1/14	25/16
		p-value	$p_2=0.630$	$p_1=0.630$	$p_1=0.516$	$p_1=0.778$	$p_1=0.767$
			$p_3=0.516$	$p_3=0.948$	$p_2=0.948$	$p_2=0.952$	$p_2=0.683$
			$p_4=0.778$	$p_4=0.952$	$p_4=0.576$	$p_3=0.576$	$p_3=0.359$
Flossing	m	17/17	3/5	0/0	3/6	0/0	11/7
	w	61/36	13/24	2/25	5/10	3/43	38/25
		p-value	$p_2=0.902$	$p_1=0.902$	$p_1=0.058$	$p_1=0.551$	$p_1=0.453$
			$p_3=0.058$	$p_3=0.142$	$p_2=0.142$	$p_2=0.666$	$p_2=0.687$
			$p_4=0.551$	$p_4=0.666$	$p_4=0.092$	$p_3=0.092$	$p_3=0.042^*$
Aggressive flossing	m	3/3	0/0	0/0	0/0	0/0	3/2
	w	13/7	4/7	0/0	0/0	1/14	8/5
		p-value	$p_2=0.832$	$p_1=0.832$	$p_1=0.037^*$	$p_1=0.602$	$p_1=0.975$
			$p_3=0.037^*$	$p_3=0.066$	$p_2=0.066$	$p_2=0.563$	$p_2=0.412$
			$p_4=0.602$	$p_4=0.563$	$p_4=0.008^*$	$p_3=0.008^*$	$p_3=0.057$
			$p_5=0.975$	$p_5=0.412$	$p_5=0.057$	$p_5=0.482$	$p_4=0.482$

w: - women; m: - men; abs. - absolute value; p_1 - the statistically significant of differences when comparing the corresponding study group with Group I; p_2 - the statistically significant of differences when comparing the corresponding study group with Group II; p_3 - the statistically significant of differences when comparing the corresponding study group with Group III; p_4 - the statistically significant of differences when comparing the corresponding study group with Group IV; p_5 - the statistically significant of differences when comparing the corresponding study group with Group V; * - $p\leq 0.05$.

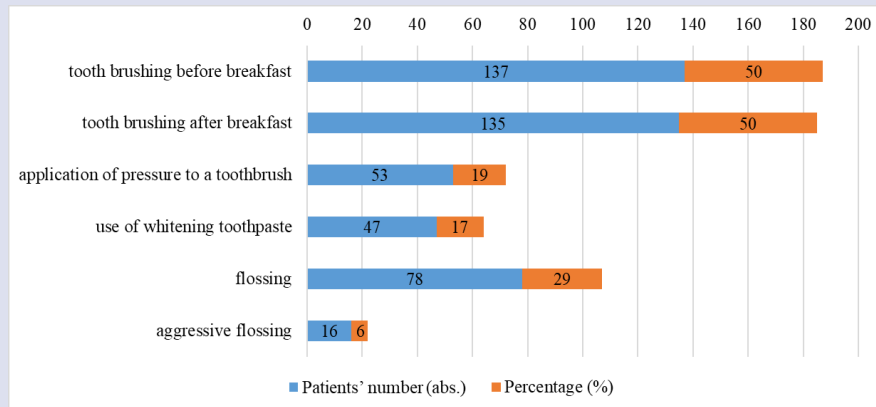


Figure 2. Prevalence of oral hygiene habits among subjects

Table 2. Comparison of study groups by frequency of tooth brushing daily with a manual toothbrush

Groups	Sex	Frequency of tooth brushing daily (abs./% of the total number of patients in the group)			p-value
		One	Two	Three	
I	m	9/16.0	13/23.0	0/0	p ₂ =0.474
	w	7/13.0	24/44.0	2/4.0	p ₃ =0.853
II	m	0/0	2/25.0	0/0	p ₄ =0.432
	w	2/25.0	4/50.0	0/0	p ₅ =0.655
III	m	7/14.6	12/25.0	1/ 2.1	p ₁ =0.474
	w	6/12.5	21/43.7	1/ 2.1	p ₃ =0.432
IV	m	0/0	1/14.3	0/0	p ₄ =0.499
	w	0/0	6/85.7	0/0	p ₅ =0.952
V	m	22/14.2	29/18.8	1/0.01	p ₁ =0.853
	w	18/11.7	75/48.7	9/6.0	p ₂ =0.432
					p ₄ =0.591
					p ₅ =0.879
					p ₁ =0.624
					p ₂ =0.499
					p ₃ =0.591
					p ₅ =0.120
					p ₁ =0.655
					p ₂ =0.952
					p ₃ =0.879
					p ₄ =0.120

w: – women; m: – men; abs. – absolute value; p₁– the statistically significant of differences when comparing the corresponding study group with Group I; p₂ – the statistically significant of differences when comparing the corresponding study group with Group II; p₃ – the statistically significant of differences when comparing the corresponding study group with Group III; p₄ – the statistically significant of differences when comparing the corresponding study group with Group IV; p₅ – the statistically significant of differences when comparing the corresponding study group with Group V

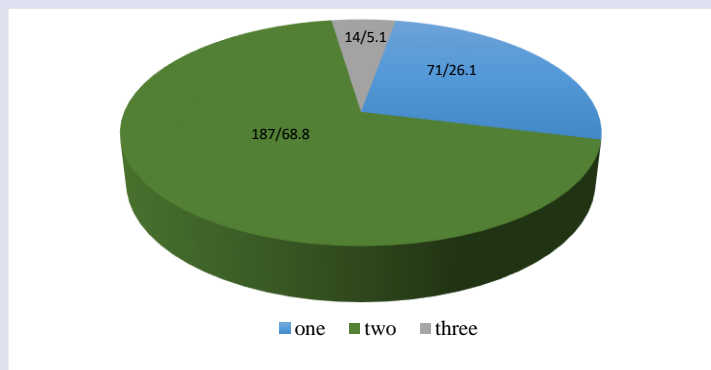
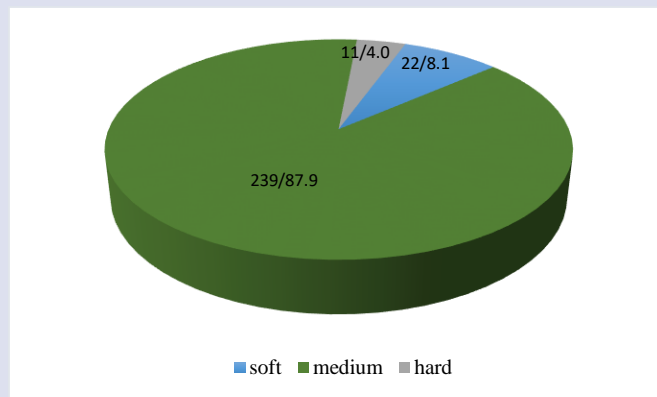


Figure 3. Frequency of tooth brushing daily with a manual toothbrush by subjects (times) (abs./%)

Table 3. Comparison of study groups by type of a manual toothbrush stiffness

Groups	Sex	Toothbrush stiffness (abs./% of the total number of patients in the group)			p-value
		Soft	Medium-hard	Hard	
I	m	2/4.0	19/34.5	1/ 2.0	p ₂ =0.615
	w	2/4.0	31/56.3	0/0	p ₃ =0.897
II	m	0/0	2/25.0	0/0	p ₄ =0.731
	w	0/0	6/75.0	0/0	p ₅ =0.257
III	m	2/4.0	18/37.5	0/0	p ₁ =0.615
	w	5/10.4	22/46.0	1/ 2.0	p ₃ =0.389
IV	m	0/0	1/14.3	0/0	p ₄ =0.489
	w	0/0	6/85.7	0/0	p ₅ =0.495
V	m	0/0	47/30.5	5/3.2	p ₁ =0.897
	w	11/7.1	87/56.5	4/2.6	p ₂ =0.389
					p ₄ =0.706
					p ₅ =0.325
					p ₁ =0.731
					p ₂ =0.489
					p ₃ =0.706
					p ₅ =0.555
					p ₁ =0.257
					p ₂ =0.495
					p ₃ =0.325
					p ₄ =0.555

w: – women; m: – men; abs. – absolute value; p₁– the statistically significant of differences when comparing the corresponding study group with Group I; p₂ – the statistically significant of differences when comparing the corresponding study group with Group II; p₃ – the statistically significant of differences when comparing the corresponding study group with Group III; p₄ – the statistically significant of differences when comparing the corresponding study group with Group IV; p₅ – the statistically significant of differences when comparing the corresponding study group with Group V

**Figure 4.** The type of a manual toothbrush stiffness in subjects (abs./%)**Table 4.** Comparison of study groups by tooth brushing technique

Groups	Sex	Dominant motions of a toothbrush (abs./% of the total number of patients in the group)				p-value
		Horizontal	Vertical	Circular	Mixed	
I	m	1/1.8	1/1.8	1/1.8	19/34.5	p ₂ =0.331
	w	2/3.6	2/3.6	0/0	30/54.5	p ₃ =0.020*
II	m	0/0	0/0	0/0	2/25.0	p ₄ =0.126
	w	0/0	0/0	1/12.5	5/62.5	p ₅ =0.480
III	m	0/0	0/0	1/2.0	19/39.5	p ₁ =0.331
	w	0/0	0/0	2/4.0	26/54.2	p ₃ =0.684
						p ₄ =0.269
						p ₅ =0.412
						p ₁ =0.020*
						p ₂ =0.684
						p ₄ =0.009*
						p ₅ =0.047*

IV	m	0/0	0/0	0/0	5/71.6	$p_1=0.126$
	w	0/0	1/14.2	0/0	1/14.2	$p_2=0.269$
						$p_3=0.009^*$
						$p_5=0.538$
V	m	5/3.2	1/0.01	3/2.0	43/28.0	$p_1=0.480$
	w	3/2	3/2	2/1.3	93/60.4	$p_2=0.412$
						$p_3=0.047^*$
						$p_4=0.538$

w: - women; m: - men; abs. - absolute value; p_1 - the statistically significant of differences when comparing the corresponding study group with Group I; p_2 - the statistically significant of differences when comparing the corresponding study group with Group II; p_3 - the statistically significant of differences when comparing the corresponding study group with Group III; p_4 - the statistically significant of differences when comparing the corresponding study group with Group IV; p_5 - the statistically significant of differences when comparing the corresponding study group with Group V; * - $p \leq 0.05$.

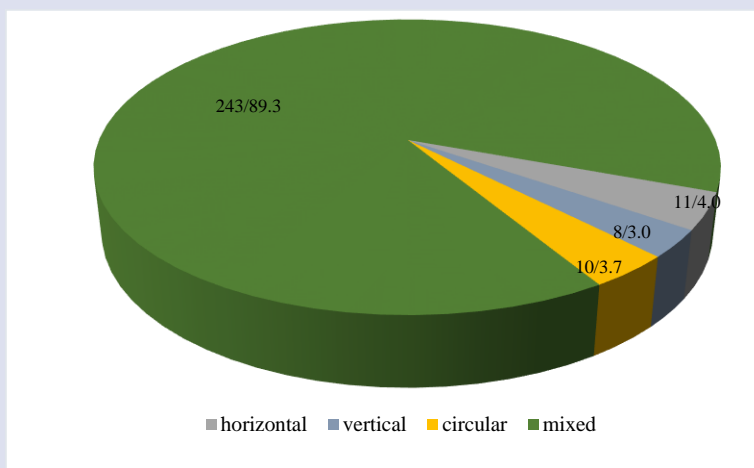


Figure 5. Dominant motions of a manual toothbrush during tooth brushing by subjects (abs./%)

Identification of Potential Differences in Dental Health Status Depending On the Peculiarities of Oral Hygiene Practice

In Group 1, DMFT indicators differed depending on the frequency of tooth brushing ($\chi^2=11.757$, $p<0.001$). Thus, when patients with WSD brushed their teeth twice daily or more, DMFT indicators reliably decreased. PBI indicators increased significantly in patients of Group I under the condition of applying more pressure to a toothbrush during tooth brushing ($\chi^2=9.006$, $p=0.003$), and in patients of group III - under the condition when the duration of the hygienic procedure was three minutes or longer ($\chi^2=5.855$, $p=0.016$). PMA indicators differed depending on the frequency of tooth brushing in patients with CC ($\chi^2=5.319$, $p=0.022$). Thus, when the number of procedures during the day was three or more, PMA indicators decreased significantly.

There was determined the influence of oral hygiene habits on the development of DH in subjects of Group I. The probability of developing clinical symptoms of DH differed depending on flossing and duration of tooth brushing in patients with WSD ($\chi^2=4.491$, $p=0.035$ and $\chi^2=5.620$, $p=0.018$, respectively). So, when patients flossed and brushed their teeth for three minutes or longer, DH was diagnosed more often. It was previously reported that degrees of TWI affected the development of symptoms of DH (in teeth with WSD - significantly - $\chi^2=8.17$, $p=0.04$, in teeth with

erosion - nonsignificantly - $\chi^2=5.60$, $p=0.06$).²³ The conducted analysis has shown that the pressure applied to a toothbrush by a patient varies depending on their psycho-emotional state ($\chi^2=7.765$, $p=0.006$). In subjects with associated cervical dental lesions, a moderate direct correlation was observed between the level of personal anxiety and indicators of PMA and OHI-S ($r=0.59$ and $r=0.38$, $p<0.05$, respectively).

In subjects of Group 1, the level of oral hygiene differed depending on tooth brushing technique ($\chi^2=3.71$, $p=0.05$). Patients with WSD had a better state of hygiene when using mixed motions of a manual toothbrush. The development of occlusal/incisal wear facets was influenced by the characteristics of oral hygiene care. The probability of their development increased in subjects with CC when the duration of tooth brushing was three minutes or longer ($\chi^2=4.324$, $p=0.038$), in subjects with WSD - when using whitening toothpaste ($\chi^2=4.626$, $p=0.032$). None of the considered oral hygiene habits had significant differences in patients with GR. Flossing significantly affected the presence of complaints of feeling of bad breath in the mouth in those subjects with associated cervical dental lesions ($\chi^2=3.73$, $p=0.05$).

Discussion

Regular tooth brushing can be attributed to socio-economic factors.¹¹ Independent daily mechanical destruction and plaque removal are important for the

health of the oral cavity. A significant number of subjects preferred a manual toothbrush among the means of oral hygiene, 29% of patients used dental floss as an additional hygiene tool. Therefore, the analysis was focused on these individual oral hygiene habits. According to,³² a manual toothbrush can remove up to 43% of dental plaque on average. So, it is recommended to use additional means to penetrate the interdental spaces.³³

There are studies that determined a reliable correlation between age, sex and oral hygiene habits.¹² The researchers did not find any correlation between age and oral hygiene habits, probably, because only young patients were examined. But women used floss and whitening toothpaste significantly more often. Individual oral hygiene in women is known to be at a higher level that also contributes to a higher prevalence of NCCL and DH because of traumatic tooth brushing techniques.^{24,34} But other scientists did not find a significant correlation between sex and oral hygiene habits in patients with erosion.³⁵ According to,⁹ different research results are probably due to the fact that sex and age factors can explain only a small percentage of differences in tooth wear.

The presence of NCCL is known to be associated with the use of toothpaste.¹⁸ At the same time, the abrasiveness of toothpaste is of great importance.^{7,15,16} Subjects used whitening toothpaste for a short period of time, although even under these circumstances, differences in the prevalence of occlusal/incisal wear facets were identified in patients with WSD. The obtained results are consistent with the data,²⁷ according to which abrasion of hard dental tissues occurs due to interactions between teeth and exogenous substances, such as highly abrasive toothpastes, especially with whitening effect. The researchers determined that patients with WSD also flossed aggressively more often than that, according to,¹⁶ is a likely cause of NCCL.

The time of tooth brushing is known to have different effects on their wear, because the erosive effect makes hard tissues more susceptible to loss because of abrasion.⁹ But no evidence has been found yet that waiting a certain period of time after breakfast before tooth brushing affects the degree of tooth wear.³⁶ The study revealed that the depth of erosion was significantly lower in patients who brushed their teeth after eating. The degree of TWI in tooth with erosion was significantly lower.

The stiffness of toothbrush bristles can affect tooth wear in different ways.⁹ Manual hard bristle toothbrushes remove dental plaque better, but can also cause more trauma to soft tissues.^{37,38} And the use of medium or hard bristle toothbrushes and application of greater pressure during tooth brushing can increase dentin wear.^{15,27} Therefore, increased application of pressure to a toothbrush is also associated with development of NCCL,³⁹ and their prevention involves reducing this effect.⁴⁰ The conducted analysis has determined that the pressure applying to a toothbrush by a patient differs depending on their psycho-emotional state. Other researchers proved

that tooth wear and WSD were diagnosed three times more often in subjects with a high level of anxiety.⁴¹ In patients with combined cervical dental lesions, correlation was observed between the level of personal anxiety and the indicators of PMA and OHI-S. Increased psychoemotional stress significantly worsens the condition of periodontal tissues that is confirmed by an increase in the indicators of periodontal indices.⁴² Therefore, the examination of patients with cervical dental lesions should be comprehensive and include both an assessment of dental and psycho-emotional states.²³

Patients with WSD brushed their teeth intensively that increased the number of lesions and PBI indicators. According to,⁴³ half of subjects with WSD brush their teeth from three to five minutes. In patients with CC, PBI indicators increased and occlusal/incisal wear facets developed when tooth brushing lasted for three minutes or longer. Therefore, the researchers recommend not exceeding the time of the hygienic procedure more than 2.5 minutes. RBI indicators varied depending on OHI-S indicators.³¹ There is a strong correlation between hygiene indices and the development of periodontal pathology.^{42,44} Therefore, it is important to teach patients the correct technique of tooth brushing in order to reduce the wear of toothbrush bristles and increase its efficiency.³²

Patients with NCCL are known to brush their teeth significantly more often,⁴⁵ most of them brush their teeth twice daily.⁴¹ Other researchers found an insignificant correlation between NCCL and frequency of tooth brushing.⁴⁶ It was determined that frequency of tooth brushing twice or more times daily contributed to a decrease in DMFT indicators in patients with WSD and to a decrease in PMA indicators in patients with CC who brushed teeth three or more times daily. There are also associations between oral hygiene and the etiology of WSD.⁴⁶ The conducted analysis identified that the most effective motions were mixed or circular ones of a manual toothbrush.

According to,³³ additional flossing can reduce the amount of dental plaque and, accordingly, the severity of gingivitis. This confirms the obtained results, namely the positive effect of flossing on the appearance of complaints of feeling of bad breath in the mouth in patients with combined cervical dental lesions. The conducted study also showed that the probability of CC development was reduced in those subjects who flossed. However, patients with WSD and combined cervical dental lesions used it more often in an aggressive technique. It contributed to development of clinical symptoms of DH in subjects with WSD, because aggressive flossing is likely to cause tooth wear.^{14,27}

Possible etiological factors of DH are tissue abrasion with a hard bristle toothbrush.⁴⁷ In the present study, a greater number of patients with DH used a medium bristle toothbrush. No differences in the development of DH were identified depending on the frequency and technique of daily tooth brushing and the time of hygienic procedures after breakfast, as in other studies.⁴⁷ When

brushing teeth for 3 minutes and longer as well flossing, DH was diagnosed patients with WSD with more often. According to,²¹ flossing was not associated with self-reported DH. Typical toothpastes alone cannot cause DH, but toothpastes with higher abrasiveness or abnormal tooth brushing can contribute to development of its symptoms due to dentin wear and the removal of the lubricated layer and development of open dentinal tubules.¹⁵ According to data,⁴⁸ oral hygiene habits were not reliably associated with development of GR that confirmed the conducted study.

Therefore, it is not always possible to find any excessive hygienic habits in the histories of patients with WSD and erosion which can lead to development of cervical dental pathology.⁷ In addition, they do not always share this information.⁵ According to,³⁹ this can explain only 68.8% of the differences in tooth wear. Although there is no clear evidence of how different forms of NCCL can be related to each other, according to,⁷ it is possible to assume that they reflect different stages of progression of the lesion, local factors play a role only in changing their form. Therefore, preventive intervention begins with individual counseling on changing the patient's attitude, for example, towards the method of tooth brushing.¹³

There were some limitations in the conducted study. To begin with, 64% of subjects were women; then, the sample was represented by young patients living in a definite geographic area and having oral hygiene habits peculiar to it; finally, after the comprehensive examination significant differences in number in the formed study groups were observed. Some differences are probably related to subjects' age, their socio-economic and cultural factors, habits in hygienic means, as well as in the exclusive trust of data obtained from questionnaires.⁴⁹ It is also impossible to consider the information got from surveys/questionnaires as completely objective. All this limits the generalization of the obtained results.

Conclusions

The conducted study revealed significant differences in the considered dental health indicators of patients with cervical dental lesions depending on the characteristics of oral hygiene habits. The obtained results are recommended to take into account when planning individual treatment and preventive measures, especially in young patients, in order to prevent the development, progression and combination of oral pathology.

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Assessment of the Content and Quality of Youtube Videos Related Subperiosteal Implants: A Cross-Sectional Study

İlgin Arı^{1,a,*}, Arzum Yılmaz^{2,b}, Somayeh Hürmüzlü^{3,c}, Erçin Samunahmetoğlu^{4,d}

¹Department of oral and Maxillofacial Surgery, , Faculty of Dentistry ,Hacettepe Üniversitesi. Ankara, Türkiye

²Kent Clinic, Cankaya, Ankara, Türkiye

³Department of Endodontics, Faculty of Dentistry, Yozgat Bozok University, Yozgat, Türkiye

⁴Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Yozgat Bozok University, Yozgat, Türkiye

*Corresponding author

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ABSTRACT

Objectives: This study aimed to evaluate the content and quality of YouTube videos related to subperiosteal implants, focusing on their educational value and reliability for both patients and healthcare professionals.

Materials and Methods: A total of 150 YouTube videos were identified using the keyword "subperiosteal implant" and filtered by English language. The videos have no audio; non-English language; off-topic content; duration exceeding 30 minutes; YouTube. The demographic data of videos as source of upload, comments, likes, interaction index, viewing and duration were recorded, and the videos were divided into low (LCG) and moderate-high content (MHG) groups according to their contents. The videos content quality was assessed using the DISCERN tool and Global Quality (GQ) scale.

Results: In this study, 69 YouTube videos on subperiosteal implants were analyzed, with 72.5% uploaded by commercial organizations and only one video by a university. The primary target audience of the analyzed YouTube videos predominantly comprised healthcare professionals. The moderate-high content group (MHG) had mean DISCERN and GQ scores of 42.89 and 2.97, respectively, compared to 31.4 and 1.82 in the low-content group (LCG) ($p=0.001$). The most frequently discussed topics included implant definitions and procedural steps, while postoperative care, complications, and contraindications were underrepresented. Statistical differences were observed in video length ($p=0.021$), but no significant differences were found for other demographic data.

Conclusions: YouTube videos related to subperiosteal implants are generally inadequate for educational purposes, especially for patients. To improve content quality, healthcare professionals and academic institutions should actively contribute accurate, evidence-based videos. Enhanced video resources could better serve as reliable educational tools in clinical dentistry.

Keywords: Subperiosteal implants, YouTube videos, content, quality

^a ariilgin@gmail.com

^c somaye.faraji88@gmail.com

^b arzumyilmaz@gmail.com

^d ercinsa@hotmail.com

^b arzumyilmaz@gmail.com

^d ercinsa@hotmail.com

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Introduction

After tooth extraction, patients often seek rehabilitation options. In traditional approaches, dental implants are the most commonly selected treatment; however, bone resorption is an inevitable part of the physiological process, sometimes limiting the feasibility of implants.¹ Rehabilitation of severely atrophic jaws presents significant challenges. Various augmentation procedures, such as distraction osteogenesis, onlay grafts, and inferior alveolar nerve lateralization, are well-documented in the literature.^{2,3} Although these methods demonstrate high success rates, their complexity, extended treatment timelines, and associated postoperative discomforts have led researchers in recent years to explore alternative options, including zygomatic implants, subperiosteal implants, and the All-on-4 system.^{4,5}

In past decades, subperiosteal implants were largely abandoned due to fitting challenges and the need for two-stage surgical procedures.^{6,7} However, with advances in 3D

scanning and CAD-CAM technology, subperiosteal implants have regained popularity as a viable option for patients with severely atrophic jaws.⁸ Although subperiosteal implants provide advantages such as reduced treatment duration and the ability to bypass complex augmentation techniques, achieving successful outcomes requires thorough planning, accurate placement, and diligent follow-up.^{9,10} Given the rising interest in subperiosteal implants, dental students, professionals, and the public are increasingly seeking information on this topic, often turning to social media platforms like YouTube.^{11,12} As YouTube is one of the most widely accessed sources of information for the public, identifying and verifying health-related content that may mislead viewers is essential.¹²

While several studies have evaluated YouTube content on dental procedures such as sinus lifts, zygomatic implants, and the All-on-4 system, to our knowledge, no study has yet assessed the content of YouTube videos specifically focused on subperiosteal implants.¹³⁻¹⁵ Therefore, the aim of this study

was to evaluate the content and quality of subperiosteal implant videos on YouTube. The study hypothesized that the information in these videos related to subperiosteal implants may be inadequate or potentially misleading.

Materials and Methods

This study evaluated YouTube videos on subperiosteal implants. Videos were located by conducting a search on YouTube (www.youtube.com; Google, San Bruno, CA), using “subperiosteal implant” as the keyword and filtering results in English. According to Google Trends data (2021), “subperiosteal implant” is the most common search term for addressing extreme maxilla atrophy in oral implantology across various languages and regions. A new Google account was created to prevent recommendations based on prior viewing history. To ensure a broad selection, search parameters were restricted to videos from “the last five years” on a “worldwide” setting.

Only the relevance filter was applied in the YouTube search, without filtering for attributes such as duration or video type. The search results were confined to the first 150 videos, as prior studies suggest that 95% of users only view the first three pages of results, with recommendations to limit viewing to between “30 to 60” or “60 to 200” videos.^{16,17} Furthermore, after the initial 150 videos, irrelevant content began to appear, so the analysis was limited to this range. To maintain consistent data as new content was added, a playlist was created, and videos from this list were systematically recorded after viewing as presented previous studies.^{13,14}

Exclusion criteria included the following: (1) absence of audio; (2) non-English language; (3) off-topic content; (4) duration exceeding 30 minutes; (5) YouTube Shorts; and (6) duplicate entries. Multipart videos were treated as single entries. Attributes like the number of days since upload, relevant jaw, origin country, video length in seconds, like/dislike counts, and viewer comments were noted. Viewer engagement was assessed using interaction index and viewing rate as described in previous research.¹¹

Two independent evaluators (IA, AY) analyzed the content of these videos for the following topics: (1) subperiosteal implant definition; (2) indications; (3) contraindications; (4) procedural steps; (5) advantages; (6) disadvantages; (7) complications; (8) implant design; (9) postoperative care; (10) interim restoration protocol; (11) definitive prosthesis protocol; (12) material selection; (13) anatomical information; (14) oral hygiene; (15) maintenance and (16) post-operative discomfort. Each topic was scored as 1 point, with a maximum total score of 16. Videos with 11–16 points were rated high content, 6–10 moderate content, and 0–5 low content. Any disagreements during evaluation were resolved in a consensus meeting.

Upload sources were divided into four categories: healthcare professionals (e.g., dentists, specialists), hospitals/universities, commercial entities (e.g., dental product companies), general individuals. Target audiences were classified as healthcare professionals, patients or both.

Qualitative assessment was conducted independently by two evaluators (IA, AY) using the DISCERN tool and GQ scale. The GQ scale is a 5-point system assessing the educational quality of videos, with scores of 1–2 considered “low,” 3 as “moderate,” and 4–5 as “high.”¹⁶ The DISCERN tool comprises

three main sections across 16 questions: reliability (questions 1–8), quality of information (questions 9–15), and an overall score (question 16). Each question was scored from 1 to 5, with 1 indicating unmet criteria and 5 indicating full criteria. Based on total average scores, videos were classified as “very poor” (16–26), “poor” (27–38), “fair” (39–50), “good” (51–62), or “excellent” (63+).¹⁴ In cases of evaluator disagreement, videos were rewatched, and consensus was reached. Since this study used publicly available data, ethical approval was not necessary.

The data analysis was conducted using IBM SPSS Statistics version 26. Categorical variables were calculated as frequencies and percentages. For numerical variables, normality was assessed by evaluating skewness and kurtosis values. According to the rules of normal distribution, skewness and kurtosis values should fall within the range of ± 1.5 .¹⁸ Within this framework, GQ scores, DISCERN scores, and total content scores followed a normal distribution, whereas other variables did not.

Based on these findings, parametric tests (independent samples t-test and Pearson correlation analysis) were applied to variables exhibiting normal distribution. Non-parametric tests (Mann-Whitney U test and Spearman correlation analysis) were employed for variables that did not meet normality assumptions. Throughout the study, significance levels were evaluated at 0.05 and 0.01 thresholds.¹⁹

Results

In this study, 150 YouTube videos were evaluated. A total of 81 videos were excluded after applying the established criteria (Table 1). Consequently, a total of 69 videos were included in the analysis. The most common source of video uploads, by continent, was Asia, with 31 videos originating from India (Figure 1). Most of the videos (n=62) were uploaded between 2019 and 2024, although the upload years ranged from 2010 to 2024.

The descriptive statistics of videos were showed in Table 2. There wasn't observed any dislike in the videos. While the mean viewing rate was 176.3 (range 0.4-784) the mean interaction index was observed 2.9 (range 0-80). The mean total content, DISCERN and GQ scores were found 5.9 (low), 37.4 (low) and 2.4 (low), respectively. (Table 2)

The content of the videos was categorized into low, moderate, and high content groups. There were 33 videos in the low-content group, 32 in the moderate-content group, and only 4 in the high-content group. Due to the limited number of high-content videos, the moderate and high-content groups were combined and analyzed as a single moderate-high content group (MHG). The mean total content scores of 7.75 and 3.91 observed for the MHG and LCG, respectively. The average number of days since upload was 1297 days for the LCG and 1039 days for the MHG. While no statistically significant differences were found between the groups in terms of views, comments, likes, viewing rate, or interaction index, a significant difference was observed in video length between groups ($p=0.021^*$, Table 3).

According to DISCERN analysis, all question scores were higher in the MHG compared to the LCG (Figure 2). The mean DISCERN scores for the MHG and LCG were 42.89 (classified as fair) and 31.4 (classified as poor), respectively. Moreover, the DISCERN scores of the MHG were significantly higher than

those of the LCG ($p=0.001^*$, Table 4). Similarly, the GQ scores were notably greater in the MHG, with a mean value of 2.97 (moderate), compared to 1.82 (low) in the LCG ($p=0.001^*$, Table 4). Positive and strong correlations were observed between total content scores, and both DISCERN and GQ scores ($r=0.714$, $p<0.001^*$; $r=0.852$, $p<0.001^*$, Table 5). Additionally, a strong positive correlation was found between DISCERN and GQ scores ($r=0.814$, $p<0.001^*$, Table 5).

The most frequently addressed video topics were subperiosteal implant definitions, indications, procedural steps, implant designs, and anatomical information. Conversely, the least addressed topics included maintenance, postoperative discomfort, contraindications, complications, disadvantages, postoperative care, and oral hygiene (Table 6). Content related to subperiosteal implant definitions, indications, procedural steps, implant designs, interim

restoration protocols, and anatomical information was significantly more prevalent in the MHG compared to the LCG ($p=0.009^*$, Table 7).

The primary target audience of the analyzed YouTube videos predominantly comprised healthcare professionals ($n=48$), with a minority targeting only patients ($n=3$) and a subset addressing both dental professionals and patients ($n=18$). Statistical analysis revealed no significant differences regarding the intended audience across groups ($p=0.107$, Table 8). In terms of upload sources, commercial organizations represented the majority ($n=50$), followed by healthcare professionals ($n=18$). Universities contributed minimally, with only one video identified, and no uploads were attributed to the general public. Furthermore, the comparison of upload sources between groups demonstrated no statistically significant differences ($p=0.579$, Table 8)

Table 1: The exclusion criteria of youtube videos.

Criteria	n	%
No audio	19	23.8
Longer than 30 minutes	4	4.9
Language other than English	14	17.2
Duplicates	7	8.6
Unrelated subjects	20	24.6
YouTube shorts	17	20.9
Total	81	100

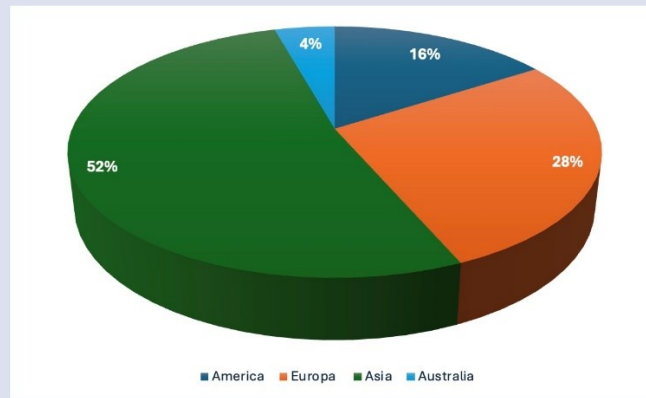


Figure 1: Distribution of videos uploading source according to continent.

Table 2: Descriptive statistics of the videos.

	Mean	Standard Deviation	Minimum	Maximum	Median
Viewing	1791.5	3807.3	15	29717	962
Video length (seconds)	291.6	319.3	15	1815	171
The number of days since upload	1162.3	889.9	14	4106	1035
Comment	1.9	3.4	0	19	0
Like	21.5	29.8	0	176	10
Dislike	0	0	0	0	0
Viewing rate	176.3	189.2	0.4	784	109
Interaction index	2.9	9.7	0	80	1.5
DISCERN	37.4	9.9	16	58	36
GQ score	2.4	0.8	1	4	2
Total content score	5.9	2.5	0	13	6

Table 3: Comparison of the demographic data of the videos according to groups.

Variables	Groups								U	p
	Low Content				Moderate-High Content Group					
	n	Mean	SD	Median	n	Mean	SD	Median		
Viewing	33	2249	5269	858	36	1372	1549	986	568.0	0.755
Video length (seconds)	33	191	180	150	36	384	387	226	402.0	0.021*
Comment	33	1	2	0	36	2	4	0	566.5	0.719
Like	33	20.3	23.7	7	36	22.6	35	11	569.5	0.962
Viewing rate	33	155.5	159.9	107.2	36	195.3	213.1	112.5	575.5	0.824
Interaction index	33	1.84	3.39	1.3	36	3.93	13.1	1.6	479.0	0.167

n: sample U: Mann Whitney U-test; SD: Standard deviation; n: sample size; *: p<0.05

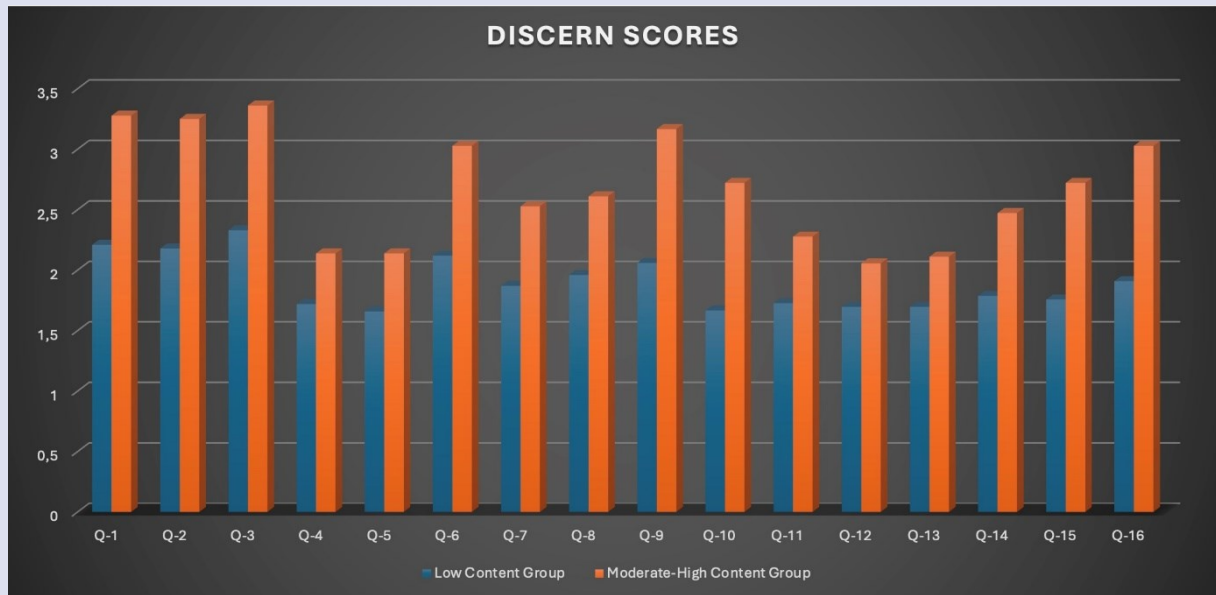


Figure 2: DISCERN question scores of videos according to low and moderate-high content groups.

Table 4: Comparison of groups according to GQ and discern scores.

Variables	Group	n	Mean	Standard Deviation	t	p
DISCERN	Low content group	33	31.4	7.444	-5.887	0.001**
	Moderate-high content group	36	42.89	8.737		
GQ	Low content group	33	1.82	0.392	-8,379	0.001**
	Moderate-high content group	36	2.97	0.696		

n: sample t: independent sample t-test; *: p<0.001

Table 5: The correlation levels between total content score, GQ, and discern scores.

Variables	Coefficient	DISCERN	GQ score
DISCERN	r	1	
	p		
	n	69	
GQ score	r	0.814**	1
	p	0.001	
	n	69	69
Total content score	r	0.741**	0.852**
	p	0.001	0.001
	n	69	69

n:sample; r: Pearson correlation coefficient, **:p<0,01

Table 6: The distribution of video contents' presence according to groups.

Video Contents	Group			
	Low Content		Moderate-High Content Group	
	n	%	n	%
Subperiosteal implant definition	30	43.5	36	52.2
Indications	28	40.6	36	52.2
Contraindications	0	0.0	1	1.4
Procedural steps	18	26.1	35	50.7
Advantages	1	1.4	22	31.9
Disadvantages	0	0	3	4.3
Complications	0	0	1	1.4
Postoperative care	0	0	3	4.3
Implant design	27	39.1	36	52.2
Oral hygiene	0	0	4	5.8
Interim restoration protocol	2	2.9	27	39.1
Definitive prosthesis protocol	0	0	22	31.9
Material selection	0	0	13	18.8
Anatomical information	23	33.3	35	50.7
Post-operative discomfort	0	0	0	0
Maintenance	0	0	5	7.2

n: sample, %: percentage

Table 7: The video contents which were mentioned significantly higher in MHG than LCG.

Content	Group				X ²	p
	Low Content		Moderate-High Content			
	n	%	n	%		
Subperiosteal implant definition	30	45.5	36	54.5	15.334	0.009**
Indications	28	43.8	36	56.3		
Procedural steps	18	34.0	35	66.0		
Implant design	27	42.9	36	57.1		
Interim restoration protocol	2	6.9	27	93.1		
Anatomical information	23	39.7	35	60.3		

n: sample, %: percentage, X²= Ki square, **:p<0,01

Table 8: Comparison of the targeted audience and source of uploaded according to groups

Table 8: Comparison of the targeted audience and source of uploaded according to groups						
The targeted audience	Group				X2	p
	Low Content Group		Moderate-High Content Group			
	n	%	n	%		
Patients	2	66.7	1	33.3	4.116	0.107
Healthcare professionals	26	54.2	22	45.8		
Both	5	27.8	13	72.2		
The uploaded source	Group				X2	p
	Low Content Group		Moderate-High Content Group			
	n	%	n	%		
Healthcare professionals	8	44.4	10	55.6	1.094	0.579
Commercial entities	25	50	25	50		
Hospitals/universities	0	0	1	100		

n: sample, %: percentage, X²= Fisher's Exact value

Discussion

According to this study results suggested that the YouTube videos related subperiosteal implants were found low depending on the total content score. Furthermore, both DISCERN and GQ scores also observed poor and low, respectively. Thus, YouTube videos related to subperiosteal implants were detected unreliable. Hence, the hypothesis that the information in these

videos related to subperiosteal implants may be inadequate or potentially misleading was accepted.

The literature highlights that the majority of videos in medical and dental fields are produced in the United States by healthcare professionals.^{13,15} However, the demographic analysis in this study shows a significant deviation from this trend, with most videos on subperiosteal implants being uploaded from Asia,

particularly India, and primarily by commercial entities. This shift may explain the observed deficiencies in content, especially in critical areas such as complications, contraindications, oral hygiene, postoperative care, and disadvantages of subperiosteal implants. These findings underscore the need for high-quality, evidence-based videos produced by healthcare professionals and academic institutions to address these gaps and ensure the dissemination of reliable and comprehensive information to both patients and clinicians.

In this study, the target audience of the analyzed videos predominantly consisted of healthcare professionals, with content primarily focusing on the indications, advantages, and procedural steps of subperiosteal implant surgeries. While procedural steps are indeed critical for the successful application of subperiosteal implants, adequate knowledge of postoperative care and effective patient-surgeon collaboration are equally essential for improving treatment success and long-term survival rates. According to the literature, one of the most commonly reported complications associated with subperiosteal implants is total or partial peri-implant mucositis.^{9,20} In severe cases, this condition may require extended follow-up periods or even implant removal. Such complications, if not communicated beforehand, could adversely impact the patient-physician relationship. Furthermore, prior studies suggest that low-quality YouTube content can further harm this relationship by spreading incomplete or misleading information.^{21,22} It is therefore important that the information in the video content is presented in an accurate and unbiased manner so that patients can understand it. Ensuring that both patients and surgeons are well-informed about the potential adverse aspects of treatment before the procedure is crucial. A comprehensive understanding of these risks can improve patient outcomes, enhance trust, and minimize the dissemination of inaccurate or insufficient knowledge.

In this study, the average video duration of the moderate-high content group (MHG) was approximately 6 minutes, significantly longer than the low-content group (LCG), which averaged 3 minutes. However, no statistical differences were observed between the groups in terms of views, comments, likes, viewing rates, or interaction index. According to the literature, as video duration increases, viewer attention tends to decline, with attention typically peaking within the first 10–15 minutes for educational videos before gradually decreasing.^{23,24} The findings of this study suggest that videos shorter than 6 minutes are insufficient to provide comprehensive information on subperiosteal implants. Even within the MHG, critical topics were often inadequately addressed. To enhance the educational value of YouTube videos, it may be beneficial to incorporate missing information into future content, with an optimal duration of approximately 10 minutes for high-quality videos. This approach could balance detailed content delivery with maintaining viewer attention effectively.

Although YouTube can serve as a valuable research tool when approached with appropriate considerations, there remains a lack of standardized methods for evaluating YouTube video content.^{14,25} Recent studies have employed various tools for video assessments, including DISCERN, m-DISCERN, the Video Information Quality Index (VIQI), and the Global Quality (GQ) scale.^{13,14,26} In this study, the DISCERN and GQ scales were chosen as the primary evaluation tools. The preference for these criteria aligns with the study's focus on assessing the reliability and educational effectiveness of health-related videos. DISCERN is specifically designed to evaluate the reliability, accuracy, and impartiality of health information, while the GQ scale emphasizes educational quality, including content clarity and viewer utility.^{14,27} In contrast, tools like VIQI primarily assess visual and overall quality attributes, which were less relevant to the study's objectives.²⁸ As the purpose of this study is to analyze the informational content of videos on subperiosteal implants, DISCERN and GQ, which directly measure content and informational quality, were chosen as the most appropriate tools. In this presented study results GQ and DISCERN scores were strongly and positively correlated with total content scores. Also, GQ and DISCERN scores were statistically higher in MHG than LCG. These results were suggested that both tools could be realizable for video assessments. Nevertheless, different assessment tools could be evaluated in future studies.

The dynamic and evolving nature of YouTube content results in continuous changes in viewer preferences, video viewing patterns, and search algorithms, making it challenging to consistently track video streams and sequences. While Google Trends was employed in this study to identify the most frequently used keywords for subperiosteal implants, it is crucial to recognize that alternative keywords, such as "additively manufactured subperiosteal implants" or "customized subperiosteal implants," may provide access to a broader and more diverse range of videos. This variability underscores the inherent difficulty in conducting a comprehensive and consistent analysis of YouTube content, highlighting the need for adaptive methodologies and keyword strategies in future research.

Conclusions

The content of YouTube videos related to subperiosteal implants has been found to be insufficient for both patients and healthcare professionals. Most of these videos are uploaded by dental companies, which may contribute to gaps in comprehensive and balanced information. To enhance the quality and quantity of video content on subperiosteal implants, university hospitals and healthcare professionals should actively contribute by creating and sharing evidence-based, detailed videos. This would not only improve the educational value of such content but also ensure the dissemination of accurate and reliable information to a broader audience.

Consent for Publication

Approval for publication has been granted.

Availability of Data and Materials

No data and material is available.

Competing Interests

There are no competing interests.

Authors' Contributions

IA: Concept/Design, Data analysis/interpretation, Drafting article, Critical revision of article, Approval of article, Statistics.

AY: Concept/Design, Drafting article, Critical revision of article, Funding, Data collection, Other.

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Biomimetic Implant Surface Functionalization with Concentrated Platelet-Rich Fibrin: An Invitro Study

Aparna Ayyalasomayajula ^{1,a}, Muthukumar Santhanakrishnan ^{1,b,*}, Sri Vidhya Marimuthu ^{2,c}, Ravindranath Dhulipalla ^{3,d}, Ramanarayana Boyapati ^{3,e}

¹Department of Periodontology and Oral Implantology, Sri Ramachandra Dental College and Hospital, Chennai

²Department of Periodontology and Oral Implantology, Sri Venkateshwara Dental College, Puducherry

³Department of Periodontology and Oral Implantology, Sibar Institute of Dental Sciences, Guntur

*Corresponding author

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ABSTRACT

Objective: With high long-term survival and success rates, implant-supported oral rehabilitation has progressively expanded the treatment options available to edentulous patients. However, osseointegration may be impacted by certain medical conditions. In order to enhance osseointegration and encourage fibrin adherence, surfaces with particular micro- and nanotopographies and biomimetic properties have been developed. Recently, there has been interest in a potential strategy that involves using the patient's autologous blood to functionalise the implant surface just prior to placement. The objective of this in vitro study is to analyse the physiochemical characterization of three commercially available dental implant surfaces and evaluate the interaction between the implant surface and C-PRF

Materials and Methods: Three commercially available implants with different macro-morphology and surface treatments - Straumann® BLX Roxolid®, Zimmer® Trabecular Metal™, and Laser-Lok® were analysed for physiochemical characterization and biofunctionalization using C-PRF. Field emission scanning electron microscope (FESEM)

Results: All the surfaces appeared visibly rough to varying degrees under FESEM with EDS. The topographies were qualitatively different for all three implant systems- Straumann® BLX Roxolid®, Zimmer® Trabecular Metal™, and Laser-Lok® that were analysed, and showed different elemental compositions. Every dental implant immersed in C-PRF had a fibrin mesh covering it. Nonetheless, distinct noncontact regions were noted, and the fibrin orientation varied across all implant surfaces.

Conclusions: There are notable differences in the initial interaction between the fibrin network and various implant surfaces. The therapeutic significance of these findings in the osseointegration process of dental implants requires further investigation.

Keywords: Dental Implants, Platelet concentrates, Biomimetic functionalization, Osseointegration, Concentrated Platelet Rich Fibrin(C-PRF)

^a aparnasrinivas10@gmail.com
^c drsividhyavidhu@gmail.com
^e dr.ramanarayana@gmail.com

^{id} 0000-0002-3483-114X
^{id} 0009-0001-5071-8358
^{id} 0000-0002-9196-0183

^b muthukumars@sriramachandra.edu.in ^{id} 0000-0001-9688-1516
^d ravident69@gmail.com ^{id} 0000-0003-4103-455X

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Introduction

Implant-supported oral rehabilitation has improved treatment options for edentulous patients with high long-term survival and prosperity rates. The success rate of dental implants can be impacted by several clinical conditions that can impede the osseointegration process. Patient cognate factors such as physiological and pathological changes occurring in conditions like ageing, low bone density, smoking, diabetes mellitus, osteoporosis, bisphosphonate and radiotherapy jeopardize bone health thereby affecting the quality and quantity of bone available for receiving dental implants, as a result, implant failures can develop early in the peri-implant bone healing process in these patients.^{1,2} The formation of a stable fibrin clot in contact with the implant surface, which accommodates a provisional scaffold for the migration of developing

osteogenic cells towards the implant surface, is a critical phase of the healing process.³ Consequently, materials with biomimetic properties and categorical micro and nano topographies have been created to enhance osseointegration and encourage fibrin adhesion.

Various approaches have been used to improve and help accelerate the osseointegration process without compromising tissue integration or mechanical outcomes.^{4,5} The implant topography plays a critical role during the early stages of bone-to-implant contact (BIC). The physiochemical properties of implants, including as surface topography, surface wettability, and energy, have been thoroughly investigated and altered to improve osseointegration.⁶⁻⁸ The initial interactions, immediately after implant surgery, take place between the host cells and the implant surface atoms through the adsorbed proteins and not the material bulk itself. Thus, modifying

the surface properties of dental implants to influence the events occurring at the implant-tissue interface has been the focus of profound research over the last decades. As a result, there are a variety of implant systems that have different implant surfaces currently available for the dental market. Altering the surface topography is one of the most commonly used surface modification techniques for dental implants. Currently, the SLActive surface, laser machined surface (LMS) and nanotextured surface topography with trabecular pattern have gained interest.

The SLA surface is created by using coarse grit of 0.25–0.5 mm corundum grit at a pressure of 5 bar and then acid-etching. SLActive surface is also produced via the same sandblasting and acid etching technique, and undergoes a nitrogen-protected rinse to prevent air exposure before being stored within a sealed glass tube filled with isotonic NaCl solution.⁹ Laser-Lok microchannels, a series of cell-sized circumferential channels generated via laser ablation, create consistently sized microchannels optimal for osteoblast and fibroblast attachment and organization, further enhanced by a repeating nanostructure increases surface area and facilitate the interdigitation of cell pseudopodia and collagen microfibrils with the Laser-Lok surface.¹⁰ The Laser-Lok surface has been characterized by a physiological response that involves inhibiting epithelial down-growth and connective tissue attachment.¹¹ Trabecular metal material is a three-dimensional, highly biocompatible material with up to 80 per cent porosity and a structure and function comparable to cancellous bone. Made from tantalum, the trabecular metal material is fabricated utilizing a proprietary vapour deposition process.¹²

In addition to methods that involve surface topography changes, other biomimetic strategies have been investigated that use materials like bone morphogenetic proteins (BMPs), hydroxyapatite (HA), calcium phosphate, and growth factors to promote osteoinduction, osteoconduction, and osteogenesis. These strategies can be used to functionalise implant surfaces and encourage osseointegration, particularly in medically compromised individuals.¹³ Recently, there has been growing interest in an alternative approach that uses the patient's autologous blood to functionalise the implant surface right before implantation.

One common way to obtain bioactive compounds from a patient's blood is through autologous blood concentrates.¹⁴ High platelet and growth factor concentrations added to surgical sites can promote both soft and hard tissue healing and make it easier to attain favourable and consistent treatment results.¹⁵ The L-PRF methodology was recently used to create the Concentrated PRF (C-PRF), which concentrates on removing just liquid material from the tiny buffy coat. It is believed that C-PRF produces extremely high levels of platelets and leukocytes.^{16,17} Two proteins, fibronectin and vitronectin, have a significant role in platelet function and later cell adhesion to the extracellular matrix during the healing process.^{18,19} Furthermore, platelet concentrates can produce growth factors (GF) that

support angiogenesis, cell migration, and differentiation, such as vascular endothelial growth factor (VEGF), transforming growth factor 1 (TGF1), and platelet-derived growth factor-AB (PDGF-AB).^{20,21} Platelet concentrations may therefore be a useful means of achieving a biomimetic autologous functionalisation of implant surfaces, which would encourage osseointegration.²²

Therefore, PRF biofunctionalization of implant surfaces may play a crucial part in encouraging and quickening osseointegration. Although platelet concentrates are frequently used in bone regeneration processes, little is known about how they affect implant osseointegration. Images at higher magnification can be seen with a Field emission scanning electron microscope (FESEM).²³

The aim of this in vitro study was to examine the physiochemical characteristics of three commercially available dental implant surfaces and evaluate their interaction with C-PRF using FESEM analysis.

Material and Methods

Ethical Considerations

Informed consent was obtained according to guidelines on human research adopted by the Institutional Ethics Committee, Sri Ramachandra Institute of Higher Education and Research, Chennai which approved the performance of this study after fulfilling the requirements of the committee with code CSP/21/NOV/102/588.

Exclusion Criteria:

- Patients with systemic diseases
- Smokers
- Patients consuming alcohol
- Pregnant and lactating women
- Patients with blood dyscrasias
- Patients who have consumed antibiotics within the last three months.

Methods of Research:

Three commercially available implants with different macro-morphology and surface treatments - Straumann® BLX Roxolid®, Zimmer® Trabecular Metal™, Laser-Lok® were analysed for physiochemical characterization and biofunctionalization using C-PRF.

Phase 1: Physiochemical Characterization

The micro and nano topography and the Chemical composition of the Straumann® BLX Roxolid®, Zimmer® Trabecular Metal™, Laser-Lok® implants were quantitatively analysed using the Field emission scanning electron microscope (FESEM) with energy dispersive X-ray spectrometer (EDS), (Thermo Scientific™ Quattro ESEM, USA) (Figure 1). Next, the water and solvent contact angles of the three commercially available implants were determined using a contact angle meter (sessile drop technique) KYOWA DMs 40 (Figure 2), half-angle method fitting, and FAMAS add-in software. The solvent droplet

range on the implant surface was 0.5–2 mL.²⁴ By measuring the contact angle of three probe liquids—water, ethylene glycol, and hexadecane—the Kitazaki Hata theory was used to determine the samples' solid surface free energy.²⁵

Phase II: Preparation of Liquid Platelet Concentrate (C-Prf):

A healthy donor's venous blood was drawn from the antecubital fossa by a phlebotomist using 9 ml noncoated vacutainer tubes devoid of anticoagulants. The obtained samples were centrifuged for three minutes at about 700 RCF. After centrifuging the collected samples at 700 RCF for 3 minutes, C-PRF was aspirated with a sterile syringe and transferred immediately to Eppendorf tubes (Figure 3).

Dental Implant Processing

The surfaces of three commercially available dental implants (Straumann® BLX Roxolid®, Zimmer® Trabecular Metal™, Laser-Lok®) are obtained through specific manufacturing techniques were analysed. At room temperature, the implants were completely submerged in concentrated platelet-rich fibrin for 60 minutes. After 60 minutes, the implants were gently removed from C-PRF, preserving the fibrin clot that was adhered to them. Immediately, 2% glutaraldehyde in 0.1 M sodium cacodylate buffer (pH 7.4) was used to fix the samples.⁸ Using a critical point dryer and sputter coater, the specimens were prepared before being analysed with a Field Emission Scanning Electron Microscope (FESEM) (Figure-4).



Figure 1. Quantitative analysis of surface topography using the FESEM with EDS

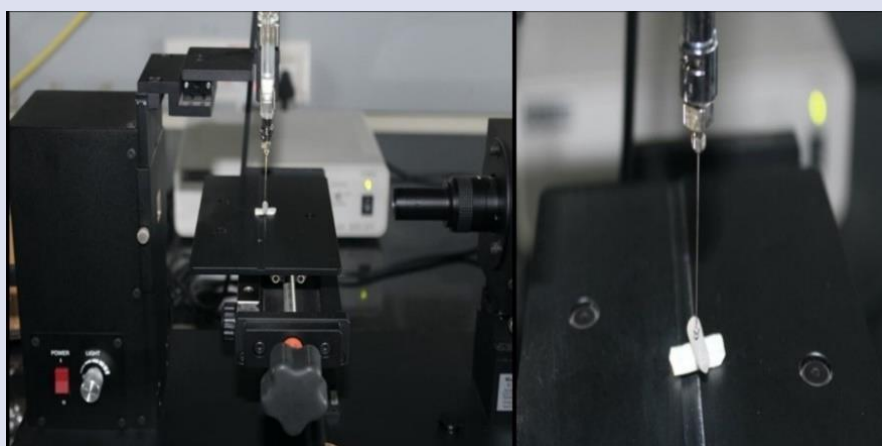


Figure 2. Surface wettability measurement using contact angle meter (sessile drop technique) KYOWA DMs-40, using half-angle method fitting and by FAMAS add-in software

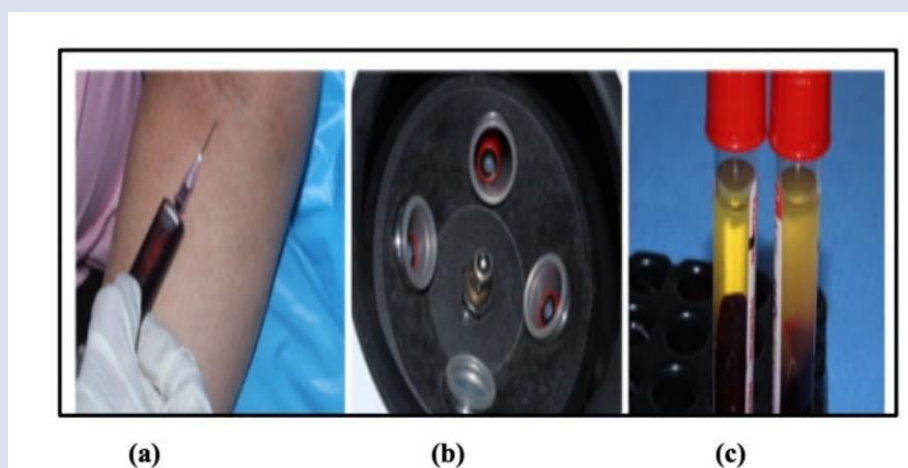


Figure 3. a – Blood collected by phlebotomist; b- Centrifugation at 700 RCF for 3 minutes; c- Concentrated platelet rich fibrin.

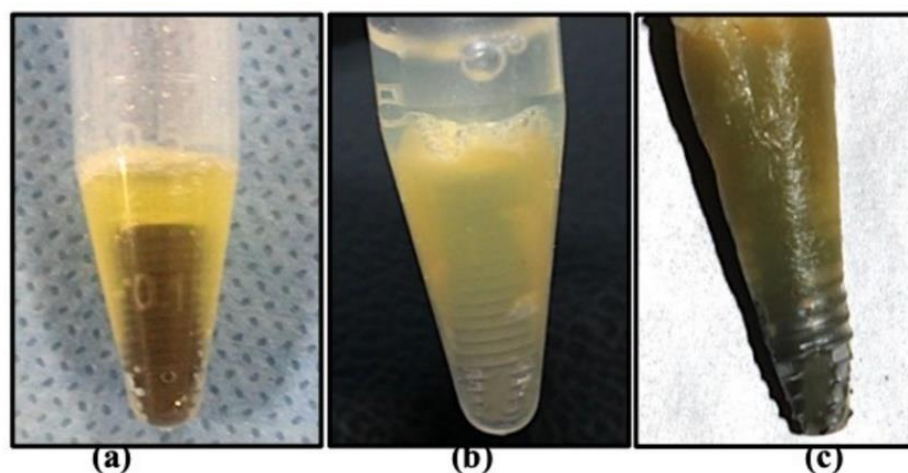


Figure 4. a – Implant immersed in C-PRF; b- Sample fixed immediately in 2% glutaraldehyde in 0.1 M sodium cacodylate buffer; c- Prepared specimen using a critical point dryer and sputter coater for an analysis with FESEM

Results

Physiochemical Characterization

Surface topography was visualized using a field emission scanning electron microscopy and the differences in the implant collar and body topography were assessed at varying magnifications- 1mm, 100µm, 50 µm, 30 µm, 10 µm and 5 µm respectively. All the surfaces appeared visibly rough to varying degrees under FESEM. The topographies were qualitatively different for all three implant systems- Straumann® BLX Roxolid®(Figure-5), Zimmer® Trabecular Metal™(Figure-6), and Laser-Lok®(Figure-7) that were analysed. The Straumann® BLX Roxolid®(fig-5), implant surface displayed irregularities, with many depressions and small indentations with numerous pores, as a result of the grit blasting and acid treatment procedure. The Zimmer® Trabecular

Metal™(Figure-6) surface exhibits a faceted, granular morphology related to the CVD whereas the machined Laser-Lok®(Figure-7) surface showed a more uniform microtextured topography. The elemental chemical spectra obtained from FESEM EDS analysis of the implant surfaces at the collar and body region are shown in Figure 8, Table 1. The Zimmer® Trabecular Metal™ surface showed peaks associated with tantalum(Ta) and titanium (Ti), along with trace amounts of aluminum (Al), calcium (Ca), sodium (Na), carbon (C), and oxygen (O), whereas the Straumann® BLX Roxolid® showed peaks associated with titanium (Ti), and traces of sodium (Na), carbon (C), aluminium (Al) and zirconium (Zr). The Laser-Lok® surface showed peaks associated with titanium (Ti), along with aluminium (Al) and traces of calcium (Ca), carbon (C), iron (Fe) and nickel(Ni). Table 1 summarizes the element content of the implant surfaces.

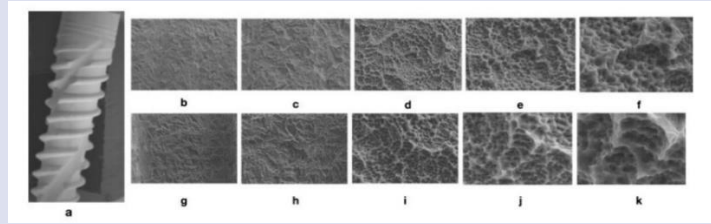


Figure 5. FESEM image of Straumann® BLX Roxolid®, a- BLX Roxolid® 1 mm magnification, b- implant collar: 100 μm , c- implant collar:50 μm , d- implant collar:30 μm , e- implant collar:10 μm , f- implant collar: 5 μm , g- implant body: 100 μm , h- implant body:50 μm , i- implant body:30 μm , j- implant body: 10 μm , k- implant body: 5 μm

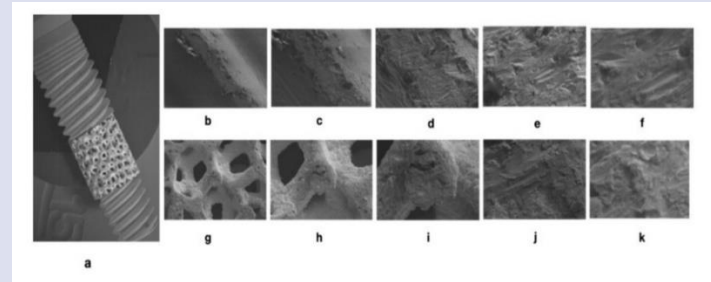


Figure 6. FESEM image of Zimmer® Trabecular Metal™, a- Trabecular Metal™ 1mm magnification, b- implant collar: 100 μm , c- implant collar:50 μm , d- implant collar:30 μm , e- implant collar:10 μm , f- implant collar: 5 μm , g- implant body: 100 μm , h- implant body:50 μm , i- implant body:30 μm , j- implant body: 10 μm , k- implant body: 5 μm

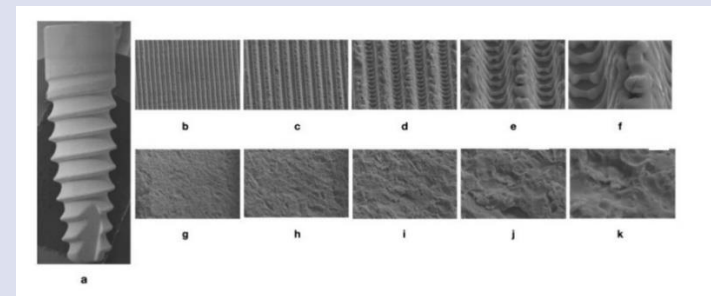


Figure 7. a – Implant immersed in C-PRF; b- Sample fixed immediately in 2% glutaraldehyde in 0.1 M sodium cacodylate buffer; c- Prepared specimen using a critical point dryer and sputter coater for an analysis with a FESEM

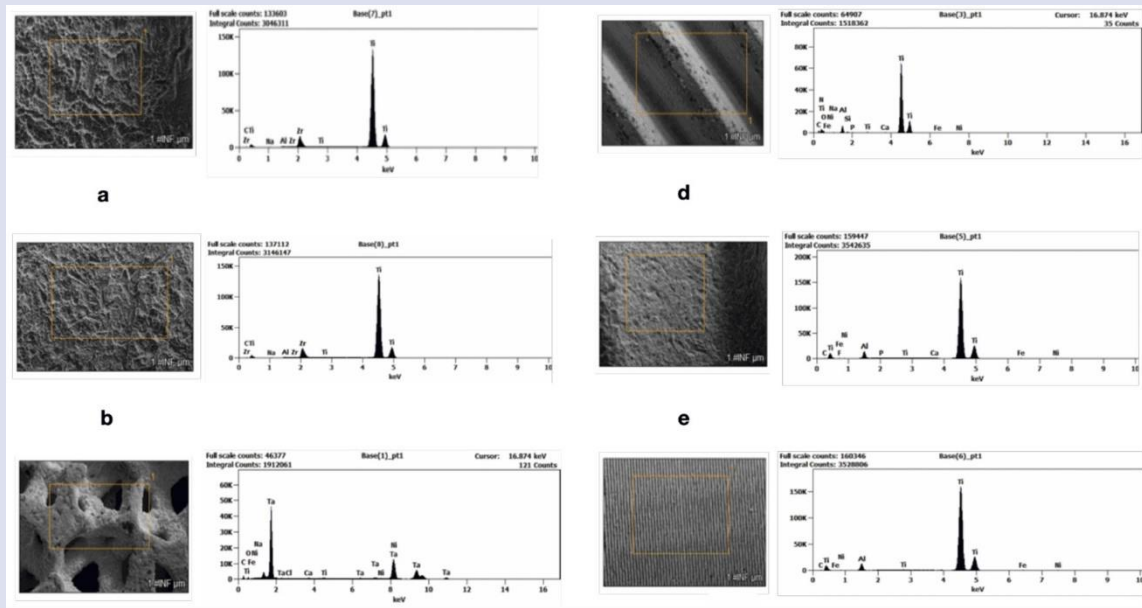


Figure 8. FESEM images with EDS:- a: FESEM with EDS image of Straumann® BLX Roxolid®(body), b: FESEM with EDS image of Straumann® BLX Roxolid®(collar), c: FESEM with EDS image of Zimmer® Trabecular Metal™ (body), d: FESEM with EDS image of Zimmer® Trabecular Metal™ (collar), e: FESEM with EDS image of Laser-Lok® (body), f: FESEM with EDS image of Laser-Lok®(collar)

Table 1. Element composition of Straumann® BLX Roxolid®, Zimmer® Trabecular Metal™ and Laser-Lok® implant surfaces (EDS)

Straumann® BLX Roxolid®

Weight %- collar

	C	Na	Al	Ti	Zr
Base (7)_pt1	0.44	0.10	0.13	88.25	11.09

Weight % - body

	C	Na	Al	Ti	Zr
Base (8)_pt1	0.44	0.05	0.09	88.21	11.20

Zimmer® Trabecular Metal™

Weight % - collar

	C	N	O	Na	Al	Si	P	Ca	Ti	Fe	Ni
Base (3)_pt	3.6	5.0	14.2	0.1	4.0	0.2	0.1	0.0	72.0	0.3	0.1
1	3	5	1	7	8	0	0	9	0	1	5

Weight % - body

	C	O	Na	Cl	Ca	Ti	Fe	Ni	Ta
Base(1)_pt1	4.97	3.27	0.14	0.22	0.13	0.22	0.31	0.71	90.04

Laser-Lok®

Weight % - collar

	C	Al	Ca	Ti	Fe	Ni
Base(5)_pt1	0.52	5.40	0.07	93.50	0.25	0.11

Weight % - body

	C	Al	Ti	Fe	Ni
Base(6)_pt1	0.58	4.91	94.09	0.31	0.12

Surface Energy and Surface Wettability

Table 2 shows the results of the contact angle measurements. The Straumann® BLX Roxolid®, Zimmer® Trabecular Metal™, and Laser-Lok® implant surfaces displayed

varying results, with the contact angles ranging from 0.2° to 130.5°. The Straumann® BLX Roxolid® (Figure 9) surface exhibited consummate wetting, composing a layer of dihydrogen monoxide across the surface, with a contact angle

approaching virtually zero (mean value of 0.50) indicative of a profoundly hydrophilic surface. The mean contact angle quantification value of Laser-Lok® (Figure 10) was 21.6, whereas the mean contact angle measurement of Zimmer® Trabecular Metal™ (Figure 11) was 130.0 suggestive of a highly hydrophobic surface. The surface free energy of all the implant

surfaces is summarised in Table 3. Utilising the Kitazaki Hata theory, the surface energy of the Straumann® BLX Roxolid®, Zimmer® Trabecular Metal™, and Laser-Lok® implant surfaces was determined to be 27.6, 27.5, and 12.7, respectively, by measuring the contact angle of three probe liquids: water, ethylene glycol, and hexadecane.

Table 2. Contact angle using sessile drop technique

Implant	C.A.(deg) collar	C.A.(deg) body	C.A(deg)AVG
Roxolid solid	0.2	0.6	0.5
laser Lok	30.7	12.5	21.6
trab	129.5	130.5	130.0

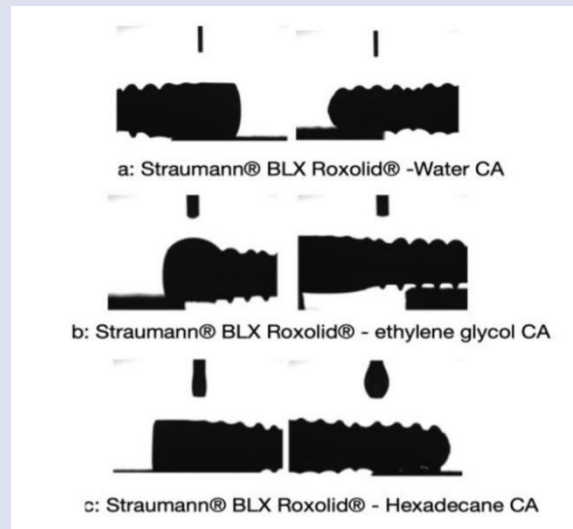


Figure 9. Contact angle meter images of Straumann® BLX Roxolid®

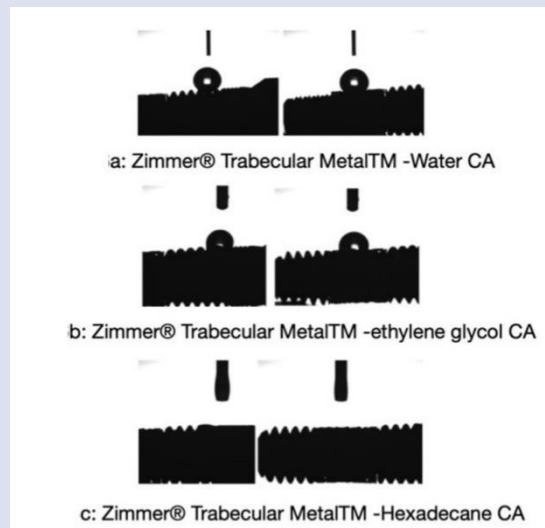


Figure 10. Contact angle meter images of Zimmer® Trabecular Metal™

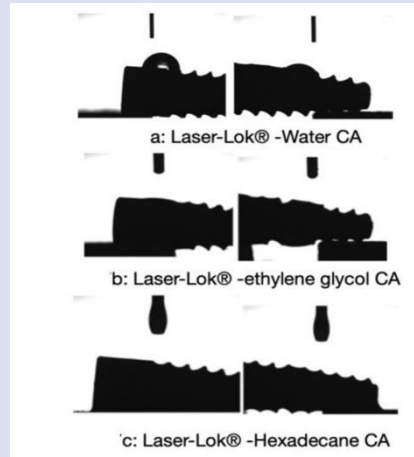


Figure 11. Contact angle meter images of Laser-Lok®

Table 3. Surface free energy- Kitazaki-Hata method

S.NO	Implant	Probe liquid	C.A.(deg.)Avg.	Probe liquid	C.A.(deg.)Avg.	Probe liquid	C.A.(deg.)Avg.	d (Kitazaki-Hata)
1	Roxolid solid	water	0.5	ethylene glycol	0.6	n- hexadecane	0.8	27.6
2	Laserlok	water	21.6	ethylene glycol	0.2	n- hexadecane	0.1	27.5
3	Trab	water	130.0	ethylene glycol	106.0	n- hexadecane	0.5	12.7

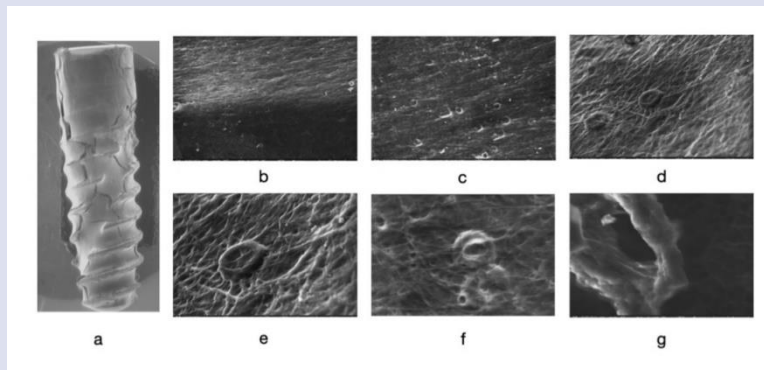


Figure 12. FESEM images of C-PRF coated Straumann® BLX Roxolid® implant; a- BLX Roxolid® 1mm magnification, b- 100 µm magnification, c- 50 µm magnification, d-30 µm magnification, e-:10 µm magnification, f- 5 µm magnification, g- 3 µm magnification

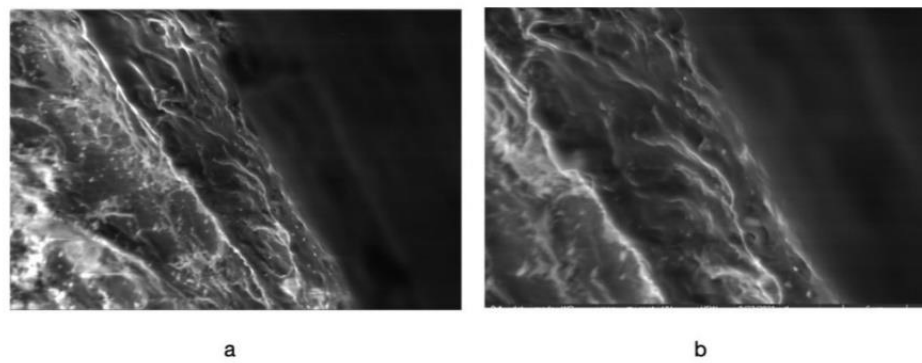


Figure 13. Cross- section of C-PRF coated Straumann® BLX Roxolid® implant

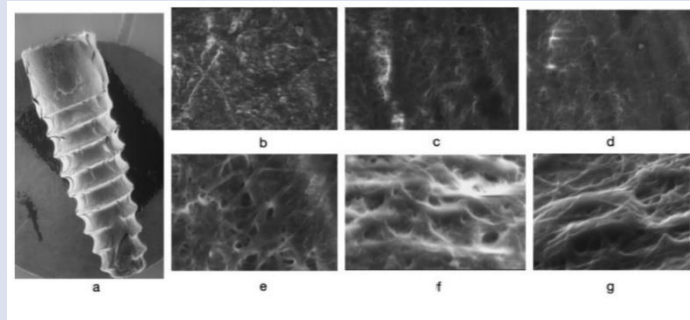


Figure 14. FESEM images of C-PRF coated Laser-Lok® implant; a- Laser-Lok® 1mm magnification, b- 100 μ m magnification, c-50 μ m magnification, d- 30 μ m magnification, e- 10 μ m magnification, f- 5 μ m magnification, g- 3 μ m magnification

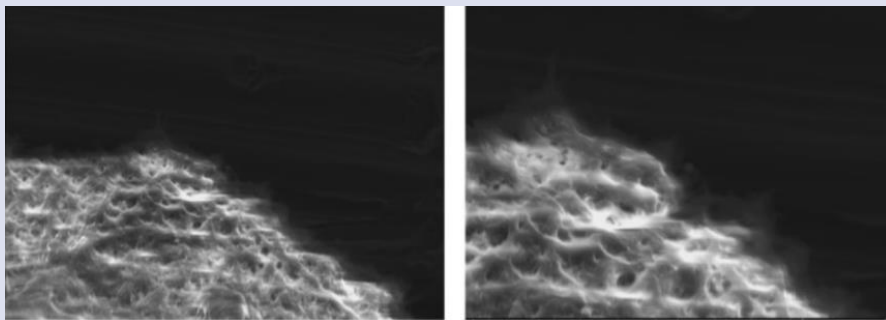


Figure 15. Cross- section of C-PRF coated Laser-Lok® implant

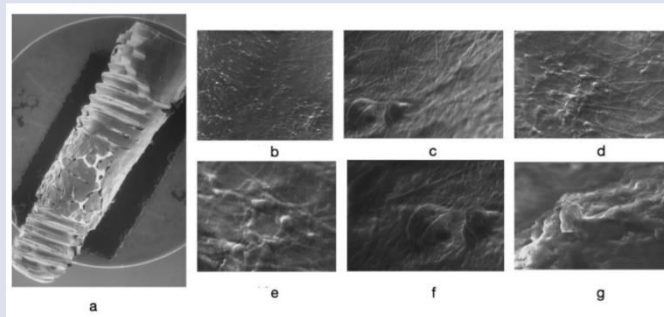


Figure 16. FESEM images of C-PRF coated Zimmer® Trabecular Metal™ implant, a- Trabecular Metal™ 1mm magnification, b- 100 μ m magnification, c- 50 μ m magnification, d- 30 μ m magnification, e- 10 μ m magnification, f- 5 μ m magnification, g- 3 μ m magnification

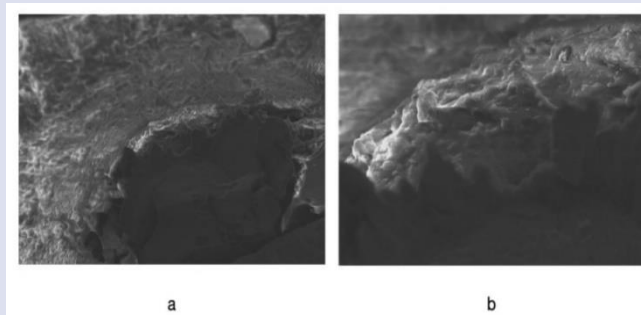


Figure 17. Cross-section of C- PRF coated Zimmer® Trabecular Metal™ implant

Biomimetic Functionalization with C-Prf Macroscopic Observation

Macroscopic visual examinations revealed the production of bubbles after submerging the implants in C-PRF and these bubbles were cognate with areas without fibrin covering after 60 minutes in the case of Straumann® BLX Roxolid®, Zimmer® Trabecular Metal™ and Laser-Lok® surfaces.

FESEM Image Interpretation

At both low and high magnification, significant differences were seen in all of the implant surfaces coated with C-PRF. In contrast to the Straumann® BLX Roxolid® and Laser-Lok® surfaces, which had a uniform and thick layer of fibrin covering the entire implant surface, the Zimmer® Trabecular Metal™ implant surface displayed crucial zones devoid of fibrin coverage (Figure 16a) (Figure 12a, 14a).

Furthermore, compared to the Straumann® BLX Roxolid® and Laser-Lok® surfaces, which had thicker and denser fibrin fibres running towards the implant surface, the Zimmer® Trabecular Metal™ implant surface showed a thinner fibrin layer with fewer fibrin fibres running towards the implant surface. Additionally, compared to the Zimmer® Trabecular Metal™ and Laser-Lok® surfaces, the Straumann® BLX Roxolid® surface showed a greater number of blood cells caught within the fibrin mesh (Figure 12).

On the Straumann® BLX Roxolid® surface, the fibrin fibres were orientated more perpendicularly to the implant surface (Figure 15, 17) than on the Laser-Lok® and Zimmer® Trabecular Metal™ surfaces, where they ran primarily parallel to the implant surface (Figure 13). With bigger diameter fibres, it was also seen that the Laser-Lok® and Straumann® BLX Roxolid® surfaces had a higher density and quantity of fibres being inserted and attached to the implant surface.

Discussion

In certain conditions, such as poorly controlled diabetes, low bone density, tobacco use, bisphosphonate medication, and radiation therapy, osseointegration is considerably less predictable, even though implant-supported oral rehabilitation has significantly improved treatment strategies for edentulous patients and demonstrated high long-term survival and success rates. Even with methods like aseptic surgical settings, optimised surgical implant procedures, and expedited postoperative care, a significant portion of implant failures happen in the early stages of peri-implant bone healing because of the patients' poor integration with nearby bone tissue.²⁶

The formation of a stable fibrin clot in contact with the implant surface is an essential step in osseointegration because it provides a temporary scaffold for the migration of developing osteogenic cells to the implant surface. If osseointegration is not hastened, implants are susceptible to encapsulation by fibrotic tissue, a condition known as the foreign body reaction.²⁷ The presence of fibrotic tissue

at the bone-implant contact often hinders implant attachment and performance. Materials with particular micro- and nano-topographies and biomimetic properties have been developed to promote fibrin adhesion and enhance osseointegration. Even though dental implants with surface microtopography have become the standard of care, only a small number of commercially available dental implants have micro-nano-textured surfaces, and biomimetic implant functionalisation techniques are not yet available for clinical usage.²⁸

Using platelet concentrates is one of the more feasible and reliable ways to accomplish a biomimetic autologous functionalisation of implant surfaces to enhance osseointegration. There is currently a lack of research on the data supporting the usage of platelet concentrates in connection with implant osseointegration. Only two studies assessing the function of leukocyte- and platelet-rich fibrin (L-PRF) products for biomimetic implant surface functionalisation have been published in the literature thus far.^{8,28} The goal of the current study was to assess the effects and interactions of applying concentrated platelet-rich fibrin (C-PRF) to several commercially available implant surfaces.

The present investigation used three commercially available implant surfaces: Laser-Lok®, Zimmer® Trabecular Metal™, and Straumann® BLX Roxolid®. The SLActive® surface of the Straumann® BLX Roxolid® is made using the same initial manufacturing process as SLA. This process includes sandblasting with large grit, acid etching to create the ideal topography for bone cells to adhere to, conditioning in nitrogen, and instant preservation in an isotonic saline solution. In contrast to other traditional titanium implants that are hydrophobic, this preserves its high surface energy, which would otherwise be lost as a result of reaction with the atmosphere, and the cell behaviour on its hydrophilic surface encourages blood coagulation and higher expressions of bone-specific differentiation factors.^{29,30}

However, Laser-Lok® uses laser ablation technology to create uniform microchannels, unlike grit-blasted and/or acid-etched implants that yield uneven surfaces. There has already been evidence of a physiological reaction to the Laser-Lok surface, including connective tissue attachment and prevention of epithelial downgrowth. Only the Laser-Lok surface has demonstrated successful soft tissue attachment in addition to osseointegration, despite random surfaces exhibiting greater osseointegration than machined surfaces.¹¹

The Zimmer® Trabecular Metal™ is a porous material with a structure similar to cancellous bone. It is made of porous tantalum with a textured surface that promotes osseointegration and improves initial stability by serving as an osteoconductive scaffold and assisting in vascularization and bone remodelling.³¹ Therefore, the surfaces listed above were chosen because they are regarded as the gold standard and have a proven track record of promoting osseointegration.

The field emission scanning electron microscope (FESEM) with energy dispersive X-ray spectrometer (EDS)

(Thermo Scientific™ Quattro ESEM, USA) was used to quantitatively analyse the micro and nano topography and chemical composition of the Straumann® BLX Roxolid®, Zimmer® Trabecular MetalTM, and Laser-Lok® implants. Then, using a contact angle meter and the sessile drop technique, the water and solvent contact angles were determined to determine the surface wettability of the three commercially available implants.²⁴ The current study utilised the sessile drop approach for surface wettability measurement due to its speed and relative simplicity. Furthermore, heterogeneity can be ascertained by depositing many droplets in different positions on the sample; the reproducibility of certain contact angle values will also represent the heterogeneity of the energy characteristics of the surface. The Kitazaki-Hata hypothesis was then used to determine surface-free energy.²⁵ In contrast to Zimmer® Trabecular MetalTM, which was hydrophobic with lower wettability and surface energy, Straumann® BLX Roxolid® and Laser-Lok® surfaces were found to have higher surface wettability and energy, indicating a more hydrophilic nature.

Given the significance of fibrin clot formation during the osseointegration process to support cell migration and differentiation, platelet concentrates may offer all the components required to support these processes, including leukocytes, growth factors, fibrin mesh, platelets, and critical proteins like vitronectin and fibronectin.¹⁸ Immediate or early implant loading may be possible with a shorter implant osseointegration period. Peri-implant bone repair may be aided by the local administration of growth factors and proteins via C-PRF preparations for biomimetic functionalisation of the implant surface. A higher concentration of platelets and leukocytes is produced by concentrated platelet-rich fibrin (C-PRF) for use in liquid injection. It is believed to generate significantly greater amounts of several growth factors, including PDGF, TGF-β1, VEGF, EGF, and IGF, in comparison to other types of PRF, which in turn promotes angiogenesis, cell migration, and differentiation. Therefore, C-PRF in conjunction with a nanotextured surface may have an osteopromotive effect during peri-implant bone healing in order to accomplish an autologous biomimetic functionalisation of implant surfaces and enhance the osseointegration process. This is especially true for patients with altered bone metabolism and less predictable osseointegration, such as those receiving bisphosphonate therapy, radiation therapy, smoking, or immediate implant placement.¹⁷

As a result, the relationship between C-PRF and various dental implant surfaces was assessed. To avoid potential bias from differences in blood components, the specimens for this study were taken from a single healthy person, and the platelet index was measured at baseline. For three minutes, the gathered samples were centrifuged at about 700 RCF.¹⁶ A sterile syringe was then used to aspirate C-PRF, which was then promptly transferred to Eppendorf tubes. For 60 minutes at room temperature, implants made of Straumann® BLX Roxolid®, Zimmer® Trabecular MetalTM, and Laser-Lok® were fully

submerged in C-PRF. After that, the implants were carefully taken out, repaired, and examined with a FESEM.⁸ In the current study, FESEM was utilised because of its high-resolution capability, which may enable evaluation of organisation from the macromolecular level upwards, and because the low electron beam energies used for imaging lessen the possibility of beam-induced specimen damage, improving the preservation of delicate structures.

One important factor influencing the outcomes was the micro/nano topography of the implant surfaces. Higher surface energy on surfaces with more nanoscale structure enhances blood wettability and, consequently, the diffusion and attachment of fibrin and matrix proteins. By encouraging cell division and proliferation, nanopatterning may alter the behaviour of cells. The surfaces of Laser-Lok® and Straumann® BLX Roxolid® displayed a consistent and thick layer of fibrin. This is explained by the implant surfaces' hydrophilic properties. On the other hand, the Zimmer® Trabecular MetalTM implant surface had sizable areas devoid of fibrin covering, which may have been caused by the hydrophobic surface. The fibrin mesh on the Straumann® BLX Roxolid® and Laser-Lok® surfaces was thicker and denser than that on the Zimmer® Trabecular MetalTM implant surface, which showed a thinner fibrin layer with fewer fibrin fibres. Additionally, in comparison to the Zimmer® Trabecular MetalTM and Laser-Lok® surfaces, the Straumann® BLX Roxolid® surface displayed a greater number of cells trapped within the fibrin mesh.

In order to understand the orientation and interaction of fibrin fibres at the level of surface modification, cross sections of the Straumann® BLX Roxolid® and Zimmer® Trabecular MetalTM implants were taken at the level of the implant body, while cross sections of the Laser-Lok® implant were taken at the collar region. In contrast to the Laser-Lok® and Zimmer® Trabecular MetalTM surfaces, where the fibre orientation was more perpendicular to the surface, the Straumann® BLX Roxolid® surface had fibres orientated parallel to the implant surface. The perpendicular orientation of the fibres may be due to the elemental tantalum surface of Zimmer® Trabecular MetalTM, which is chemically stable and biologically inert, as well as the nanotextured surface with enhanced and uniform pore size. Regarding the Laser-Lok®, the perpendicular orientation of fibrin fibres might have been the consequence of the microchannels that increased the surface area.

Since this is the first study that compares the interactions of the implant surfaces of Straumann® BLX Roxolid®, Zimmer® Trabecular MetalTM, and Laser Lok® with C-PRF, these results cannot be compared with those of other studies. However, Catherine X. Andrade et al. 8 assessed the interaction between liquid fibrinogen and five distinct dental implant surfaces (OsseospeedTM, TiUniteTM, SLActive®, Osseon®, and Plenum®) in an in vitro investigation. All implant surfaces developed a stable fibrin mesh when exposed to liquid fibrinogen, which was consistent with the current study's findings despite a

variety of macroscopic and microscopic variations in the uniformity, thickness, number, and orientation of the fibrin fibres.⁸

The present study's results demonstrated how various implant surface characteristics, including topography, wettability, and coatings, can alter the way the implant surface interacts with the fibrin mesh. Accordingly, some implant surfaces may be more suitable for biomimetic functionalisation using platelet concentrates.

The observational nature of the data and the small number of implant surfaces examined are limitations of the current study, despite the fact that it assessed implants with unique nano surfaces, such as SLActive surface, laser microtextured surface (LMS), and trabecular implants, which demonstrated promising clinical outcomes in fostering osseointegration and soft tissue attachment. Additional research is necessary to assess how biomimetic functionalisation with C-PRF promotes osseointegration and the therapeutic consequences of these findings on the longevity and success of dental implants.

Conclusions

Within the limitations of the present study, the following conclusions can be drawn, the Zimmer® Trabecular Metal™, Laser-Lok® implant surfaces exhibited perpendicular orientation of fibrin fibres, though there were no cells present. On the other hand, the Straumann® BLX Roxolid® surface featured an increased number of cells with a parallel fibrin orientation which is an important finding that could be detrimental for osseointegration in clinical scenarios. In the future, a new hybrid surface should be developed with laser lok microchannel at the collar region for enhanced tissue adaptation and an effective biologic seal, nano-textured porous body structure similar to the cancellous bone that supports bone integration, remodelling, and vascularization and with an SLActive surface to improve hydrophilicity and cellular infiltration to facilitate optimal osseointegration and improve long-term treatment outcomes.

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Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Parents' Awareness of the Effects of Iron Supplementation on Tooth Staining and Dental Caries in Pediatric Populations

Turkan Mahyaddinova^{1,a,*}, Emine Gülşen^{1,b}, Fatma Nur Kızılay^{2,c}

¹Specialist Pediatric Dentist, Alanya Oral and Dental Health Center, Alanya, Türkiye.

²Assistant Professor Doctor, Department of Pedodontics, Faculty of Dentistry, Inönü University, Malatya/Türkiye.

*Corresponding author

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ABSTRACT

Objectives: This study aimed to evaluate parents' knowledge and attitudes regarding the effects of iron supplementation on tooth staining and dental caries in children and to examine the influence of demographic factors on knowledge and behaviors.

Materials and Methods: This cross-sectional study was conducted in 2024 with a randomly selected group of 281 parents who visited the Department of Pediatric Dentistry at İnönü University Faculty of Dentistry. Data were collected using a structured 12-question survey consisting of three sections: demographic information, knowledge, and attitudes regarding iron supplementation. Responses were scored as 1 for correct answers and 0 for incorrect answers, with knowledge levels categorized as follows: >66.7% (adequate), 33.7–66.7% (moderate), and <33.7% (inadequate). Statistical analyses were performed using the Chi-square and Fisher's Exact tests, with a significance level set at $p < 0.05$.

Results: Among the 140 parents who participated in the study, 49.8% reported using iron supplements for their children; however, only 50.4% adhered to a regular usage schedule. While 47.7% correctly identified the appropriate time to start supplementation, only 16% accurately stated that iron does not cause dental caries, and 35% associated iron supplementation with tooth staining. Although 60.9% of parents had a moderate level of knowledge, adherence to recommended practices was low, with only 16.3% demonstrating high adherence. Significant differences were observed between genders, with mothers displaying higher knowledge levels and adherence than fathers ($p < 0.01$). Additionally, parental education level had a positive effect on knowledge and behavior.

Conclusions: This study revealed that parents' misconceptions and lack of knowledge regarding iron supplementation and oral health affect supplement use. Comprehensive educational programs are needed to address these misconceptions and promote proper supplementation practices among parents.

Keywords: iron supplementation, tooth staining, dental caries, parental awareness, pediatric oral health

Ebeveynlerin Çocuklarda Demir Takviyesinin Diş Lekelenmesi ve Çürük Üzerindeki Etkilerine Yönelik Farkındalığı

Araştırma Makalesi

Süreç

Geliş: 08/01/2025

Kabul: 07/04/2025

ÖZET

Amaç: Bu çalışmada, ebeveynlerin çocuklarda demir takviyesinin diş lekelenmesi ve çürük üzerindeki etkilerine ilişkin bilgi ve tutumlarının değerlendirilmesi ve demografik faktörlerin bilgi ve davranışlar üzerindeki etkisinin incelenmesi amaçlanmıştır.

Gereç ve Yöntemler: Bu kesitsel çalışma, 2024 yılında İnönü Üniversitesi Diş Hekimliği Fakültesi Pedodonti Anabilim Dalı'na başvuran 281 ebeveyn üzerinde rastgele bir tasarımla gerçekleştirilmiştir. Veriler, demografik bilgiler ile demir takviyesine ilişkin bilgi ve tutumları değerlendiren üç bölümden oluşan 12 soruluk yapılandırılmış bir anket aracılığıyla toplanmıştır. Yanıtlar, doğru için 1, yanlış için 0 puanlanmış ve bilgi düzeyleri: >66,7 (yeterli), %33,7–66,7 (orta) ve <%33,7 (yetersiz) olarak sınıflandırılmıştır. İstatistiksel analizler Chi-kare ve Fisher's Exact testleri ile gerçekleştirilmiş olup anlamlılık düzeyi $p < 0,05$ olarak kabul edilmiştir.

Bulgular: Çalışmaya katılan 140 ebeveynin (%49,8) çocukları için demir takviyesi kullandığı belirlenmiş, ancak bunların yalnızca %50,4'ü düzenli kullanım programına uymuştur. Katılımcıların %47,7'si takviyeye başlanması gereken doğru zamanı bilirken, %16'sı demirin diş çürüğüne neden olmadığını doğru bilmiş ve %35'i demir takviyesini diş lekelenmesiyle ilişkilendirmiştir. Ebeveynlerin %60,9'u orta düzeyde bilgiye sahip olmasına rağmen, önerilen uygulamalara uyum oranı düşüktü ve yalnızca %16,3'ü yüksek uyum göstermiştir. Cinsiyetler arasında anlamlı farklılıklar gözlemlenmiş olup, anneler babalara kıyasla daha yüksek bilgi düzeyi ve uyum göstermiştir ($p < 0,01$). Eğitim düzeyinin ebeveynlerin bilgi ve davranışları üzerinde olumlu bir etkisi olduğu belirlenmiştir.

Sonuçlar: Bu çalışma, ebeveynlerin demir takviyesi ve diş sağlığına ilişkin bilgi eksiklikleri ve yanlış inanışlarının takviye kullanımını etkilediğini ortaya koymuştur. Ebeveynlerin demir takviyesi hakkındaki yanlış inanışlarını gidermek ve doğru kullanım alışkanlıklarını teşvik etmek amacıyla kapsamlı eğitim programlarına ihtiyaç duyulmaktadır.

Anahtar Kelimeler: demir takviyesi, diş lekelenmesi, diş çürüğü, ebeveyn bilgisi, pediatrik ağız sağlığı

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International License

^a turkan.m.st.27@gmail.com

^c ftmnr_hrrl@hotmail.com

^b eminegulsenpd@gmail.com

^c ftmnr_hrrl@hotmail.com

^b eminegulsenpd@gmail.com

^c ftmnr_hrrl@hotmail.com

Introduction

Dental deformities and discolorations are widely recognized for their negative impact on the psychological well-being of children and adolescents, often leading to a loss of self-confidence in social interactions. The growing emphasis on aesthetics, reinforced by advertisements and societal prioritization of visual appeal, has heightened parental concern regarding their children's appearance and amplified children's self-consciousness about their physical presentation. Different types of tooth discolorations, including those caused by genes, the environment, bacteria, medical conditions, and dental work, are grouped by where they are found and are called either extrinsic or intrinsic.^{1,2}

Extrinsic discoloration results from the deposition of substances on the tooth surface or within the acquired pellicle. These compounds can impart stains either through their inherent coloration or via chemical reactions occurring on the tooth surface. Conversely, intrinsic discolorations arise from the incorporation of pigmented substances into the tooth structure during its development. Such intrinsic staining is associated with systemic or local factors. Conditions like phenylketonuria, porphyria, erythroblastosis fetalis, thalassemia, amelogenesis imperfecta, dentinogenesis imperfecta, fluorosis, age-related discoloration, and tetracycline staining are examples of systemic factors. Local factors, on the other hand, are mostly trauma and pulp necrosis.^{1,3}

One of the most frequent concerns prompting parents to seek clinical consultation is the black discoloration of deciduous teeth. Interestingly, this happens a lot when kids take iron supplements because chromogenic bacteria become more active when iron is present. This makes the discolorations more common in those kids.⁴

Iron deficiency (ID) and iron deficiency anemia (IDA) are significant public health concerns in developing countries. The prevalence of IDA in a region is directly associated with the socioeconomic and cultural structure, as well as the development level of that region.⁵ Turkey, as a developing country, exhibits notably high anemia rates, whereas this prevalence is considerably lower in developed countries. Iron deficiency is particularly common among individuals with chronic diseases and women of childbearing age, especially during periods of rapid growth, such as infancy. In communities with low socioeconomic status, malnutrition and infections are the primary factors contributing to an increased risk of anemia.⁶

Pediatricians in Turkey frequently recommend iron supplementation at an early age to address this issue and prevent iron deficiency.⁷ These supplements are commonly prescribed in syrup or drop form. However, one of the most prevalent challenges associated with iron supplements, aside from their unpleasant taste, is their tendency to cause black stains on teeth following

consumption. This staining is particularly pronounced on hypomineralized or calcium-deficient tooth surfaces. It is thought that the staining is caused by an insoluble ferric compound (like ferric sulfide) that is made when bacteria produce hydrogen sulfide and interact with Fe ions or parts of gingival fluid.⁸

Some parents mistakenly believe that iron supplements contribute to tooth decay, leading them to refuse their use in children.⁹ However, research indicates that iron supplements do not cause tooth decay; rather, they may play a role in preventing enamel demineralization.¹⁰⁻¹²

The aim of this study was to assess the knowledge and attitudes of parents regarding the effects of iron supplementation on tooth staining and dental caries in children.

Materials and Methods

This randomized, cross-sectional study was conducted in 2024 among the parents of 281 children who visited the Department of Pediatric Dentistry at the Faculty of Dentistry, İnönü University. Ethics approval for the study was obtained from the İnönü University Non-Interventional Clinical Research Ethics Committee (Decision Number: 2024/6729).

Participants were asked to complete a structured questionnaire consisting of 12 questions, divided into three sections. The first section collected demographic information, including the parents' age, education level, employment status, and gender. The second and third sections focused on evaluating parents' knowledge and attitudes regarding the effects of iron supplementation on dental caries and tooth staining in children (*Table 1*).¹³

Responses were scored as 1 for correct answers and 0 for incorrect answers. Based on the percentages of correct answers, knowledge levels were categorized as follows: >66.7% (Adequate), 33.7–66.7% (Fair), and <33.7% (Poor). The reliability of the questionnaire was assessed using the Cronbach's Alpha method, following a pilot distribution of the questionnaire to 20 parents.

Before participation, all parents were provided with detailed information about the study and asked to sign informed consent forms. The questionnaires were completed in a quiet and distraction-free environment to ensure the accuracy and reliability of responses.

Statistical Method

The data were analyzed using IBM SPSS Statistics 25.0. Chi-square and Fisher's Exact tests were employed to compare categorical variables across groups. Categorical data were presented as frequencies and percentages. A significance level of $p < 0.05$ was considered for all statistical analyses. Knowledge and behavior scores were calculated based on the total responses, and statistical evaluations were conducted accordingly.

Table 1: Survey questions

Category	Questions/Options
Parent Information	
Parent's Role	<input type="checkbox"/> Mother <input type="checkbox"/> Father
Age Group	<input type="checkbox"/> 18–24 <input type="checkbox"/> 25–34 <input type="checkbox"/> 35–54 <input type="checkbox"/> 55 and over
Education Level	<input type="checkbox"/> None <input type="checkbox"/> Primary School <input type="checkbox"/> Secondary School <input type="checkbox"/> High School <input type="checkbox"/> University and above
Employment Status	<input type="checkbox"/> Working <input type="checkbox"/> Not working
Iron Supplement Use	
Did/do you use iron supplements for your child?	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't remember
If yes, how frequently did/do you use it?	<input type="checkbox"/> Every day regularly <input type="checkbox"/> Several times a week <input type="checkbox"/> Several times a month
Should iron supplements be used 4 months after birth?	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know
Does iron supplementation cause tooth decay?	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know
Does iron supplementation cause tooth staining?	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know
Administration of Iron Supplements	
Do you combine iron supplements with water or juice?	<input type="checkbox"/> Yes <input type="checkbox"/> No
Do you use iron supplements after brushing your child's teeth?	<input type="checkbox"/> Yes <input type="checkbox"/> No
Which part of your child's mouth do you use iron supplements for?	<input type="checkbox"/> I drip it from the front of the mouth <input type="checkbox"/> I try to drip it in the back of the mouth <input type="checkbox"/> I do not pay attention

Results

A total of 140 participants (49.8%) reported using iron supplements for their children. Among these, 50.4% adhered to a regular usage interval, while the remaining participants administered supplements inconsistently. Regarding the recommended timing of iron supplementation, 47.7% of parents correctly identified that it should begin at four months of age, indicating a partial awareness but also highlighting the need for further education. When evaluating parental perceptions of iron supplementation and its effects on oral health, only 16% of participants correctly recognized that iron does not cause dental caries, while 35% acknowledged its role in tooth staining. Furthermore, 25.3% of parents reported mixing iron supplements with water or fruit juice, whereas 89.3% administered them after brushing their child's teeth. Only 19.6% applied the supplement toward the back of the mouth, a recommended practice to minimize staining (Table 2).

Parental knowledge about iron supplementation was categorized into three levels: low, moderate, and high.

Among participants, 60.9% demonstrated a moderate level of knowledge, 29.2% exhibited a high level, and 10% had low knowledge. Similarly, parental behaviors related to iron supplementation followed the same pattern, with 79.0% displaying moderate behavior, 16.3% high behavior, and 4.6% low behavior (Table 3).

A statistically significant difference was found between mothers and fathers in terms of knowledge levels. Among mothers, 59.0% had a moderate level of knowledge, 32.9% had a high level, and 8.1% had a low level. In contrast, 66.2% of fathers exhibited moderate knowledge, 18.3% had high knowledge, and 15.5% had low knowledge.

Similarly, parental behavior levels also showed significant differences ($p < 0.01$) (Table 4). Among mothers, 73.8% exhibited moderate behavior, 21.0% high behavior, and 5.2% low behavior. In comparison, 94.4% of fathers demonstrated moderate behavior, while only 2.8% exhibited high behavior and another 2.8% showed low behavior.

Table 2: Distribution of parents' answers about iron supplements for their children

Survey Questions	Correct Answers (n/%)
Did/do you use iron supplements for your child?	140 (49.8%)
If yes, in which range did/do you use it?	65 (50.4%)
Should iron supplements be used 4 months after birth?	134 (47.7%)
Does iron supplementation cause tooth decay?	45 (16.0%)
Does iron supplementation cause tooth staining?	101 (35.0%)
Do you combine iron supplements with water or juice?	71 (25.3%)
Do you use iron supplements after your child brushes their teeth?	251 (89.3%)
In which part of your child's mouth do you use iron supplements?	55 (19.6%)

* Frequency distributions of correct answers given by parents to knowledge and behavior questions

Table 3: Distribution of parental knowledge and behavior levels about iron supplementation for their children

	Level of knowledge		Level of behavior	
	N	%	N	%
Poor	28	10.0	13	4,6
Moderate	171	60.9	222	79.0
Sufficient	82	29.2	46	16,3
Total	281	100.0	281	100.0

Table 4: Comparison of knowledge and behaviors of parents

Category	Low (N/%)	Middle (N/%)	High (N/%)	Chi-Square	p-value
Knowledge					
Mother	17 (8.1%)	124 (59.0%)	69 (32.9%)	7.208	0.027
Father	11 (15.5%)	47 (66.2%)	13 (18.3%)		
Behavior					
Mother	11 (5.2%)	155 (73.8%)	44 (21.0%)	14.171	0.001
Father	2 (2.8%)	67 (94.4%)	2 (2.8%)		

Discussion

This study assessed parents' knowledge and behaviors regarding iron supplementation in children, focusing on common misconceptions and knowledge gaps. The findings indicate that 49.8% of parents used iron supplements for their children, but only 50.4% adhered to a regular usage schedule. This inconsistency highlights the need for more structured education on supplement administration and adherence to recommended guidelines.

Regarding the initiation of iron supplementation, 47.7% of parents correctly identified that it should begin at four months of age. However, more than half of the participants either had incorrect information or were unaware of the correct initiation period. These findings emphasize the necessity of raising parental awareness on this issue.

When evaluating parental concerns about the effects of iron supplementation on oral health, only 16% correctly recognized that iron does not cause dental caries, while 35% associated iron supplementation with tooth staining. These results suggest that misconceptions about iron and oral health may lead to a decline in supplement use. Talebi et al., reported a similar observation, finding that parental misconceptions significantly restricted iron supplement use.¹⁴

Contrary to these misconceptions, extensive research highlights the protective effects of iron on enamel health. The results show that iron ions stop demineralization and help build a protective enamel layer, which makes teeth more resistant to acid.^{10-12,15,16} However, many parents mistakenly believe that iron causes cavities, contradicting scientific findings and potentially leading to unnecessary discontinuation of supplementation.

Behavioral findings also reveal improper administration practices. Only 25.3% of parents combined iron supplements with water or fruit juice, a method known to reduce staining. Additionally, 89.3% administered supplements after brushing their child's teeth, which may increase the risk of discoloration. Furthermore, only 19.6% of parents applied the supplement toward the back of the mouth, an effective technique for minimizing staining.¹⁷ These results highlight the need for better parental guidance on the proper administration of iron supplements.

Contrary to parental concerns, previous studies suggest that iron supplementation may have a protective effect against dental caries. Miguel et al. reported that the

combination of iron and fluoride reduces the incidence of caries.¹² Similarly, Rezende et al., conducted a meta-analysis and found that people whose teeth turned black from taking iron supplements had a lower incidence of cavities. This was probably because iron makes teeth stronger.¹⁸ However, a study conducted in 2015 reported that iron and multivitamin supplements could also have negative effects on tooth enamel.¹³ In particular, iron and multivitamin drops with low pH levels have been suggested to reduce enamel surface hardness, leading to erosion. These findings indicate that iron supplements may have a dual effect on enamel health. While they can play a protective role against caries formation, low-pH formulations may contribute to enamel softening, increasing the risk of erosion. Therefore, special attention should be given to oral hygiene when using iron and multivitamin drops, and preventive measures such as rinsing the mouth with water after consumption or using a straw are recommended.

When analyzing parental knowledge and behavior levels, 60.9% demonstrated a moderate level of knowledge, while 29.2% had high knowledge. However, behavioral adherence was lower, with only 16.3% of parents exhibiting high adherence and 4.6% demonstrating weak compliance.¹⁹ These findings indicate that while parents generally understand the importance of iron supplementation, they often struggle with proper administration.

Statistically significant gender-based differences were observed in both knowledge and behavior. Among mothers, 59.0% had moderate knowledge, 32.9% had high knowledge, and 8.1% had low knowledge. In contrast, 66.2% of fathers exhibited moderate knowledge, 18.3% had high knowledge, and 15.5% had low knowledge. Previous studies indicate that mothers are typically more involved in child healthcare than fathers, suggesting that increasing fathers' participation in pediatric health education could help reduce this knowledge gap.^{10-12,15}

Similarly, behavioral adherence also differed significantly between mothers and fathers ($p < 0.01$). Among mothers, 73.8% exhibited moderate behavior, 21.0% high behavior, and 5.2% low behavior. In contrast, 94.4% of fathers demonstrated moderate behavior, while only 2.8% exhibited high behavior and another 2.8% showed low behavior. These findings suggest that mothers are more likely to follow recommended practices for iron supplementation, highlighting the need for

targeted educational programs for fathers. Demographic factors also influenced knowledge and behavior. No significant differences were observed based on maternal employment status. However, working parents generally displayed more informed attitudes and behaviors, likely due to increased exposure to health-related information. Also, parents with higher levels of education were significantly more knowledgeable about and consistent with supplementation practices. Parents with lower levels of education, on the other hand, were less sure about how to use supplements correctly. These findings align with previous research highlighting the positive relationship between parental education and health-related behaviors.¹⁹ Similarly, studies on general oral hygiene habits have also demonstrated the decisive role of education level in oral health. For example, Karaaslan et al. reported that individuals with lower education levels had a lower frequency of tooth brushing and a significantly lower rate of regular dental visits. In our study, it was also observed that as parental education levels increased, their knowledge of iron supplementation and correct application rates improved. These findings highlight the impact of parental education not only on general oral health habits but also on children's use of iron supplements.²⁰ A similar finding was reported in a study by Demircan et al., which indicated that parents lacked sufficient knowledge regarding the impact of oral habits on malocclusions. That study also found a significant correlation between the level of education and the level of knowledge. In our study, when evaluating parents' knowledge and behaviors concerning iron supplementation, similar gaps in knowledge were identified, highlighting the necessity of parental education.²¹

A study conducted by Onur et al., which investigated risk factors for caries prevalence among children in Turkey, found a significant association between parental education level and the development of caries in children—a result consistent with our study findings.²² These results emphasize the crucial role of parental education in improving knowledge, attitudes, and behaviors regarding both iron supplementation and pediatric oral health.

Conclusions

This study highlights the need for targeted parental education programs that address misconceptions about iron supplementation, ensure proper administration practices, and promote adherence to recommended guidelines. Future research should focus on assessing the long-term impact of structured educational interventions on parental knowledge and behavior, as well as children's overall oral and systemic health outcomes.

Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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Evaluation of Parents' Knowledge Levels and Awareness Regarding Emergency Management of Tooth Avulsion: An Institutional Cross-Sectional Study

Arzu Koçkanat^{1,a,*}

¹Department of Pediatric Dentistry, Faculty of Dentistry, Sivas Cumhuriyet University, Türkiye

*Corresponding author

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ABSTRACT

Objectives: The purpose of this study was to evaluate parental awareness and knowledge regarding the management of tooth avulsion.

Materials and Methods: This study was designed as a cross-sectional survey. 250 parents who had applied to the Department of Pediatric Dentistry at Sivas Cumhuriyet University Faculty of Dentistry were included. A self-administered survey consisting of 19 items in 3 section was used to assess the awareness and knowledge level of parents regarding emergency management of tooth avulsion. Non-parametric data were analyzed using the Mann-Whitney U and Kruskal-Wallis tests.

Results: Of the parents who participated in the study, 52% were in their thirties, 59.6% were female and 28.8% were university graduates. 91.6% of the parents had received no training on dental injuries. While 84% of the parents stated that they would not be able to reimplant the avulsed tooth, 10.4% stated that they would store the avulsed tooth in milk. Only 37.2% of parents were aware of the proper treatment of an avulsed primary tooth. There was no statistically significant difference between parents' knowledge level regarding tooth avulsion and age and gender ($p=0.189$, $p=0.553$), while a significant difference was found between educational level ($p<0.001$). The mean total score of the correct responses regarding emergency management of avulsed teeth was 4.54 ± 1.97 and the percentage of correct responses was 45.4%.

Conclusions: This study revealed that parents do not have sufficient knowledge about the emergency management of tooth avulsion and that university graduates have higher knowledge than primary and high school graduates. Therefore, educational programs should be organized in accordance with the educational level of parents on emergency treatment management of tooth avulsion.

Keywords: Tooth Avulsion, Dental trauma, Knowledge level, Parents

Ebeveynlerin Diş Avülsiyonunun Acil Tedavisine İlişkin Bilgi Düzeylerinin ve Farkındalıklarının Değerlendirilmesi: Kurumsal Bir Kesitsel Çalışma

Araştırma Makalesi

Süreç

Geliş: 12/01/2025

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ÖZET

Amaç: Bu çalışmanın amacı diş avülsiyonunun yönetimine ilişkin ebeveyn farkındalığını ve bilgisini değerlendirmektir.

Gereç ve Yöntemler: Bu çalışma kesitsel bir anket olarak tasarlanmıştır. Sivas Cumhuriyet Üniversitesi Diş Hekimliği Fakültesi Çocuk Diş Hekimliği Anabilim Dalı'na başvuran 250 ebeveyn çalışmaya dahil edilmiştir. Ebeveynlerin diş avülsiyonunun acil yönetimi ile ilgili farkındalık ve bilgi düzeyini değerlendirmek için 19 soru ve 3 bölümden oluşan kendi kendine uygulanan bir anket kullanılmıştır. Parametrik olmayan veriler Mann-Whitney U ve Kruskal-Wallis testleri kullanılarak analiz edilmiştir.

Bulgular: Çalışmaya katılan ebeveynlerin %52'si otuzlu yaşlardaydı, %59,6'sı kadındı ve %28,8'i üniversite mezunuydu. Ebeveynlerin %91,6'sı diş yaralanmaları konusunda herhangi bir eğitim almamıştı. Ebeveynlerin %84'ü avülse dişi tekrar implante edemeyeceklerini belirtirken, %10,4'ü avülse dişi süt içinde taşıyacaklarını belirtmiştir. Ebeveynlerin sadece %37,2'si avülse süt dişinin uygun tedavisi hakkında bilgi sahibiydi. Ebeveynlerin diş avülsiyonu hakkındaki bilgi düzeyi ile yaş ve cinsiyet arasında istatistiksel olarak anlamlı bir fark bulunmazken ($p=0,189$, $p=0,553$), eğitim durumu ile arasında anlamlı bir fark bulunmuştur ($p<0,001$). Avülse dişlerin acil yönetimine ilişkin doğru cevapların toplam puan ortalaması $4,54\pm1,97$ ve doğru cevap yüzdesi %45,4' idi.

Sonuç: Bu çalışma, ebeveynlerin diş avülsiyonunun acil yönetimi hakkında yeterli bilgiye sahip olmadıklarını ve üniversite mezunlarının ilköğretim ve lise mezunlarına göre daha yüksek bilgiye sahip olduklarını ortaya koymuştur. Bu nedenle, diş avülsiyonunun acil tedavi yönetimi konusunda ebeveynlerin eğitim düzeyine uygun eğitim programları düzenlenmelidir.

Anahtar Kelimeler: Diş avülsiyonu, Dental travma, Bilgi düzeyi, Ebeveynler

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Introduction

Traumatic dental injuries are common oral and dental health problems in children and young adults. Traumatic dental injuries frequently occur due to causes such as falls, collisions, fights and traffic accidents. This can range from simple enamel fracture to complicated injuries involving supporting structures and avulsion of teeth.^{1,2}

Avulsion, which is defined as complete removal of the tooth from the alveolar socket as a result of trauma, is a complex form of injury affecting the alveolar bone and periodontal ligaments as well as the pulp.³ Avulsion constitutes 7-13% of all traumatic dental injuries in primary dentition and 0.5-16% in permanent dentition. Also, it mostly affects maxillary central teeth.^{4,5} Avulsion is more common in the 8-12 age group and in males. Early loss of anterior teeth causes negative effects on quality of life, physiological development, loss of aesthetics and function, and psychological trauma.⁶⁻⁸

Immediate and appropriate emergency management after tooth avulsion is very important for the prognosis of the affected tooth.⁹ Since the time that the avulsed tooth spends outside the socket is critical for preserving periodontal ligament viability, the ideal is to reimplant the tooth into the socket correctly as soon as possible.¹⁰ The prognosis of a reimplanted tooth depends on the time interval between trauma and reimplantation, where and how the tooth is stored, the presence of contamination, the stage of root formation, and the oral and systemic health status of the child.^{11,12} Therefore, it is crucial that parents, teachers or lay people who are among the most frequently present when the injury occurs, should be informed about when and how to intervene in this situation.^{13,14}

Although there have been many studies evaluating the knowledge and attitudes of parents about avulsed teeth in different countries, studies evaluating the awareness and knowledge level of parents living in Türkiye are limited.^{6,15-19} To our knowledge, no similar study has been reported on parents living in Sivas province. Hence, current study aimed to assess parents' awareness and knowledge about emergency management of avulsed tooth in Sivas province, Türkiye.

Materials and Methods

Study Design

The current study was designed as a cross-sectional survey. The participants of the study consisted of the parents of patients who applied to Department of Pediatric Dentistry at Sivas Cumhuriyet University Faculty of Dentistry for routine treatment between 10.06.2024-10.08.2024. Our study was conducted according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) protocol.²⁰

Ethical Approval

Ethical approval was obtained from Non-Interventional Clinical Research Ethics Committee at Sivas Cumhuriyet University with permission number 2024/05-01. The ethical standards of the Helsinki Declaration were followed.

Sample Size Calculation

The minimum sample size was determined as 250 participants with a 90% confidence interval, 0.05 alpha value and 0.5 medium effect size. 250 parents participated in this study.

Participants

Parents were informed about the purpose and content of the study, and written informed consent was obtained from those who agreed to participate. Parents older than 20 years of age who agreed to participate in the study and responded all the items were included in the study, while illiterate parents who did not agree to participate in the present study, who did not respond the items completely, who were younger than 20 years of age, who did not speak Turkish, and who worked in any dentistry-related place (dentists, dental technicians, dental assistants, etc.) were not included in the present study.

Survey Procedure

The self-administered questionnaire form consisting of 3 sections and 19 multiple-choice items was distributed to the parents during their free time in the dental clinic. A structured questionnaire based on similar studies in the literature was used in this study.^{6,18,19} Section 1 of the questionnaire consisted of demographic information regarding age, gender and education of the participants. Section 2 of the questionnaire evaluated the parents' past experiences with dental trauma, whether they had received training on dental trauma, the source and adequacy of this training if they had received training, whether they wanted to learn about dental trauma and whether they distinguished primary teeth. Section 3, which evaluated parental awareness and knowledge of tooth avulsion, consisted of 10 items. Parents were asked items about what to do in case of permanent tooth avulsion injury, how to handle the avulsed tooth, how to clean it if it is contaminated, how to store it, how long it takes to reach the dentist, and their awareness about the avulsed primary tooth and tetanus vaccination. Some of the items in this section have more than one correct response. A total knowledge score was calculated by giving 1 point for each correct response. In the questionnaire, participants could score a minimum of 0 points and a maximum of 10 points.

Data Analysis

IBM SPSS Statistics for Windows 23 (SPSS Inc., Chicago, IL, USA) was used for data analysis. Continuous variables are presented as mean, standard deviation, minimum, and maximum values, while categorical variables are presented as frequencies and percentages. Normality distribution was examined with Kolmogorov-Smirnov test. Non-parametric data were analyzed using the Mann-Whitney U and Kruskal-Wallis tests. Post-hoc comparisons were performed using the Mann-Whitney U test with the Bonferroni correction. Statistical significance was set at $p < 0.05$.

Results

Demographic information of the parents evaluated in section 1 of the questionnaire is given in Table 1. 59.6% of the parents were female and 40.4% were male. 52% of the participants were between the ages of 31-40 and 30.4% were between the ages of 41-50. 38% of the parents were primary school graduates, 33.2% were high school graduates and 28.8% were university graduates. While there was no significant difference between age and gender and parents' knowledge level about tooth avulsion ($p=0.189$, $p=0.553$), a significant difference was observed between educational level ($p<0.001$).

The responses evaluating the parents' previous dental trauma experiences and awareness are given in Table 2. 91.6% of the parents stated that they did not receive any training about dental trauma and only 4.4% of the parents who received sufficient training. While 39.6% of the parents stated that they wanted to receive training about dental trauma, 34.4% did not want to receive training and 26% were undecided. The knowledge level of parents who wanted to receive training was found to be significantly lower ($p<0.001$). 34% of the parents stated that their child had experienced dental trauma before and 66% stated that they had no dental trauma experience. While 39.6% of the parents stated that they could distinguish between primary and permanent teeth, 34.4% stated that they could not, 26% stated that they were undecided. A statistically significant difference was observed between the knowledge level of parents who were aware and not aware of primary and permanent teeth about tooth avulsion ($p=0.001$).

The responses of the parents to the items evaluating the knowledge level regarding tooth avulsion are given in Table 3. When asked what you do in case of avulsion of a permanent tooth, 51.6% of the parents stated that they would find the avulsed tooth and apply to the dentist in an appropriate medium. When asked how you would hold the avulsed tooth, 35.2% of the parents stated that they

would hold it by the crown, 13.2% by the root, while 36.8% did not know. When asked how do you handle a avulsed tooth if it is dirty, 34% of the parents stated that they would wrap it in a paper napkin, 23.6% stated that they would hold it in water without rubbing it, and 18% did not know. When asked where do you keep the avulsed tooth while taking it to the dentist, 44.4% of the parents responded in a paper napkin, 10.4% in milk, 8.4% in water. When asked how long it takes to reach the dentist, 38.4% of the parents responded within 1 hour, 22.4% within 20 minutes, and 17.2% within a day. When asked where you would first apply for the treatment of your child, 50.8% stated that they would go to a dental hospital and 29.2% stated that they would go to a faculty of dentistry. When asked whether it is important to lose time in reaching the dentist, 92% of the parents responded yes. When asked whether it is important for your child to have tetanus vaccination, 90.4% of the parents responded yes. When asked if the tooth displaced as a result of trauma is a primary tooth, 37.2% of the parents stated that it is not placed back into its socket in the jawbone, while 56.8% stated that they had no opinion.

The mean correct responses of the items measuring the knowledge level of the parents regarding tooth avulsion was 4.54 ± 1.97 and the percentage of correct responses was 45.4%. The mean correct responses and percentages of parents with different educational levels are given in Table 4. There was a statistically significant difference between the knowledge level regarding tooth avulsion and educational level ($p<0.001$). Post-hoc comparisons were performed using The Mann-Whitney U test with Bonferroni correction and adjusted p -value was calculated 0.017. Pairwise comparisons showed that university graduates had significantly higher knowledge levels regarding tooth avulsion than both primary and high school graduates ($p<0.001$). No significant difference was observed between primary and high school graduates in terms of knowledge level about tooth avulsion ($p=0.057$).

Table 1. Distribution of demographic information of the participants and the significance between the parents' knowledge level about tooth avulsion

Demographic information		n (%)	p-value
Gender	Female	149 (59.6)	0.553
	Male	101 (40.4)	
Age	20-30	30 (12)	0.189
	31-40	130 (52)	
	41-50	76 (30.4)	
	51 and over	14 (5.6)	
Education Level	Primary school	95 (38)	<0.001
	High school	83 (33.2)	
	University	72 (28.8)	
Total		250 (100)	

Table 2. Distribution of participants' responses to items assessing the dental trauma experiences and the significance between the parents' knowledge level about tooth avulsion

Items	Responses	n (%)	p-value
Have you received training on dental injuries before?	Yes	21 (8.4)	0.127
	No	229 (91.6)	
If yes, what is the source of the training you received?	First aid course	4 (1.6)	0.879
	Dentist	13 (5.2)	
	Other health workers	2 (0.8)	
	Friend	1 (0.4)	
	Internet	1 (0.4)	
	Other (school etc.)	-	
How would you rate the training you received?	Adequate	11 (4.4)	0.484
	Not enough	6 (2.6)	
	Undecided	4 (1.6)	
Has your child had dental injuries before?	Yes	85 (34)	0.131
	No	165 (66)	
Can you distinguish between primary and permanent teeth?	Yes	99 (39.6)	0.001
	No	86 (34.4)	
	Undecided	65 (26)	
Would you like to receive training on dental injuries?	Yes	99 (39.6)	<0.001
	No	86 (34.4)	
	Undecided	65 (26)	

Table 3. Distribution of participants' responses to items regarding emergency management of tooth avulsion

Items	Responses	n (%)
What do you do if your child's front permanent tooth is completely avulsed after a cycling accident?	I don't look for the tooth, I don't go to the dentist, the tooth has already come out.	13 (5.2)
	I go to the dentist without trying to find the avulsed tooth	55 (22)
	I find the displaced tooth and apply to the dentist in a suitable medium	129 (51.6)
	I find the avulsed tooth, wash and replace it if it is contaminated and then consult a dentist.	15 (6)
	I don't know	38 (15.2)
Where would you first contact for the treatment of your child?	Any hospital emergency department	45 (18)
	Private Dental Office	5 (2)
	Dental hospital	127 (50.8)
	Faculty of dentistry	73 (29.2)
How do you hold the avulsed tooth?	From the root	33 (13.2)
	From the surface visible in the mouth	88 (35.2)
	I don't think it's important	37 (14.8)
	I don't know	92 (36.8)
How do you proceed if the avulsed tooth is dirty?	I wrap it in a napkin	85 (34)
	I try to clean it with a toothbrush	28 (11.2)
	I hold it in water without rubbing it	59 (23.6)
	I don't clean	33 (13.2)
	I don't know	45 (18)
Where do you keep the avulsed tooth when you take it to the dentist?	On a paper napkin	111 (44.4)
	In tap water	21 (8.4)
	In milk	26 (10.4)
	In saliva	3 (1.2)
	In saline	19 (7.6)
	Alcohol	7 (2.8)
	I don't think it's important	13 (5.2)
	I don't know	50 (20)
How long does it take to reach the dentist?	In the first 20 minutes	56 (22.4)
	In the first hour	96 (38.4)
	In a few hours	42 (16.8)
	During the day	43 (17.2)
	At any time	8 (3.2)
	I don't know	5 (2)

Do you think it is important to lose time in reaching the dentist?	Yes	230 (92)
	No	20 (8)
Can you replace the avulsed permanent tooth?	Yes	6 (2.4)
	No	210 (84)
	Undecided	34 (13.6)
Do you think it is important for your child to have tetanus vaccination?	Yes	226 (90.4)
	No	24 (9.6)
If your child's avulsed tooth after injury is a primary tooth;	Can be placed back into its socket in the jawbone	15 (6)
	Cannot be placed back into its socket in the jawbone	93 (37.2)
	No opinion	142 (56.8)
Total		250 (100)

Table 4. Distribution of the number and percentage of correct responses according to education level

Education Level	Number of correct responses			Percentage of correct responses	p-value
	n	Min-max	Mean±SD		
Primary School	95	0-8	3.78±1.81	37.8	<0.001
High School	83	0-8	4.40±1.80	44	
University	72	1-9	5.71±1.82	57.1	
Total	250	0-9	4.54±1.97	45.4	

Discussion

Traumatic dental injuries occur most commonly at school or at home.²¹ Tooth avulsion is the most critical type of injury and requires immediate and proper emergency management. Correct first intervention with adequate knowledge and awareness of parents is of critical importance in terms of prognosis of trauma and prevention of complications.²² There are limited number of studies evaluating the knowledge and awareness of parents regarding tooth avulsion management in Türkiye.^{6,15-19} There is a need to assess the attitudes and behaviors of parents in different countries and geographical regions at the time of trauma in order to plan educational programs appropriate to their level of education. To our knowledge, there is no study evaluating the knowledge level of parents in Sivas province regarding emergency management of tooth avulsion. The purpose of this study was to evaluate parents' awareness and knowledge regarding the emergency management of tooth avulsions in Sivas province.

According to the results of this study, the mean of the correct responses given by the parents to the items was 4.54±1.97 and the percentage of correct responses was 45.4%. This result is compatible with the study conducted by Güler et al. in Türkiye.¹⁹ In studies conducted in other countries measuring the knowledge level of parents regarding emergency management tooth avulsion, percentage of knowledge level of parents was similarly found to be low.^{11,23,24} A significant difference was found between parents' level of knowledge about tooth avulsion and their level of education. Parents who graduated from university were found to have statistically better knowledge level about tooth avulsion than both primary school and high school graduates ($p<0.001$). No significant difference was found between knowledge level about tooth avulsion gender and age. Similar results to current study were found in studies in the literature.^{9,18,19} There was no significant difference between the knowledge level of the parents who received dental trauma training and who encountered any type of dental trauma, but the knowledge

level of the parents who had the awareness of distinguishing between primary and permanent teeth was significantly higher ($p=0.001$). While 39.6% of the parents stated that they could distinguish between primary and permanent teeth, 34.4% stated that they could not distinguish between primary and permanent teeth and 26% stated that they were undecided. Kaul et al.²⁵ and Hashim²⁶ reported similar rates to current study in terms of permanent and primary tooth awareness, while Güler et al. reported a slightly higher rate.¹⁹ Only 39.6% of the parents wanted to receive training about dental trauma and the knowledge level of the parents who wanted to receive training about dental trauma was found to be significantly low ($p<0.001$). The rate of these parents was found to be lower compared to studies in the literature.^{6,18,25,26} This may have been due to the fact that parents were not aware that they would play an active role in the emergency management of avulsion injuries or that they did not prioritize participation in the training program among their daily responsibilities.

In section 3 of present study, the parents were asked items evaluating their knowledge level and awareness regarding emergency management of tooth avulsion. The prognosis of an avulsed tooth is determined by the time out of the socket, the transportation medium, the minimal damage to the periodontal ligament cells, and the presence of contamination.¹⁰ Therefore, immediate and proper emergency management of the trauma process by the parents is directly related with the prognosis of the avulsed tooth.²⁷ The most appropriate treatment for avulsed permanent tooth is immediate reimplantation. According to the results of this study, 51.6% of the parents stated that they would refer the avulsed tooth to the dentist in the appropriate medium, while only 6% stated that they could replace the avulsed tooth. These results are similar to the results of studies conducted with Turkish parents, but slightly lower. In the study of Özer et al.⁶, 9.3% of the parents and in the study of Doğusal et al.²⁸, 7.4% of the parents stated that they could replace the avulsed tooth. These rates are also lower compared to studies

conducted in different countries.²³⁻²⁵ This may be due to differences in medical educational information between countries and cities. As a result, the lack of knowledge among parents about this important issue is clearly visible in Türkiye.

The appropriate transport medium of a tooth that cannot be immediately reimplanted is an important factor affecting clinical success. Pasteurized milk is considered to be the most suitable transport medium to prevent dehydration of the periodontal ligaments. Milk is compatible with periodontal ligament cells, including appropriate pH and osmolality, and is easy to access in an emergency.²⁹ In current study, 10.4% of the parents preferred milk as the transport medium. The rate founded in this study is higher than the rate reported by Özer et al.⁶ and similar to Soğukpınar Önsüren et al.¹⁸ Alharbi et al. reported a rate of 27.7 % in parents who transported avulsed teeth in milk.²⁴

When asked how do you hold the tooth, 35.2% of the parents stated that they would hold it by the crown. When asked how do you clean the soiled tooth, 23.6% of the parents responded that they would hold it in water without rubbing. Alyahya et al. reported much higher rates than founded in this study for the same items.³⁰ Alharbi et al. reported rates similar to current results.²⁴ Although the knowledge level of parents regarding tooth avulsion varies in different countries, the percentages of the findings in the Saudi study are similar to current study. Unfortunately, this shows parents' lack of knowledge about important factors affecting prognosis after reimplantation.

The first institution preferred by the parents for the treatment of avulsed tooth was the dental hospital with 50.8%, followed by the faculty of dentistry with 29.2%. Most of the parents in this study are aware of the need to reach a dentist. While the success rate of teeth reimplanted within the first 30 minutes reaches 90%, the chance of success decreases as the reimplanting time prolongs.³¹ In present study, 22.4% of parents responded within 20 minutes when asked how long it would take to reach the dentist. Unfortunately, most of the parents in current study were not aware of the importance of reimplantation of the avulsed tooth immediately or as soon as possible in terms of clinical success. The delay in reaching the dentist may be due to the fact that parents are primarily concerned with bleeding and pain control. 84% of the parents stated that they could not replace the avulsed tooth. The reason for this situation may be the parents' fear of harming their children, lack of knowledge about trauma, and inability to manage stress during trauma. In a study conducted in Türkiye, Güler et al. reported that 28.5% of the parents received professional help within 30 minutes and 77.2% could not replace the avulsed tooth, similar to current results.¹⁹

An important aspect of the present study is that it includes an item assessing parental awareness when primary tooth avulsion, whereas previous studies mostly included items about permanent tooth avulsion. 37.2% of the parents thought that the avulsed primary tooth should not be reimplanted. Consistent with the present findings, Alharbi et al. reported that 40.7% of parents were aware of the correct treatment of an avulsed primary tooth.²⁴

Another important issue in avulsed tooth injuries is sterilization. Since the avulsed tooth is likely to come into contact with soil and dirt, there is a risk of tetanus. In current study, 90.4% of all parents and 91.76% of parents with dental trauma experience were aware of the necessity of tetanus vaccination. Consistent with the present findings, Kaul et al.

reported that the most of parents were aware of the necessity of tetanus vaccination.²⁵

Limitations

The current study has some limitations. This study was conducted in only one institution and different institutions were not included. A field study involving more institutions could be conducted to get a better idea. This study did not include training on tooth avulsion for parents. The results reflect the parents' personal knowledge and experience. Future studies could be planned to evaluate the attitudes and behaviors of parents before and after training on tooth avulsion. Also, from a broader perspective, further research could be planned to assess the level of knowledge of parents as well as teachers, coaches, doctors and nurses regarding dental trauma. In this way, people's awareness and knowledge levels on trauma management could be assessed and training programs could be planned according to their knowledge levels.

Conclusions

This study revealed that parents do not have sufficient knowledge about the emergency management of tooth avulsion and that university graduates have higher knowledge than primary and high school graduates. Educational programs should be organized in accordance with the educational levels of parents about dental traumas that require emergency treatment management such as tooth avulsion. In current study, it was determined that parents were not willing to receive education about dental trauma. The reasons for parents' reluctance to participate in dental trauma education programs should be revealed and they should be motivated to participate. In addition, in order to increase the awareness of parents about dental trauma, posters with diagrams showing what to do in case of dental trauma can be hung in the emergency departments of hospitals, primary health centers and pediatricians' offices, and social media tools can be used.

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Conflict of Interest Statement

No competing interests.

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Bibliometric Analysis of Turkey-Affiliated International Publications in Pediatric Dentistry Using RStudio Package: A Cross-Sectional Research

Tülin Taşdemir ^{1,a,*}, Melek Taşöker ^{2,b}

¹Department of Pediatric Dentistry, Faculty of Dentistry, Hacettepe University, Ankara, Turkey

²Department of Dentomaxillofacial Radiology, Faculty of Dentistry, Necmettin Erbakan University, Konya, Turkey

*Corresponding author

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ABSTRACT

Objectives: This study aims to perform a bibliometric analysis of studies published in international journals affiliated with Turkey in the field of pediatric dentistry and to determine the position of Turkish Pediatric Dentistry at the international level.

Materials and Methods: The research was conducted using the 'Web of Science' and 'Scopus' databases. The search was performed by entering the following terms into the databases: 'pediatric dentistry' OR 'paediatric dentistry' OR 'pedodontics' and 'children' AND ('dentistry' OR 'teeth' OR 'tooth' OR 'dental' OR 'caries' OR 'oral health' OR 'oral hygiene'). Subsequently, publications were filtered by selecting 'Turkey' on a country basis. Using the 'bibliometrix' package in RStudio, data obtained from the two databases were merged. The analysis included a total of 1,949 publications. The identified publications were evaluated based on publication years, journals in which they were published, citation counts, authors, affiliated institutions, and preferred keywords. Analyses and visualizations from package in RStudio were utilized.

Results: Turkey's international collaboration rate is 5%. The United States emerges as the most frequent collaboration partner, with the journal *Dental Traumatology* standing out among the sources. Hacettepe University is the most productive institution, with 390 publications. The thematic map reveals that 'pulpotomy,' 'mineral trioxide aggregate,' 'fluoride,' and 'remineralization' are the most actively researched topics.

Conclusions: Based on data from the Web of Science and Scopus databases, there has been a significant scientific productivity in the field of Turkish Pediatric Dentistry between 1984 and 2024. In future studies, the comprehensiveness of the results can be expanded by analyzing different databases.

Keywords: Bibliometrics; pediatric dentistry; Rstudio package; international; Turkish

^a dt.tulintasdemir@gmail.com

^b 0000-0003-4884-4715

^b dishekmelek@gmail.com

^b 0000-0003-2062-5713

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Introduction

Scientific progress is achieved through the findings of scientific studies reported in scientific articles.¹ Examining scientific results is a valuable approach for enhancing policy-making and planning, comprehending historical contexts, establishing research priorities, and pinpointing gaps and shortcomings in the production of scientific knowledge.² A comprehensive and effective method for analyzing scientific output and gaining insights into the overall state of research is to conduct a thorough evaluation of articles that are indexed in various academic databases. Bibliometrics is a comprehensive analytical approach to literature that delves into the production and standing of publications within a specific research domain, examining both quantitative metrics, such as publication counts and citation rates, and qualitative aspects, such as the impact and relevance of the research.^{3,4} During the analysis, we can gather comprehensive information about authors, countries, journals, institutions, keywords, references, and other relevant aspects within the research field.³ Bibliometric tools like VoSviewer,⁵ CiteSpace,⁶

HistCite⁷ and R package "bibliometrix"⁸ are commonly employed to create visual representations of the findings from literature analyses. This type of analysis can help determine the extent and nature of research conducted by each country, organization, scientific field, and individual. Additionally, citation analysis serves as a crucial indicator in bibliometric research. The number of citations impacts the impact factor of the journal in which the work is published, reflecting the approval, productivity, quality, and reputation of both the article and its authors.⁹⁻¹¹ The most cited articles represent milestones in any field and can significantly influence research and clinical practices. The 100 most cited articles in a field are regarded as the most influential within that domain. Conducting a bibliometric analysis of these influential publications enhances our understanding of research progress and key topics of interest. This type of analysis, which has gained considerable attention in recent years, illustrates the publication trends, scientific developments, and evidence-based practices surrounding a topic over time. Compiling the most cited publications can help physicians

and experts better grasp the nature of that field. Although the total number of citations may not be a conclusive measure of an article's quality, it is often utilized to gauge the article's influence within the scientific community. Generally, higher-quality articles tend to receive significantly more citations than lower-quality ones.¹²

When the dental literature in Turkey is examined, bibliometric analyses of studies published in the fields of orthodontics,¹³ endodontics,^{14,15} prosthetic dentistry,^{16,17} oral and maxillofacial surgery,¹⁸ pediatric dentistry¹⁹ and theses written in some dentistry fields^{20,21} are reached. As a result of this examination, no bibliometric analysis of studies published in international journals in the field of pediatric dentistry in Turkey was found. This study aims to perform a bibliometric analysis of studies published in international journals affiliated with Turkey in the field of pediatric dentistry and to determine the position of Turkish Pediatric Dentistry at the international level.

Materials and Methods

Since it is a document review study and not a study conducted on animals or humans, ethics committee approval was not obtained. The research was conducted on November 19, 2024 using the "Web of Science Core Collection" (WoS) and "Scopus" databases. Since the relevant databases are updated daily, analyses were performed only in a single day. The databases were searched by writing "pediatric dentistry" OR "paediatric dentistry" OR "pedodontics" and "children" AND ("dentistry" OR "teeth" OR "tooth" OR "dental" OR "caries" OR "oral health" OR "oral hygiene") (Figure 1). Then, "Turkey" was selected on a country basis and the publications were filtered. In the obtained results, the Rstudio 4.4.2 package program was used to extract common publications both within the databases and between the databases and to analyze the data. The WoS database reached 1787 publications and the Scopus database reached 2816 publications on children's oral and dental health published between 1984 and 2024. After combining the data obtained from the two databases, 903 common publications were removed and 3700 publications were obtained. The obtained articles were then examined and 1751 publications belonging to authors not affiliated with the pediatric dentistry department were excluded from the study. 1949 publications related to children's oral and dental health

published by authors affiliated with the pediatric dentistry department were included in the analysis (Figure 2).

All document types (research articles, reviews, case reports, letters to the editor) were included in the study. No language filtering was performed, studies in all published languages (English, Turkish, Polish, Italian, Croatian, Spanish, and Japanese) were included. Publications are included in Science Citation Index Expanded, Emerging Sources Citation Index, Social Sciences Citation Index, Conference Proceedings Citation Index–Social Science & Humanities, Conference Proceedings Citation Index–Science indexes. The accessed publications were evaluated in terms of publication years, publication type, journals published, number of citations, authors, institutions they are affiliated with, and preferred keywords. Analysis and visualizations of the "biblioshiny" program were used through "bibliometrix" in the Rstudio 4.4.2 package program.

Results

In the literature review, total of 1,949 publications from the international pediatric dentistry departments in Turkey, sourced from the WoS and Scopus databases, spanning the years 1984 to 2024. The first publication was a case report by Özkan et al., published in 1984 in the "Journal of Dentistry for Children" from Istanbul University.²²

It has been observed that the number of publications has been increasing since 2000. The year with the highest number of publications is 2022 (n=163) (Figure 3a). The highest citation rate per publication is 1.9 in 2020 (Figure 3b). In total, 3236 different authors are included in the publications. 47 publications are single-authored.

1949 publications were published in 398 different journals. "Journal of Clinical Pediatric Dentistry" (n=159), "Dental Traumatology" (n=82), "Journal of Dentistry for Children" (n=78), "European Journal of Paediatric Dentistry" (n=76), "Nigerian Journal of Clinical Practice" (n=66) and "International Journal of Paediatric Dentistry" (n=61) were found to be the journals with the most Turkish-based publications in the field of pediatric dentistry.

Among the authors, Figen Seymen, Betül Kargül and Zafer Çehreli are the authors with the most publications (Figure 4). Hacettepe University is the most productive institution with 390 publications. This ranking is followed by Istanbul, Ege and Marmara Universities (Table 1).

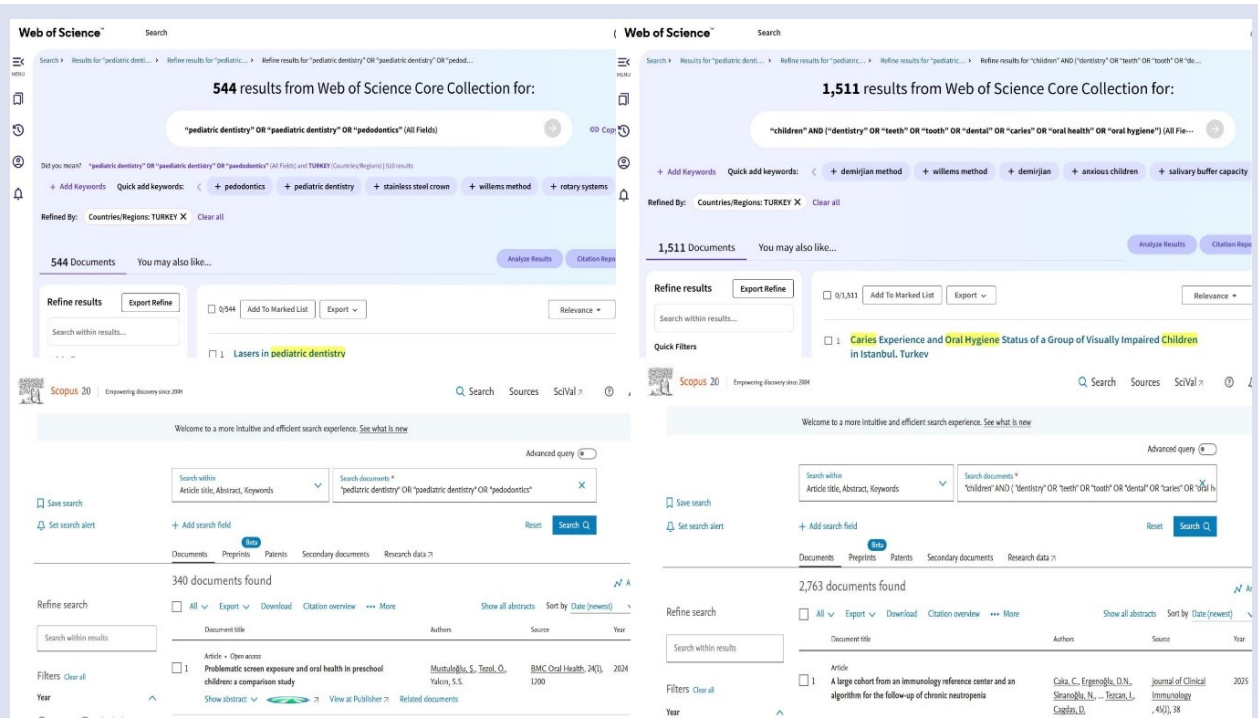


Figure 1. Database searches view

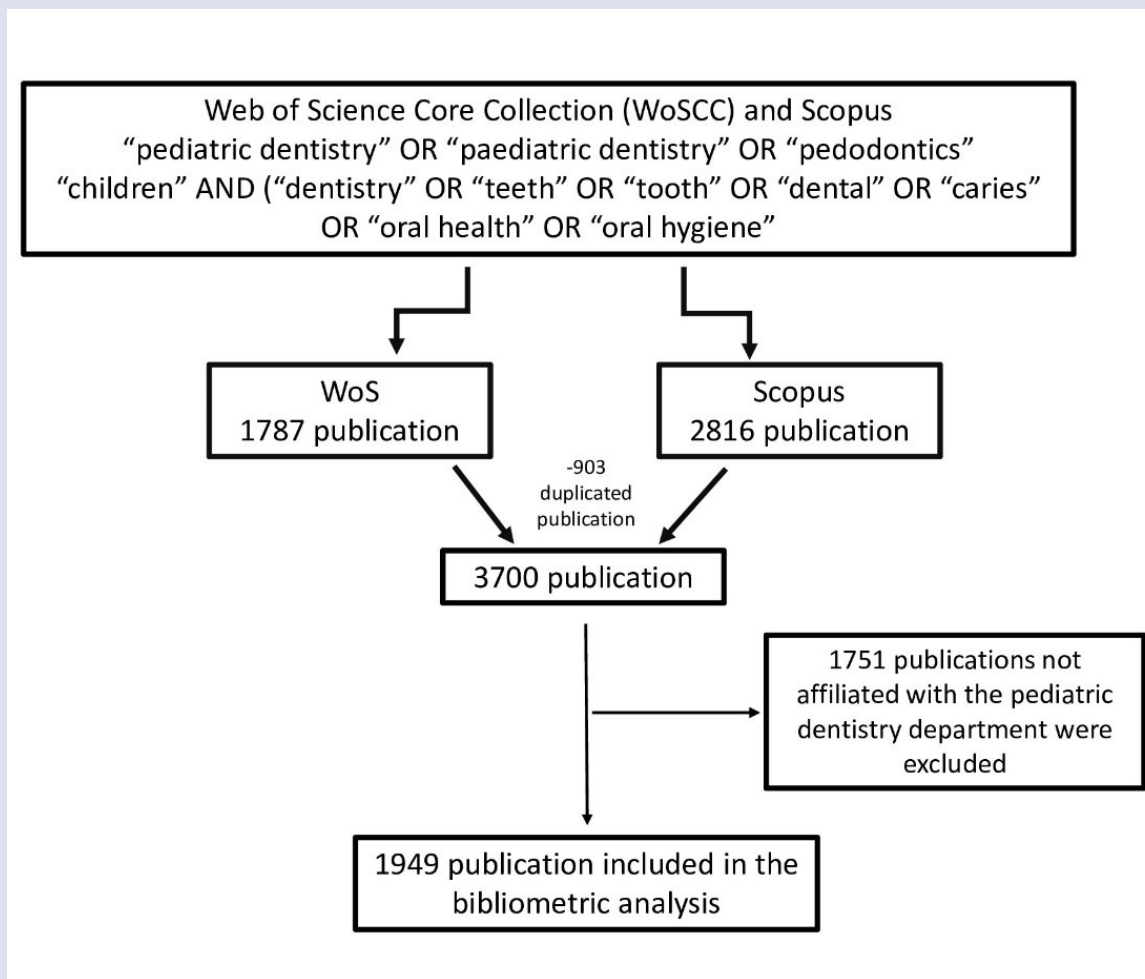


Figure 2. Flow chart of literature review

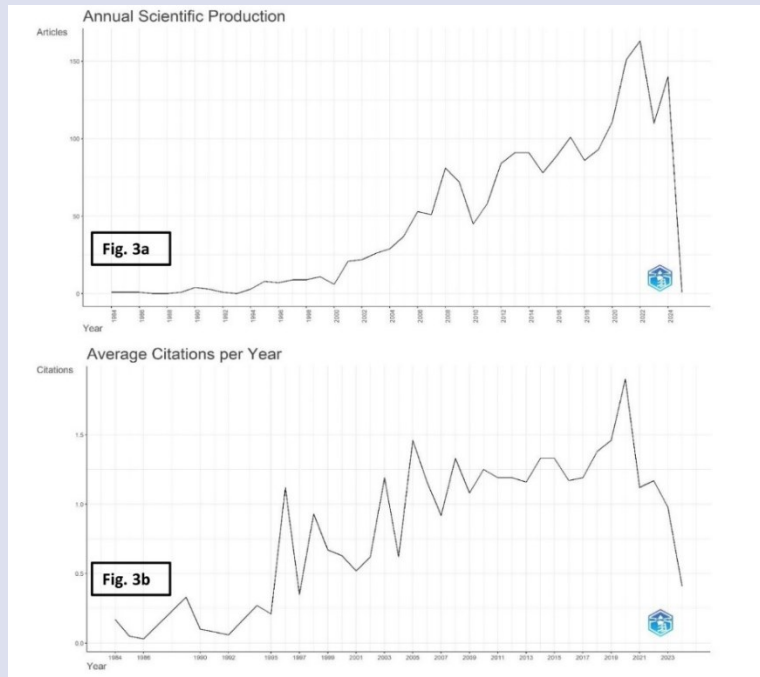


Figure 3. Distribution of publications and citations by year Fig. 3a. Distribution of the number of publications by year Fig. 3b. Distribution of citation numbers by year

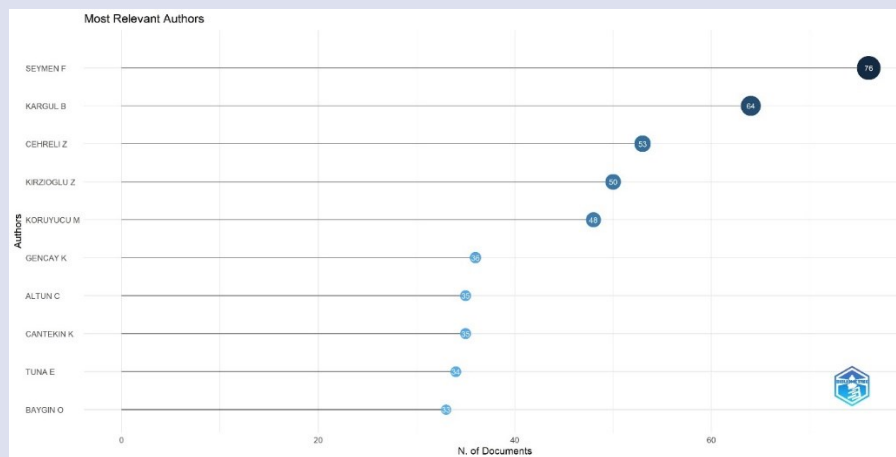


Figure 4. Examining the top 10 authors with the most publications

Table 1. Distribution of publications according to affiliated institutions

Affiliated Institution	Number of Publications
Hacettepe University	390
Istanbul University	371
Ege University	308
Marmara University	285
Ankara University	231
Gazi University	213
Erciyes University	174
Ataturk University	155
19 May University	151
Yeditepe University	135

*For all authors, their institutions are added to the list as numerical values.

When the most cited publications were examined, it was concluded that the 2020 Dental Trauma Guide received the most citations. The top 10 most cited publications are listed in Table 2. The most cited articles cover a diverse range of topics in dental research. Key areas include traumatic dental injuries, which focus on effective management strategies, and dental implantology, highlighting advancements in restorative practices. Endodontics and regeneration address innovative treatments for necrotic teeth, while public health and pediatric dentistry emphasize preventive measures for younger populations. Finally, the exploration of genetic factors in dental health reflects an interest in how genetics influence oral conditions (Table 2).

Turkey's cooperation with other countries is 5%. The countries with the most cooperation are the United States (n=46 publications), Brazil (n=14 publications), the United Kingdom (n=11 publications) and Italy (n=8 publications), respectively (Figure 5).

The three field plot used in bibliometric analysis is a type of graph consisting of three main columns, which allows easier examination of the relationship between the columns. According to the findings of the three field plot in Figure 6, which shows the relationships between authors and journals that collaborate across countries in the data set, it is seen that the most effective authors in cross-country collaboration are

Figen Seymen, Zafer Cehreli, Betül Kargul and Mine Koruyucu. When the sources show that the country with the most collaboration is the United States, it is seen that the Dental Traumatology journal stands out.

3368 keywords were used in 1949 publications. The most preferred keywords are "children" (n=178), "dental care" (n=135), "pediatric dentistry" (n=98), "primary teeth" (n=94) and "oral health" (n=92) (Figure 7). Additionally, which keywords are preferred together and which topics are studied are shown in Figure 8. Figure 8 shows the relationship between research topics intuitively. The size of nodes can reflect the frequency of keywords: the higher the frequency of the keyword, the larger the size of the node. Line thickness is proportional to the closeness of the links between two keywords, the thicker the line between two words, the closer the relationship.

Figure 9 shows the thematic analysis of 1949 publications. In the thematic map, it can be seen that the keyword group "pulpotomy", "mineral trioxide aggregate", "primary molar" and the keyword group "fluoride" and "remineralization" are currently the most preferred and the most studied active topics. However, although there are publications on the subjects of "amelogenesis imperfecta", "enamel" and "dental materials", it is noteworthy that they are less studied subjects than other subjects.

Table 2. Review of the 10 most cited publications

Reference	Publication name	Source	Number of citations	Year of publication
Bourguignon C et al. ²³	"International Association of Dental Traumatology guidelines for the management of traumatic dental injuries: 1. Fractures and luxations"	Dental Traumatology	246	2020
Oshida Y et al. ²⁴	"Dental implant systems"	International Journal of Molecular Sciences	178	2010
Cehreli ZC et al. ²⁵	"Regenerative endodontic treatment (revascularization) of immature necrotic molars medicated with calcium hydroxide: a case series"	Journal of Endodontics	172	2011
Ayhan H et al. ²⁶	"The effect of nursing or rampant caries on height, body weight and head circumference"	Journal of Clinical Pediatric Dentistry	161	1996
Onçag O et al. ²⁷	"Comparison of antibacterial and toxic effects of various root canal irrigants"	International Endodontic Journal	149	2003
Day PF et al. ²⁸	"International Association of Dental Traumatology guidelines for the management of traumatic dental injuries: 3. Injuries in the primary dentition"	Dental Traumatology	142	2020
Bezgin T et al. ²⁹	"Efficacy of platelet-rich plasma as a scaffold in regenerative endodontic treatment"	Journal of Endodontics	140	2015
Sen Tunc E et al. ³⁰	"Dental age assessment using Demirjian's method on northern Turkish children"	Forensic Science International	128	2008
Jeremias F et al. ³¹	"Genes expressed in dental enamel development are associated with molar-incisor hypomineralization"	Archives of Oral Biology	126	2013
Patir A et al. ³²	"Enamel formation genes are associated with high caries experience in Turkish children"	Caries Research	116	2008

Country Collaboration Map



Figure 5. International cooperation map

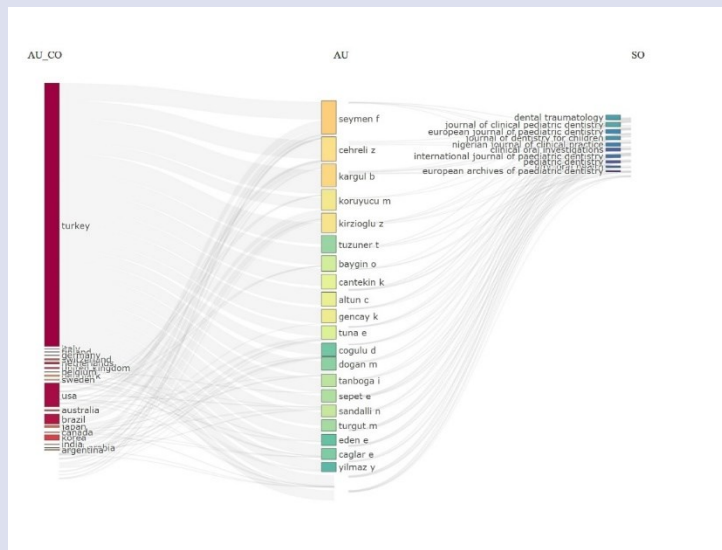


Figure 6. Three field plot with countries-authors-sources



Figure 7. Word cloud of publications

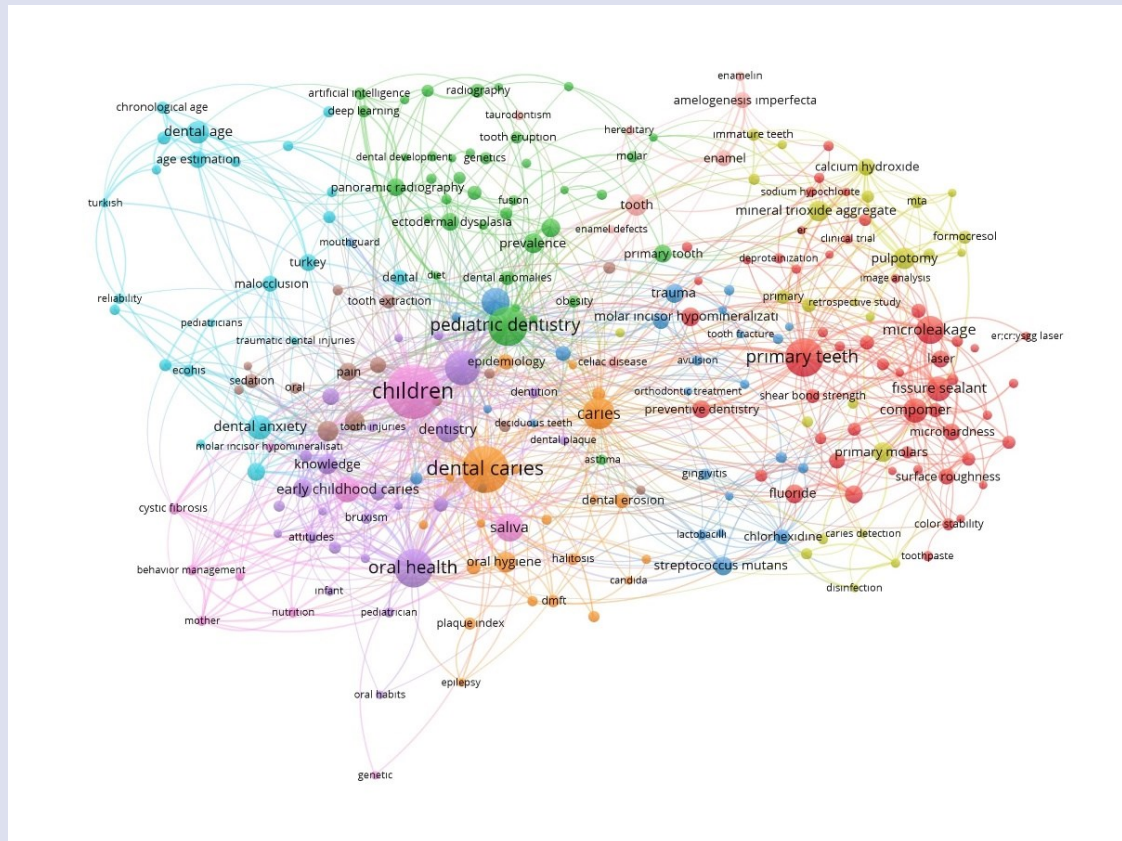


Figure 8. Authors' keywords visualization map (keyword threshold = 5; 244 out of 3368 keywords displayed). Each color represents different co-occurrence patterns based on multiple keywords from the dataset.

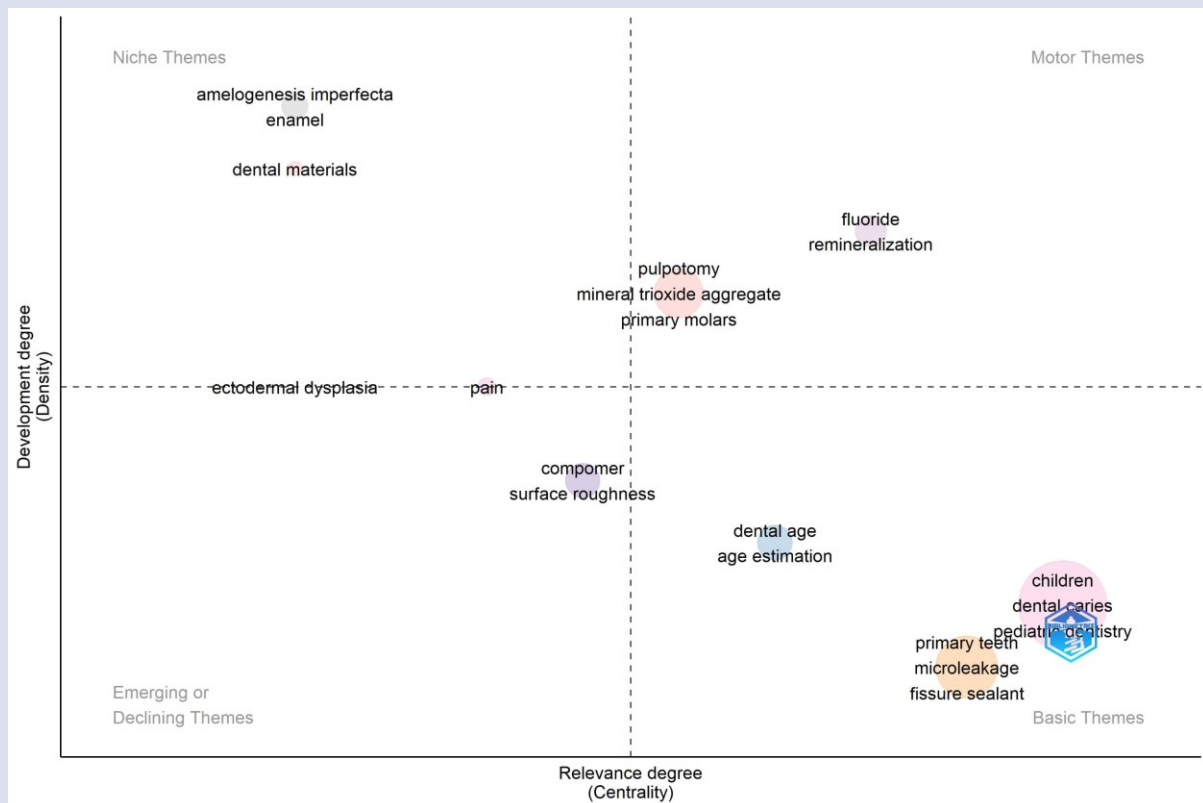


Figure 9. Thematic map of publications

Discussion

Health sciences are making progress and changes in the way they produce, use and interpret information. Therefore, professionals must constantly try to keep up with the latest developments. A large body of scientific research has been made available, helping to disseminate the results obtained. Bibliometric analyses are widely used to measure the scientific impact of any scientific publication. As a result of the bibliometric analysis, it can be seen what the level of the selected subject is at the international level or on a country basis, and areas where there is a trend and need to be studied more can be revealed. These results shed light on future studies.

The 1949 publications in the field of Turkish Pediatric Dentistry between 1984 and 2024 are important indicators of increasing academic productivity at the national level and contribution to the international literature. The increase in the number of publications, especially since 2000, indicates that the field has gained a rising momentum in Turkey. However, the highest rate per citation in 2020 (1.9) indicates the potential for an increase in the academic impact of the studies conducted in recent years. The thematic analysis results show that Turkish researchers focus on active topics of global interest such as “pulpotomy”, “mineral trioxide aggregate” and “fluoride”. However, less studied themes such as “amelogenesis imperfecta” and “dental materials” offer opportunities for future specialization in different subjects. In addition, when we look at the most cited studies, it is seen that field-oriented journals such as Dental Traumatology stand out, and the publications in these journals are internationally recognized. However, the fact that Turkey's international collaboration rate remains at a low level of 5% reveals that the field needs to be improved in terms of internationalization. The limited number of collaborations with countries such as the United States, Brazil and the United Kingdom indicate that these relations should be further expanded in the future. The limited number of authors who are effective in cross-country collaboration suggests that new initiatives are needed to expand these collaboration networks.

When the dental literature in Turkey is examined, it is seen that bibliometric analyses have been performed in the fields of orthodontics,¹³ endodontics,^{14,15} prosthodontics,^{16,17} oral and maxillofacial surgery,¹⁸ pediatric dentistry¹⁹ and theses^{20,21} in some fields of dentistry. Considering the publication dates of the publications, it is seen that bibliometric analysis in Turkey has come to the forefront in 2020 and after. These analyses show that the number of Turkish publications in international journals has increased from past to present. The reasons for this increase are likely to be easier access to journals with the development of technology, easier cooperation between countries, and changing academic promotion criteria in Turkey. In the literature review, no bibliometric analysis was found in the field of pediatric dentistry in Turkey.

In recent years, bibliographic databases have become increasingly important as they provide essential publication

metadata and bibliometric indicators used for research evaluation and everyday academic tasks. Among the most recognized are WoS and Scopus, both of which offer extensive data for various purposes, including literature reviews and citation analysis. While WoS and Scopus share some common data, such as core journal articles and citation information, they are not entirely inclusive of one another. Each database has its unique strengths and coverage areas, which can lead to different citation metrics and bibliometric analyses. This distinction is crucial for researchers who aim to obtain a comprehensive understanding of their field and to accurately assess the reach and influence of their work. Consequently, many scholars and institutions find value in utilizing both databases to ensure a thorough and nuanced approach to research evaluation.³³ For this reason, WoS and Scopus databases were used in our study in order to reach more publications by minimizing data loss.

In our study, we conducted a bibliometric analysis using RStudio and the R bibliometrix package, enhanced by the Biblioshiny plugin. This tool generates research outputs that help analyze various aspects of scientific production, including identifying the most prolific authors, frequently used keywords, popular journals, and cross-country collaborations related to the chosen research topic.³⁴ One of the important reasons why R programming language was preferred in the study is that it enables analysis by combining data from multiple databases, as seen in this study. Other reasons for choosing R are that it makes data analysis easier and faster, visualizations and data are clearer, there are many features that can be used for analysis, Biblioshiny's web interface is constantly updated and open access.

Co-authorship analysis explores the interactions among academics within a research field. Since co-authorship represents a formal mode of intellectual collaboration, it is essential to understand how these partnerships influence research dynamics and knowledge development.^{35,36} Scholars engage with one another, considering factors such as their affiliations and countries. Collaborative efforts among researchers can enhance the quality of research; for instance, input from diverse scholars can provide greater clarity and deeper insights.³⁷ In this context, collaborating academics create a network that can advance research initiatives. For instance, analysis can reveal clusters of research among scholars in a specific region, providing insights that can encourage and justify new studies in underrepresented areas. Additionally, this analysis enables the mapping of collaborations over time, allowing researchers to observe the progression of intellectual growth within collaborative networks and facilitating connections between emerging scholars and established or trending figures in the field.³⁸ Upon examining the triple area graph, we observe that various authors have engaged in international interactions over time, reinforcing the significance of collaboration in research. It is gratifying to recognize the value of such cooperation.

Turkey's current collaboration rate in pediatric dentistry stands at a mere 5%, a figure that highlights the

urgent need for enhanced international cooperation. To address this issue, several strategies can be implemented. Establishing partnerships with leading dental schools and clinics worldwide could facilitate knowledge exchange and professional training programs. Encouraging joint research projects focused on pediatric dentistry may lead to shared innovations and findings that benefit both local and international communities. Additionally, creating professional networks would allow dental practitioners to connect with their counterparts abroad, sharing best practices and case studies. Continuing education opportunities, such as workshops and seminars featuring international experts, could further enhance the skills of local professionals. Government support for international collaboration initiatives, including funding for exchange programs, is also crucial. Participation in international conferences can foster networking opportunities, while telemedicine initiatives can enable Turkish dentists to consult with specialists globally, thereby improving care quality. Finally, public awareness campaigns about the significance of pediatric dental care could attract international interest and collaboration in community outreach efforts. By implementing these strategies, Turkey can significantly improve its collaboration in pediatric dentistry, ultimately benefiting the health of its younger population.

Citation analysis is a key method in science mapping based on the idea that citations reflect intellectual connections between publications, as one work cites another.³⁹ Through this analysis, a publication's impact is assessed based on the total number of citations it garners, enabling the identification of the most influential works within a particular research area. Citations serve as the most straightforward and objective indicator of the influence of publications within a research field.^{40,41} Consequently, by analyzing citations, one can identify the most influential works within a research area to gain insights into the intellectual dynamics of that field; thus, we focused our examination on the publications with the highest citation counts.

Evaluating the titles of the most cited publications in Table 2 reveals several key themes in dental research. A notable focus is on traumatic dental injuries, with two publications dedicated to guidelines from the International Association of Dental Traumatology. This underscores the importance of standardized protocols for managing dental emergencies, particularly concerning fractures and luxations, as well as injuries in primary dentition. Additionally, the inclusion of a publication on "Dental implant systems" highlights the ongoing interest in implant technology, a critical area in restorative dentistry. The theme of endodontics and regeneration is also prominent, with multiple entries discussing regenerative endodontic treatments for immature necrotic teeth, indicating a growing emphasis on innovative healing techniques, such as the use of calcium hydroxide and platelet-rich plasma. Furthermore, public health concerns are addressed through studies that examine the effects of nursing and rampant caries on

children's growth metrics, along with dental age assessment methods in specific populations, such as northern Turkish children.

Genetic factors in dental health are explored as well, with two publications investigating the genetic basis of conditions like molar-incisor hypomineralization and caries experience, suggesting an increasing recognition of genetics' role in dental health and disease susceptibility. Lastly, research comparing the antibacterial and toxic effects of various root canal irrigants points to an ongoing evaluation of treatment modalities aimed at enhancing patient outcomes in endodontic therapy. Overall, these titles reflect a diverse range of interests in dentistry, emphasizing trauma management, endodontic regeneration, pediatric health, and the genetic underpinnings of dental conditions, all crucial for advancing clinical practices and improving patient care.

The findings indicate that the number of publications in the field of pediatric dentistry in Turkey has been steadily increasing over the years. To further enhance this growth, it is essential to continue promoting additional research efforts. Given Turkey's international economic standing, there should be an increase in financial support for these studies to foster continued advancement in the field.

Similar to how an article's keywords can signify its core content, the frequency of occurrence and co-occurrence can also indicate the themes emphasized within a specific area.⁴² The more two keywords are found together, the closer the relationship between them. To uncover the structure and evolution of research areas, several common word analysis techniques, including cluster analysis and social network analysis, have been utilized based on a common word matrix. These methods assist researchers in gaining an overall understanding of a particular field. Consequently, it is crucial for assessing the significance of an academic discipline.^{42,43} In our keyword analysis, it is seen that some topics remain in the background and are less studied. Therefore, the remaining research areas need to be investigated further.

Limitations

Although an extensive literature review was conducted using two different databases in our study, some publications may not have been reached. When the files of different databases were combined, some data losses such as the number of individual citations of the authors, cooperation between institutions within the country, and the open access nature of the publications were not included in these findings.

While our study involved an extensive literature review using two different databases, it's worth noting that some publications may have been inadvertently overlooked. This possibility could introduce certain gaps in the data, particularly in areas such as individual citations, institutional cooperation within the country, and the open-access status of publications. The absence of these data points may subtly influence the overall findings, potentially leading to an incomplete representation of the research landscape in the

field. For example, not capturing the number of citations might limit our ability to fully assess the impact and relevance of specific studies, while missing collaboration data could diminish our understanding of the interdisciplinary partnerships that are essential for advancing pediatric dentistry. Acknowledging these limitations allows us to recognize areas for improvement and encourages future research to adopt more comprehensive approaches, ensuring that the full spectrum of available literature is considered.

To mitigate these issues, several solutions can be proposed. First, expanding the search to include additional databases or grey literature sources could enhance the comprehensiveness of the review. Utilizing citation-tracking tools may also help in identifying overlooked studies and their impact. Furthermore, conducting a follow-up survey or interviews with key researchers and institutions could provide insights into unpublished data and foster a better understanding of collaboration dynamics. Lastly, establishing a system for regular updates and reviews of the literature could ensure that future analyses remain current and inclusive, thereby improving the overall robustness of the research outcomes. By addressing these data losses proactively, the study can achieve a more accurate and representative understanding of the pediatric dentistry landscape.

Conclusions

Studies conducted in the field of Turkish Pediatric Dentistry between 1984 and 2024 have demonstrated significant advancements in scientific productivity and impact. An analysis of a total of 1,949 publications reveals that Hacettepe University is the most productive institution, while Figen Seymen, Zafer Cehreli, and Betul Kargul are identified as the most influential authors. The majority of publications focus on active themes such as 'pulpotomy,' 'mineral trioxide aggregate,' 'fluoride,' and 'remineralization'; however, it has been noted that the rate of international collaboration is limited to just 5%. These findings indicate a need for the field to enhance international collaborations and thematic diversity. Future studies could broaden the scope of these results by analyzing additional databases.

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Conflicts of Interest Statement

No conflict of interest was declared by the authors.

Authorship Contributions

Concept: T.T., M.T., Design T.T., M.T., Data Collection or Processing: T.T., M.T., Analysis or Interpretation: T.T., M.T., Literature Search: T.T., M.T., Writing: T.T., M.T.

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Assessing the Success of ChatGPT-4o in Oral Radiology Education and Practice: A Pioneering Research

Fatma Akkoca^{1,a,*}, Melih Özdede^{1,b}, Günnur İlhan^{1,c}, Emre Koyuncu^{1,d}, Hülya Ellidokuz^{2,3,e}

¹Department of Dentomaxillofacial Radiology, Faculty of Dentistry, Dokuz Eylül University, İzmir, Türkiye

²Department of Biostatistics and Medical Informatics, Faculty of Medicine, Dokuz Eylül University, İzmir, Türkiye

³Department of Preventive Oncology, Institute of Oncology, Dokuz Eylül University, İzmir, Türkiye

*Corresponding author

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ABSTRACT

Objectives: This study aims to assess the comprehension and interpretation performance of Chat Generative Pre-Train Omni (GPT-4o) in the context of oral radiology education and practice.

Materials and Methods: Utilizing a set of 99 questions derived from the book "White and Pharoah's Oral Radiology: Principles and Interpretation 8th Edition," this study employed ChatGPT-4o to respond to these questions thrice daily at varying times over 10 days, generating a total of 60 responses for each question. Two oral radiologists independently answered the same questions and verified their answers with the relevant textbook. Responses were compared to those of ChatGPT-4o.

Results: The study revealed that ChatGPT-4o's correct answer rate was 59.4%. Time-based analysis revealed performance differences across specific day periods. Specifically, during noon and evening sessions, the success rate on the first and seventh days was statistically significantly higher ($p = 0.003$ and $p = 0.002$, respectively), while morning performance on those days was significantly lower ($p < 0.05$), indicating that the time and day of the query may influence response accuracy. In contrast, no significant relationship was found between the difficulty level of the questions and the model's accuracy ($p > 0.05$).

Conclusions: Presently, ChatGPT exhibits inadequacies in its application to oral radiology training and clinical practice. Despite this, expectations for platform improvement and expansion in utility persist, particularly with increased data input and advancements in artificial intelligence.

Keywords: Artificial Intelligence, ChatGPT, Dental Education, Oral Radiology

Oral Radyoloji Eğitimi ve Uygulamasında ChatGPT-4o'nun Başarısının Değerlendirilmesi: Öncü Bir Araştırma

Araştırma Makalesi

Süreç

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ÖZET

Amaç: Bu çalışma, Chat Generative Pre-Train Omni (GPT-4o) platformunun oral radyoloji eğitimi ve pratiği konusunda anlama ve yorumlama performansını değerlendirmeyi amaçlamaktadır.

Gereç ve Yöntemler: Çalışmada, "White and Pharoah's Oral Radiology: Principles and Interpretation 8th Edition" kitabından alınan 99 sorudan oluşan bir set kullanılmıştır. Bu sorular, ChatGPT-4o tarafından günün üç farklı periyodunda, 10 gün boyunca yanıtlanmış ve her soru için toplam 60 yanıt üretilmiştir. Aynı soruları iki ağız, diş ve çene radyolojisi uzmanı da yanıtlanmış ve verdikleri cevaplar ilgili ders kitabı ile doğrulanmıştır. ChatGPT-4o'nun cevapları ile uzmanların cevapları karşılaştırılmıştır.

Bulgular: Çalışmada ChatGPT-4o'nun doğru yanıt verme oranı %59,4 olarak bulunmuştur. Zaman temelli analiz, belirli gün ve saat dilimlerinde performans farklılıkları olduğunu ortaya koymuştur. Özellikle öğle ve akşam oturumlarında, birinci ve yedinci günlerdeki başarı oranı istatistiksel olarak anlamlı şekilde daha yükseken (sırasıyla $p = 0,003$ ve $p = 0,002$), aynı günlerdeki sabah performansı anlamlı derecede daha düşüktü ($p < 0,05$). Bu bulgular, sorgulamanın yapıldığı gün ve saatin yanıt doğruluğunu etkileyebileceğini göstermektedir. Öte yandan, soruların zorluk düzeyi ile modelin doğruluk oranı arasında anlamlı bir ilişki bulunmamıştır ($p > 0,05$).

Sonuç: Mevcut durumda, ChatGPT oral radyoloji eğitimi ve klinik pratiğinde yetersizlikler göstermiştir. Buna rağmen, platformun daha fazla veri girişi ve yapay zekadaki ilerlemelerle birlikte gelişmesi ve kullanım alanlarının genişlemesi konusunda beklentiler devam etmektedir.

Anahtar Kelimeler: ChatGPT, Diş Hekimliği Eğitimi, Oral Radyoloji, Yapay Zekâ

^a fatma.akkoca@deu.edu.tr

^c gunnur.ilhan@deu.edu.tr

^e hulya.ellidokuz@deu.edu.tr

^b melih.ozdede@deu.edu.tr

^d emre.koyuncu@deu.edu.tr

^e hulya.ellidokuz@deu.edu.tr

^b melih.ozdede@deu.edu.tr

^d emre.koyuncu@deu.edu.tr

^e hulya.ellidokuz@deu.edu.tr

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Introduction

Artificial intelligence (AI) signifies the ability of computer systems to emulate cognitive functions and execute tasks with a human-like proficiency.¹ This is achieved through the refinement of algorithms that enable machines to process, learn, and autonomously tackle complex problems.² The field of AI has experienced rapid advancements, marked by an increasing prevalence of artificial intelligence-based chatbots and conversational agents.³

In 2018, Open AI introduced the Generative Pre-Train (GPT) language model, with subsequent developments leading to the creation of ChatGPT in subsequent years.³ Operating on the foundation of Large Language Models (LLMs), this software is designed to replicate human speech, comprehend the nuances of language, and generate novel content based on its exposure to training data.⁴ ChatGPT finds applications in diverse areas such as idea generation, creative endeavors, coding, text editing, and academic article writing.^{5,6}

Launched on May 13, 2024, GPT-4o became a significant upgrade to the GPT series, offering promising features such as multimodal capabilities (text, image, and audio processing), faster performance, expanded multilingual support, a larger context window, and improved accuracy. Launched on March 14, 2023, GPT-4 uses a Transformer-based model, a paradigm that includes pre-training using both public data and “licensed data from third-party providers” to predict the next token.⁷ However, ChatGPT’s ability to access only a variety of internet data until 2021, combined with its limited access to relevant databases, raises concerns about the timeliness and reliability of the information it produces.⁸ Another drawback lies in its tendency to spread false information, which poses a challenge for inexperienced users to distinguish between real and fake information.⁶

While studies in the medical field have showcased ChatGPT’s potential as a medical consultation tool, comprehensive examinations are essential to evaluate its performance across different medical specialties.^{9,10,11} In the realm of oral radiology, ChatGPT offers swift access to a vast repository of medical information, providing clinical guidelines and current research for various oral conditions and diseases. Dentists and oral radiologists can leverage ChatGPT to enhance diagnostic skills and clinical practice.¹² Multiple studies have been conducted exploring the applicability and effectiveness of ChatGPT in the field of oral radiology, investigating its potential to support diagnostic accuracy, clinical decision-making, and educational purposes.¹³⁻¹⁷ Moreover, the software has the potential to augment diagnostic quality by analyzing patient symptoms and relevant data, guiding oral radiologists toward potential diagnoses and imaging options.¹³ Beyond this, ChatGPT holds promise for the future of distance consultation and telemedicine.¹⁸

This study aims to assess the comprehension and interpretation performance of ChatGPT-4o in the context of oral radiology education and practice.

Materials and Methods

Ethical Approval

There is no human as a participant in the study and ethical approval for this research was not required.

Question Design

The questions set are prepared based on ‘White and Pharoah’s Oral Radiology: Principles and Interpretation 8th Edition’.¹⁹ It was arranged as three questions from each section, totally 99 questions in from 33 sections. According to difficulty levels, questions were classified as easy, medium, and difficult.

Generating Answers in ChatGPT

Two authors (GI, EK), using two different accounts, performed response generation using ChatGPT-4o. ChatGPT responses were captured three times (morning:09.00, noon:12.00, and evening:17.00) by selecting the ‘new chat’ option for 10 days until 60 responses per question were obtained. This study benefited from the study of Soares *et al.*²⁰

Human Expert Answers

Two dentomaxillofacial radiologists with at least five years of experience (FA, MO) independently answered (‘yes’ or ‘no’) to 99 questions. In case of inconsistency in expert answers the questions and literature were re-evaluated and a consensus was reached.

Statistical Analysis

All answers were recorded in an Excel spreadsheet and analyzed using the statistical software program of SPSS (Version 29, IBM, Armonk, NY, USA). Kappa and McNemar tests were used for the agreement of two profiles, and the agreement of different days. Chi-square test was performed for the comparison of difficulty levels and correct answers. Cochran-Q test was used for the relationship between different days, also between three periods of the days. The significance level was set to 0.05.

Results

The overall accuracy rate of ChatGPT-4o in providing correct answers was found to be 59.4%. A detailed time-based analysis further delineated the accuracy rates as 59.1% at 09:00, 59.5% at 12:00, and 59.5% at 17:00.

The agreement between profiles was assessed using Kappa and McNemar tests. It was observed that there was perfect agreement for all queries ($p = 1.000$, indicating perfect agreement), and the analysis continued with a single profile.

Sixty ChatGPT-4o queries with expert responses were evaluated using McNemar and Kappa tests (refer to Table 1). There was no significant agreement between ChatGPT-4o responses and expert responses ($p > 0.05$). ChatGPT-4o’s performance was evaluated based on the accuracy of its answers to questions from different subjects since only three questions were asked per subject. The obtained accuracy percentages are as follows: while it performed

well in theoretical and structured subjects such as Physics (100%) and Quality Assurance & Infection Control (100%), its accuracy declined in complex diagnostic fields such as Prescribing Diagnostic Imaging (26.7%), Forensics (33.3%), and Cysts (33.3%) (refer to Table 2).

The difficulty level of the questions and the rates of correct and incorrect answers were compared using a chi-square test for a total of 60 queries. No significant relationship was detected between the difficulty level and the correct answer rate for any of these questions ($p > 0.05$). The Kappa values were ranged from 0.091 to 0.863. The relationship between answers and correct answers to questions asked on different days was evaluated using the

Cochran-Q test. There was no significant difference between different days during morning interrogations ($p = 0.558$). However, during noon and evening interrogations, the success rate on the first and seventh days was statistically significantly higher (P-values of noon and evening, respectively: $p = 0.003$, $p = 0.002$).

The relationship between periods of the day and the given answers was assessed using the Cochran Q test (refer to Table 3). It was determined that the morning inquiries on the first and seventh days were statistically lower than other day periods ($p < 0.05$).

Table 1. Evaluation of expert response and ChatGPT response of 60 queries

	Chatgpt response					P value	Chatgpt response					P value
	Day and time	Answer	Yes	No	Day and time		Answer	Yes	No			
Expert response	1M	Yes	33	9	0.192	6M	Yes	34	8	0.265		
			78.60%	21.40%				81.0%	19.0%			
		No	50.00%	27.30%			No	53.1%	22.9%			
			33	24				30	27			
	1N	Yes	57.90%	42.10%	0.168	6N	Yes	52.6%	47.4%	0.265		
			50.00%	72.70%				46.9%	77.1%			
		No	35	7			No	34	8			
			83.30%	16.70%				81.0%	19.0%			
	1E	Yes	48.60%	25.90%	0.168	6E	Yes	53.1%	22.9%	0.265		
			37	20				30	27			
		No	64.90%	35.10%			No	52.6%	47.4%			
			51.4	74.10%				46.9%	77.1%			
	2M	Yes	35	7	0.205	7M	Yes	34	8	0.192		
			83.30%	16.70%				81.0%	19.0%			
		No	48.60%	25.90%			No	53.1%	22.9%			
			37	20				30	27			
	2N	Yes	64.90%	35.10%	0.265	7N	Yes	52.6%	47.4%	0.168		
			51.40%	74.10%				46.9%	77.1%			
		No	32	10			No	33	9			
			76.2%	23.8%				78.6%	21.4%			
	2E	Yes	50.8%	27.8%	0.265	7E	Yes	50.0%	27.3%	0.168		
			31	26				33	24			
		No	54.4%	45.6%			No	57.9%	42.1%			
			49.2%	72.2%				50.0%	72.7%			
3M	Yes	34	8	0.18	8M	Yes	35	7	0.205			
		81.0%	19.0%				83.3%	16.7%				
	No	53.1%	22.9%			No	48.6%	25.9%				
		30	27				37	20				
	Yes	52.6%	47.4%	0.265		Yes	64.9%	35.1%	0.168			
46.9%		77.1%	51.4%				74.1%					
No	34	8	No			35	7					
	81.0%	19.0%				83.3%	16.7%					
	Yes	53.1%	22.9%	0.265		Yes	48.6%	25.9%	0.168			
30		27	37				20					
No	52.6%	47.4%	No			64.9%	35.1%					
	46.9%	77.1%				51.4%	74.1%					
	Yes	34	8	0.18		Yes	32	10	0.205			
81.0%		19.0%	76.2%				23.8%					
No	49.3%	26.7%	No			50.8%	27.8%					
	35	22				31	26					
	No	61.4%	38.6%	0.18		No	54.4%	45.6%	0.205			
50.7%		73.3%	49.2%				72.2%					

3N	Yes	32 76.2%	10 23.8%	0.205	8N	Yes	34 81.0%	8 19.0%	0.265
	No	50.8%	27.8%			No	53.1%	22.9%	
3E	Yes	31 54.4%	26 45.6%	0.205	8E	Yes	30 52.6%	27 47.4%	0.265
	No	49.2%	72.2%			No	46.9%	77.1%	
4M	Yes	32 76.2%	10 23.8%	0.265	9M	Yes	34 81.0%	8 19.0%	0.18
	No	50.8%	27.8%			No	53.1%	22.9%	
4N	Yes	31 54.4%	26 45.6%	0.265	9N	Yes	30 52.6%	27 47.4%	0.205
	No	49.2%	72.2%			No	46.9%	77.1%	
4E	Yes	34 81.0%	8 19.0%	0.265	9E	Yes	34 81.0%	8 19.0%	0.205
	No	53.1%	22.9%			No	49.3%	26.7%	
5M	Yes	30 52.6%	27 47.4%	0.252	10M	Yes	35 61.4%	22 38.6%	0.265
	No	46.9%	77.1%			No	50.7%	73.3%	
5N	Yes	34 81.0%	8 19.0%	0.205	10N	Yes	32 76.2%	10 23.8%	0.265
	No	53.1%	22.9%			No	50.8%	27.8%	
5E	Yes	30 52.6%	27 47.4%	0.205	10E	Yes	31 54.4%	26 45.6%	0.265
	No	46.9%	77.1%			No	49.2%	72.2%	

M: morning, N: noon, E: evening

Table 2. Percentage of correct answers by ChatGPT-4o for subtopic questions in 'Oral Radiology: Principles and Interpretation, 8th Edition'

Subjects		Correct Percentage
1	Physics	100.0%
2	Quality Assurance and Infection Control	100.0%
3	Dental Caries	91.1%
4	Periodontal Diseases	82.2%
5	Safety and Protection	77.8%
6	Biologic Effects of Ionizing Radiation	73.3%
7	Paranasal Sinus Diseases	68.9%
8	Beyond Three-Dimensional Imaging	66.7%
9	Trauma	66.7%

10	Diseases Affecting the Structure of Bone	66.7%
11	Benign Tumors and Neoplasms	66.7%
12	Soft Tissue Calcifications and Ossifications	66.7%
13	Inflammatory Conditions of the Jaws	66.7%
14	Craniofacial Anomalies	66.7%
15	Intraoral Projections	66.7%
16	Digital Imaging	66.7%
17	Radiographic Anatomy	64.4%
18	Salivary Gland Diseases	60.0%
19	Other Imaging Modalities	57.8%
20	Malignant Neoplasms	55.6%
21	Dental Implants	54.4%
22	Film Imaging	51.1%
23	Principles of Radiographic Interpretation	48.9%
24	Dental Anomalies	48.9%
25	Cone Beam Computed Tomography: Volume Acquisition	42.2%
26	Cephalometric and Skull Imaging	42.2%
27	Projection Geometry	42.2%
28	Temporomandibular Joint Abnormalities	35.6%
29	Cone Beam Computed Tomography: Volume Preparation	35.6%
30	Forensics	33.3%
31	Cysts	33.3%
32	Panoramic Imaging	33.3%
33	Prescribing Diagnostic Imaging	26.7%

Table 3. Assessment of relationship between periods of the day and given answers

Days	Morning (Yes-No)	Noon (Yes-No)	Evening (Yes-No)	P value
D1	66-33	72-27	72-27	0.011*
D2	63-36	64-35	64-35	0.926
D3	69-30	63-36	63-36	0.050
D4	64-35	64-35	64-35	1.0
D5	67-32	63-36	63-36	0.264
D6	64-35	64-35	64-35	1.0
D7	66-33	72-27	72-27	0.011*
D8	63-36	64-35	64-35	0.926
D9	69-30	63-36	63-36	0.050
D10	64-35	64-35	64-35	1

Assessment of relationship between periods of the day and given answers using the Cochran Q Test *P < 0.05

Discussion

In recent times, ChatGPT has gained popularity as a valuable research tool, with studies exploring its applications in both clinical and educational contexts within the medical field.^{7,9,12,20} Focusing on oral and maxillofacial radiology, a specialized branch of dentistry dealing with image acquisition and interpretation in the maxillofacial region for diagnosis and treatment planning, this study delves into the educational and clinical efficacy of ChatGPT-4o, the latest iteration of the ChatGPT series.¹⁴

Suarez *et al.* conducted a study assessing the platform's effectiveness in endodontics, achieving a success rate of 57.3%, consistent with the findings of this study.²⁰ Their study also highlighted consistency across different times of the day. Similarly, Antaki *et al.* utilized the ChatGPT Plus BCSC test set, obtaining 59.4% accuracy in a simulated Ophthalmic Knowledge Assessment Program examination and 49.2% accuracy in the OphthoQuestions test set.²¹ The accuracy rates in the field of ophthalmology align closely with the performance of ChatGPT-4o in the realm of oral radiology in this study.

Contrastingly, Bragazzi *et al.* evaluated ChatGPT's diagnostic accuracy in endodontic cases, reporting varied results.²² While it correctly identified existing endodontic treatments, tooth

decay, and dental restorations in certain cases, it displayed limitations in detecting endodontic lesions, resulting in an overall correct interpretation rate of 11%. In the present study, clinical cases were not directly evaluated as images; however, when lesions were described with clinical-radiological features in written form, ChatGPT-4o exhibited more accurate verbal interpretation.

Mago *et al.* explored the use of ChatGPT-3 for radiology report writing and educational purposes in oral and maxillofacial radiology, emphasizing the need for improvement in queries related to anatomical landmarks and radiographic features of pathologies.¹⁵ This study, utilizing ChatGPT-4o, suggests advancements in the platform, showcasing its continuous development and improvement, which bodes well for the future of artificial intelligence technologies.

Bhayana *et al.* evaluated ChatGPT's performance on multiple-choice examination questions in medical radiology without images, achieving a 69% correct response rate.¹⁶ While their results appear more successful than this study, which focused on oral radiology, the differences in question types and content may account for variations in performance.

Ozturk *et al.* conducted a study evaluating ChatGPT's success in oral radiology education, where ChatGPT-4o

demonstrated a high success rate, correctly answering 15 out of 20 multiple-choice questions (75%).¹⁷ However, the smaller question set and focus on undergraduate education may have contributed to a seemingly higher success rate compared to this study. Despite its numerous advantages, ChatGPT raises ethical concerns, persistent misinformation issues, copyright considerations, and legal and regulatory challenges.¹⁵ Addressing these concerns necessitates additional studies and research efforts to ensure this technology's responsible and effective use in various domains.

An analysis of ChatGPT-4o's performance revealed significant variations in accuracy across different subjects. While it performed well in theoretical and structured subjects, such as Physics and Quality Assurance & Infection Control, its accuracy declined in complex diagnostic domains, including Diagnostic Imaging Prescribing, Forensic Medicine, and Cysts. These findings suggest that ChatGPT-4o excels in well-defined, rule-based topics because it can process structured information efficiently. However, the results also indicate that the AI requires further training in clinical diagnosis-based areas, particularly those that rely on visual support. Its lower accuracy in complex diagnostic fields may be attributed to the need for contextual understanding and interpretation of visual data, which remains a challenge for language-based AI models.

Conclusions

This study showed that ChatGPT-4o has limitations in terms of its suitability in oral radiology education and clinical practice due to intra- and inter-day inconsistencies and low correct response rates. It also demonstrates that it is very important and mandatory for the platform to undergo special training that focuses specifically on medical information. However, it is foreseeable that the platform will be further developed, and its scope of use is expected to expand in parallel with increasing data entry and developments in artificial intelligence. Continuous improvement and development of the platform hold the potential to overcome current limitations and make ChatGPT a more robust and effective tool in the field of oral radiology and medical education.

Ethics Approval

Formal ethical approval was not required for this study. The research did not involve human participants and therefore was not subject to ethical standards pertaining to human experimentation.

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Conflicts of Interest Statement

The authors declare that they have no conflicts of interest

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Assessing the Success of ChatGPT-4o in Oral Radiology Education and Practice: A Pioneering Research

Fatma Akkoca^{1,a,*}, Melih Özdede^{1,b}, Günnur İlhan^{1,c}, Emre Koyuncu^{1,d}, Hülya Ellidokuz^{2,3,e}

¹Department of Dentomaxillofacial Radiology, Faculty of Dentistry, Dokuz Eylül University, İzmir, Türkiye

²Department of Biostatistics and Medical Informatics, Faculty of Medicine, Dokuz Eylül University, İzmir, Türkiye

³Department of Preventive Oncology, Institute of Oncology, Dokuz Eylül University, İzmir, Türkiye

*Corresponding author

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ABSTRACT

Objectives: This study aims to assess the comprehension and interpretation performance of Chat Generative Pre-Train Omni (GPT-4o) in the context of oral radiology education and practice.

Materials and Methods: Utilizing a set of 99 questions derived from the book "White and Pharoah's Oral Radiology: Principles and Interpretation 8th Edition," this study employed ChatGPT-4o to respond to these questions thrice daily at varying times over 10 days, generating a total of 60 responses for each question. Two oral radiologists independently answered the same questions and verified their answers with the relevant textbook. Responses were compared to those of ChatGPT-4o.

Results: The study revealed that ChatGPT-4o's correct answer rate was 59.4%. Time-based analysis revealed performance differences across specific day periods. Specifically, during noon and evening sessions, the success rate on the first and seventh days was statistically significantly higher ($p = 0.003$ and $p = 0.002$, respectively), while morning performance on those days was significantly lower ($p < 0.05$), indicating that the time and day of the query may influence response accuracy. In contrast, no significant relationship was found between the difficulty level of the questions and the model's accuracy ($p > 0.05$).

Conclusions: Presently, ChatGPT exhibits inadequacies in its application to oral radiology training and clinical practice. Despite this, expectations for platform improvement and expansion in utility persist, particularly with increased data input and advancements in artificial intelligence.

Keywords: Artificial Intelligence, ChatGPT, Dental Education, Oral Radiology

Oral Radyoloji Eğitimi ve Uygulamasında ChatGPT-4o'nun Başarısının Değerlendirilmesi: Öncü Bir Araştırma

Araştırma Makalesi

Süreç

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ÖZET

Amaç: Bu çalışma, Chat Generative Pre-Train Omni (GPT-4o) platformunun oral radyoloji eğitimi ve pratiği konusunda anlama ve yorumlama performansını değerlendirmeyi amaçlamaktadır.

Gereç ve Yöntemler: Çalışmada, "White and Pharoah's Oral Radiology: Principles and Interpretation 8th Edition" kitabından alınan 99 sorudan oluşan bir set kullanılmıştır. Bu sorular, ChatGPT-4o tarafından günün üç farklı periyodunda, 10 gün boyunca yanıtlanmış ve her soru için toplam 60 yanıt üretilmiştir. Aynı soruları iki ağız, diş ve çene radyolojisi uzmanı da yanıtlanmış ve verdikleri cevaplar ilgili ders kitabı ile doğrulanmıştır. ChatGPT-4o'nun cevapları ile uzmanların cevapları karşılaştırılmıştır.

Bulgular: Çalışmada ChatGPT-4o'nun doğru yanıt verme oranı %59,4 olarak bulunmuştur. Zaman temelli analiz, belirli gün ve saat dilimlerinde performans farklılıkları olduğunu ortaya koymuştur. Özellikle öğle ve akşam oturumlarında, birinci ve yedinci günlerdeki başarı oranı istatistiksel olarak anlamlı şekilde daha yüksekken (sırasıyla $p = 0,003$ ve $p = 0,002$), aynı günlerdeki sabah performansı anlamlı derecede daha düşüktü ($p < 0,05$). Bu bulgular, sorgulamanın yapıldığı gün ve saatin yanıt doğruluğunu etkileyebileceğini göstermektedir. Öte yandan, soruların zorluk düzeyi ile modelin doğruluk oranı arasında anlamlı bir ilişki bulunmamıştır ($p > 0,05$).

Sonuç: Mevcut durumda, ChatGPT oral radyoloji eğitimi ve klinik pratiğinde yetersizlikler göstermiştir. Buna rağmen, platformun daha fazla veri girişi ve yapay zekadaki ilerlemelerle birlikte gelişmesi ve kullanım alanlarının genişlemesi konusunda beklentiler devam etmektedir.

Anahtar Kelimeler: ChatGPT, Diş Hekimliği Eğitimi, Oral Radyoloji, Yapay Zekâ

^a fatma.akkoca@deu.edu.tr

^c gunnur.ilhan@deu.edu.tr

^e hulya.ellidokuz@deu.edu.tr

^b melih.ozdede@deu.edu.tr

^d emre.koyuncu@deu.edu.tr

^e hulya.ellidokuz@deu.edu.tr

^b melih.ozdede@deu.edu.tr

^d emre.koyuncu@deu.edu.tr

^e hulya.ellidokuz@deu.edu.tr

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Introduction

Artificial intelligence (AI) signifies the ability of computer systems to emulate cognitive functions and execute tasks with a human-like proficiency.¹ This is achieved through the refinement of algorithms that enable machines to process, learn, and autonomously tackle complex problems.² The field of AI has experienced rapid advancements, marked by an increasing prevalence of artificial intelligence-based chatbots and conversational agents.³

In 2018, Open AI introduced the Generative Pre-Train (GPT) language model, with subsequent developments leading to the creation of ChatGPT in subsequent years.³ Operating on the foundation of Large Language Models (LLMs), this software is designed to replicate human speech, comprehend the nuances of language, and generate novel content based on its exposure to training data.⁴ ChatGPT finds applications in diverse areas such as idea generation, creative endeavors, coding, text editing, and academic article writing.^{5,6}

Launched on May 13, 2024, GPT-4o became a significant upgrade to the GPT series, offering promising features such as multimodal capabilities (text, image, and audio processing), faster performance, expanded multilingual support, a larger context window, and improved accuracy. Launched on March 14, 2023, GPT-4 uses a Transformer-based model, a paradigm that includes pre-training using both public data and "licensed data from third-party providers" to predict the next token.⁷ However, ChatGPT's ability to access only a variety of internet data until 2021, combined with its limited access to relevant databases, raises concerns about the timeliness and reliability of the information it produces.⁸ Another drawback lies in its tendency to spread false information, which poses a challenge for inexperienced users to distinguish between real and fake information.⁶

While studies in the medical field have showcased ChatGPT's potential as a medical consultation tool, comprehensive examinations are essential to evaluate its performance across different medical specialties.^{9,10,11} In the realm of oral radiology, ChatGPT offers swift access to a vast repository of medical information, providing clinical guidelines and current research for various oral conditions and diseases. Dentists and oral radiologists can leverage ChatGPT to enhance diagnostic skills and clinical practice.¹² Multiple studies have been conducted exploring the applicability and effectiveness of ChatGPT in the field of oral radiology, investigating its potential to support diagnostic accuracy, clinical decision-making, and educational purposes.¹³⁻¹⁷ Moreover, the software has the potential to augment diagnostic quality by analyzing patient symptoms and relevant data, guiding oral radiologists toward potential diagnoses and imaging options.¹³ Beyond this, ChatGPT holds promise for the future of distance consultation and telemedicine.¹⁸

This study aims to assess the comprehension and interpretation performance of ChatGPT-4o in the context of oral radiology education and practice.

Materials and Methods

Ethical Approval

There is no human as a participant in the study and ethical approval for this research was not required.

Question Design

The questions set are prepared based on 'White and Pharoah's Oral Radiology: Principles and Interpretation 8th Edition'.¹⁹ It was arranged as three questions from each section, totally 99 questions in from 33 sections. According to difficulty levels, questions were classified as easy, medium, and difficult.

Generating Answers in ChatGPT

Two authors (GI, EK), using two different accounts, performed response generation using ChatGPT-4o. ChatGPT responses were captured three times (morning:09.00, noon:12.00, and evening:17.00) by selecting the 'new chat' option for 10 days until 60 responses per question were obtained. This study benefited from the study of Soares *et al.*²⁰

Human Expert Answers

Two dentomaxillofacial radiologists with at least five years of experience (FA, MO) independently answered ('yes' or 'no') to 99 questions. In case of inconsistency in expert answers the questions and literature were re-evaluated and a consensus was reached.

Statistical Analysis

All answers were recorded in an Excel spreadsheet and analyzed using the statistical software program of SPSS (Version 29, IBM, Armonk, NY, USA). Kappa and McNemar tests were used for the agreement of two profiles, and the agreement of different days. Chi-square test was performed for the comparison of difficulty levels and correct answers. Cochran-Q test was used for the relationship between different days, also between three periods of the days. The significance level was set to 0.05.

Results

The overall accuracy rate of ChatGPT-4o in providing correct answers was found to be 59.4%. A detailed time-based analysis further delineated the accuracy rates as 59.1% at 09:00, 59.5% at 12:00, and 59.5% at 17:00.

The agreement between profiles was assessed using Kappa and McNemar tests. It was observed that there was perfect agreement for all queries ($p = 1.000$, indicating perfect agreement), and the analysis continued with a single profile.

Sixty ChatGPT-4o queries with expert responses were evaluated using McNemar and Kappa tests (refer to Table 1). There was no significant agreement between ChatGPT-4o responses and expert responses ($p > 0.05$). ChatGPT-4o's performance was evaluated based on the accuracy of its answers to questions from different subjects since only three questions were asked per subject. The obtained accuracy percentages are as follows: while it performed

well in theoretical and structured subjects such as Physics (100%) and Quality Assurance & Infection Control (100%), its accuracy declined in complex diagnostic fields such as Prescribing Diagnostic Imaging (26.7%), Forensics (33.3%), and Cysts (33.3%) (refer to Table 2).

The difficulty level of the questions and the rates of correct and incorrect answers were compared using a chi-square test for a total of 60 queries. No significant relationship was detected between the difficulty level and the correct answer rate for any of these questions ($p > 0.05$). The Kappa values were ranged from 0.091 to 0.863. The relationship between answers and correct answers to questions asked on different days was evaluated using the

Cochran-Q test. There was no significant difference between different days during morning interrogations ($p = 0.558$). However, during noon and evening interrogations, the success rate on the first and seventh days was statistically significantly higher (P-values of noon and evening, respectively: $p = 0.003$, $p = 0.002$).

The relationship between periods of the day and the given answers was assessed using the Cochran Q test (refer to Table 3). It was determined that the morning inquiries on the first and seventh days were statistically lower than other day periods ($p < 0.05$).

Table 1. Evaluation of expert response and ChatGPT response of 60 queries

	Chatgpt response					P value	Chatgpt response					P value
	Day and time	Answer	Yes	No	Day and time		Answer	Yes	No			
Expert response	1M	Yes	33	9	0.192	6M	Yes	34	8	0.265		
			78.60%	21.40%				81.0%	19.0%			
		No	50.00%	27.30%			No	53.1%	22.9%			
			33	24				30	27			
	1N	Yes	57.90%	42.10%	0.168	6N	Yes	52.6%	47.4%	0.265		
			50.00%	72.70%				46.9%	77.1%			
		No	35	7			No	34	8			
			83.30%	16.70%				81.0%	19.0%			
	1E	Yes	48.60%	25.90%	0.168	6E	Yes	53.1%	22.9%	0.265		
			37	20				30	27			
		No	64.90%	35.10%			No	52.6%	47.4%			
			51.4	74.10%				46.9%	77.1%			
	2M	Yes	35	7	0.205	7M	Yes	34	8	0.192		
			83.30%	16.70%				81.0%	19.0%			
		No	48.60%	25.90%			No	53.1%	22.9%			
			37	20				30	27			
	2N	Yes	64.90%	35.10%	0.265	7N	Yes	52.6%	47.4%	0.168		
			51.40%	74.10%				46.9%	77.1%			
		No	32	10			No	33	9			
			76.2%	23.8%				78.6%	21.4%			
	2E	Yes	50.8%	27.8%	0.265	7E	Yes	50.0%	27.3%	0.168		
			31	26				33	24			
		No	54.4%	45.6%			No	57.9%	42.1%			
			49.2%	72.2%				50.0%	72.7%			
3M	Yes	34	8	0.18	8M	Yes	35	7	0.205			
		81.0%	19.0%				83.3%	16.7%				
	No	53.1%	22.9%			No	48.6%	25.9%				
		30	27				37	20				
	Yes	52.6%	47.4%	0.265		Yes	64.9%	35.1%	0.168			
46.9%		77.1%	51.4%				74.1%					
No	34	8	No			35	7					
	81.0%	19.0%				83.3%	16.7%					
	Yes	53.1%	22.9%	0.265		Yes	48.6%	25.9%	0.168			
30		27	37				20					
No	52.6%	47.4%	No			64.9%	35.1%					
	46.9%	77.1%				51.4%	74.1%					
	Yes	34	8	0.18		Yes	32	10	0.205			
81.0%		19.0%	76.2%				23.8%					
No	49.3%	26.7%	No			50.8%	27.8%					
	35	22				31	26					
	No	61.4%	38.6%	0.18		No	54.4%	45.6%	0.205			
50.7%		73.3%	49.2%				72.2%					

3N	Yes	32 76.2%	10 23.8%	0.205	8N	Yes	34 81.0%	8 19.0%	0.265
	No	50.8%	27.8%			No	53.1%	22.9%	
3E	Yes	31 54.4%	26 45.6%	0.205	8E	Yes	30 52.6%	27 47.4%	0.265
	No	49.2%	72.2%			No	46.9%	77.1%	
4M	Yes	32 76.2%	10 23.8%	0.265	9M	Yes	34 81.0%	8 19.0%	0.18
	No	50.8%	27.8%			No	53.1%	22.9%	
4N	Yes	31 54.4%	26 45.6%	0.265	9N	Yes	30 52.6%	27 47.4%	0.205
	No	49.2%	72.2%			No	46.9%	77.1%	
4E	Yes	34 81.0%	8 19.0%	0.265	9E	Yes	34 81.0%	8 19.0%	0.205
	No	53.1%	22.9%			No	49.3%	26.7%	
5M	Yes	30 52.6%	27 47.4%	0.252	10M	Yes	35 61.4%	22 38.6%	0.265
	No	46.9%	77.1%			No	50.7%	73.3%	
5N	Yes	34 81.0%	8 19.0%	0.205	10N	Yes	32 76.2%	10 23.8%	0.265
	No	53.1%	22.9%			No	50.8%	27.8%	
5E	Yes	30 52.6%	27 47.4%	0.205	10E	Yes	31 54.4%	26 45.6%	0.265
	No	46.9%	77.1%			No	49.2%	72.2%	

M: morning, N: noon, E: evening

Table 2. Percentage of correct answers by ChatGPT-4o for subtopic questions in 'Oral Radiology: Principles and Interpretation, 8th Edition'

Subjects		Correct Percentage
1	Physics	100.0%
2	Quality Assurance and Infection Control	100.0%
3	Dental Caries	91.1%
4	Periodontal Diseases	82.2%
5	Safety and Protection	77.8%
6	Biologic Effects of Ionizing Radiation	73.3%
7	Paranasal Sinus Diseases	68.9%
8	Beyond Three-Dimensional Imaging	66.7%
9	Trauma	66.7%

10	Diseases Affecting the Structure of Bone	66.7%
11	Benign Tumors and Neoplasms	66.7%
12	Soft Tissue Calcifications and Ossifications	66.7%
13	Inflammatory Conditions of the Jaws	66.7%
14	Craniofacial Anomalies	66.7%
15	Intraoral Projections	66.7%
16	Digital Imaging	66.7%
17	Radiographic Anatomy	64.4%
18	Salivary Gland Diseases	60.0%
19	Other Imaging Modalities	57.8%
20	Malignant Neoplasms	55.6%
21	Dental Implants	54.4%
22	Film Imaging	51.1%
23	Principles of Radiographic Interpretation	48.9%
24	Dental Anomalies	48.9%
25	Cone Beam Computed Tomography: Volume Acquisition	42.2%
26	Cephalometric and Skull Imaging	42.2%
27	Projection Geometry	42.2%
28	Temporomandibular Joint Abnormalities	35.6%
29	Cone Beam Computed Tomography: Volume Preparation	35.6%
30	Forensics	33.3%
31	Cysts	33.3%
32	Panoramic Imaging	33.3%
33	Prescribing Diagnostic Imaging	26.7%

Table 3. Assessment of relationship between periods of the day and given answers

Days	Morning (Yes-No)	Noon (Yes-No)	Evening (Yes-No)	P value
D1	66-33	72-27	72-27	0.011*
D2	63-36	64-35	64-35	0.926
D3	69-30	63-36	63-36	0.050
D4	64-35	64-35	64-35	1.0
D5	67-32	63-36	63-36	0.264
D6	64-35	64-35	64-35	1.0
D7	66-33	72-27	72-27	0.011*
D8	63-36	64-35	64-35	0.926
D9	69-30	63-36	63-36	0.050
D10	64-35	64-35	64-35	1

Assessment of relationship between periods of the day and given answers using the Cochran Q Test *P < 0.05

Discussion

In recent times, ChatGPT has gained popularity as a valuable research tool, with studies exploring its applications in both clinical and educational contexts within the medical field.^{7,9,12,20} Focusing on oral and maxillofacial radiology, a specialized branch of dentistry dealing with image acquisition and interpretation in the maxillofacial region for diagnosis and treatment planning, this study delves into the educational and clinical efficacy of ChatGPT-4o, the latest iteration of the ChatGPT series.¹⁴

Suarez *et al.* conducted a study assessing the platform's effectiveness in endodontics, achieving a success rate of 57.3%, consistent with the findings of this study.²⁰ Their study also highlighted consistency across different times of the day. Similarly, Antaki *et al.* utilized the ChatGPT Plus BCSC test set, obtaining 59.4% accuracy in a simulated Ophthalmic Knowledge Assessment Program examination and 49.2% accuracy in the OphthoQuestions test set.²¹ The accuracy rates in the field of ophthalmology align closely with the performance of ChatGPT-4o in the realm of oral radiology in this study.

Contrastingly, Bragazzi *et al.* evaluated ChatGPT's diagnostic accuracy in endodontic cases, reporting varied results.²² While it correctly identified existing endodontic treatments, tooth

decay, and dental restorations in certain cases, it displayed limitations in detecting endodontic lesions, resulting in an overall correct interpretation rate of 11%. In the present study, clinical cases were not directly evaluated as images; however, when lesions were described with clinical-radiological features in written form, ChatGPT-4o exhibited more accurate verbal interpretation.

Mago *et al.* explored the use of ChatGPT-3 for radiology report writing and educational purposes in oral and maxillofacial radiology, emphasizing the need for improvement in queries related to anatomical landmarks and radiographic features of pathologies.¹⁵ This study, utilizing ChatGPT-4o, suggests advancements in the platform, showcasing its continuous development and improvement, which bodes well for the future of artificial intelligence technologies.

Bhayana *et al.* evaluated ChatGPT's performance on multiple-choice examination questions in medical radiology without images, achieving a 69% correct response rate.¹⁶ While their results appear more successful than this study, which focused on oral radiology, the differences in question types and content may account for variations in performance.

Ozturk *et al.* conducted a study evaluating ChatGPT's success in oral radiology education, where ChatGPT-4o

demonstrated a high success rate, correctly answering 15 out of 20 multiple-choice questions (75%).¹⁷ However, the smaller question set and focus on undergraduate education may have contributed to a seemingly higher success rate compared to this study. Despite its numerous advantages, ChatGPT raises ethical concerns, persistent misinformation issues, copyright considerations, and legal and regulatory challenges.¹⁵ Addressing these concerns necessitates additional studies and research efforts to ensure this technology's responsible and effective use in various domains.

An analysis of ChatGPT-4o's performance revealed significant variations in accuracy across different subjects. While it performed well in theoretical and structured subjects, such as Physics and Quality Assurance & Infection Control, its accuracy declined in complex diagnostic domains, including Diagnostic Imaging Prescribing, Forensic Medicine, and Cysts. These findings suggest that ChatGPT-4o excels in well-defined, rule-based topics because it can process structured information efficiently. However, the results also indicate that the AI requires further training in clinical diagnosis-based areas, particularly those that rely on visual support. Its lower accuracy in complex diagnostic fields may be attributed to the need for contextual understanding and interpretation of visual data, which remains a challenge for language-based AI models.

Conclusions

This study showed that ChatGPT-4o has limitations in terms of its suitability in oral radiology education and clinical practice due to intra- and inter-day inconsistencies and low correct response rates. It also demonstrates that it is very important and mandatory for the platform to undergo special training that focuses specifically on medical information. However, it is foreseeable that the platform will be further developed, and its scope of use is expected to expand in parallel with increasing data entry and developments in artificial intelligence. Continuous improvement and development of the platform hold the potential to overcome current limitations and make ChatGPT a more robust and effective tool in the field of oral radiology and medical education.

Ethics Approval

Formal ethical approval was not required for this study. The research did not involve human participants and therefore was not subject to ethical standards pertaining to human experimentation.

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Conflicts of Interest Statement

The authors declare that they have no conflicts of interest

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Rat Gingiva Histology: Comparison of two Histological Stains

Daniela Botero-González ^{1,a,*}

¹Faculty of Dentistry, Institución Universitaria Visión de las Américas, Pereira, Colombia.

*Corresponding author

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ABSTRACT

Objectives: Describe rat gingiva histology with a traditional hematoxylin-eosin stain and non-traditional Goldner trichrome stain technique.

Materials and Methods: Samples of gingiva of adult Wistar rats were processed for histological purposes. The classic hematoxylin and eosin stain and Goldner trichrome stain technique were applied to the tissue. Digital microphotography of the three parts of the gingiva were obtained.

Results: For the free gingiva its oral, sulcular and junctional epitheliums were described. For the attached gingiva, its oral epithelium and for the interdental gingiva, its particular epithelium was detailed as well. Each layer of the stratum of the five epitheliums were specified and the cellular morphology explained. The gingiva lamina propria was also detailed. Among others, structures such as the gingival groove, the collagen fibers corresponding with the transseptal fibers, the bone on the alveolar crest, the enamel space, the dentin and the pulp were also identified.

Conclusions: Goldner's trichrome stain allows simpler tissue identification, easier epithelium stratum establishment and detailed cellular morphology observation for the rat free, attached and interdental gingiva.

Keywords: Gingiva; Histological Techniques; Histology; Trichrome stain; Wistar rat

^a danibgo@hotmail.com

0000-0002-0156-4997

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Introduction

Gingiva is a part of the oral mucosa. It functions as an effective barrier for microorganisms' entry, protects the deeper tissues from mechanical forces and from abrasive nature of foodstuffs. Additionally, gingiva as a part of the digestive tract, is sensitive to touch, pressure, pain, and temperature.¹

Embryologically, the gingival component of the periodontium is derived from the ectoderm of the pharyngeal arches.² Anatomically is the mucosa covering the alveolar bone ridge surrounding the cervical section of the tooth³ and has being divided into three regions: free or marginal gingiva, attached gingiva, and interdental zone.⁴ Histologically it is surrounded with keratinized stratified squamous epithelium on its masticatory surface and non-keratinized stratified

squamous epithelium on its crevicular and junctional surface.^{2,5}

Free gingiva microanatomy can be understood according to the gingival epithelium, which is divided into three different sections: oral, sulcular, and junctional epithelium. The last one being the closest to the tooth surface.² The attached gingiva presents keratinized stratified squamous epithelium and is the oral mucosa that intermingles directly with the mucogingival junction and the frenum, and indirectly to the inner surface of the cheeks, the hard palate and the mouths floor. On the other hand, the interdental gingiva exhibits a nonkeratinized stratified squamous epithelium^{6,7} (Table 1).

The aim of this paper was to describe rat gingiva histology with a traditional hematoxylin-eosin stain and non-traditional Goldner trichrome stain technique.

Table 1. Gingiva histology

Region	Tissue	Stratum	Cell	Cell junction
Free gingiva	Oral epithelium or keratinized stratified squamous epithelium	Corneum	Keratinized cell without cell nuclei	Desmosomes
		Granulosum	Granular cell	Desmosomes and gap junctions
		Spinosum	Prickle cell and Langerhans cell	
		Basale	Basal cell, Merkel cells and melanocyte	Gap junctions and hemidesmosomes
	Sulcular epithelium or parakeratinized stratified squamous epithelium	Corneum	Keratinized cell with cell nuclei and with highly condensed chromatin	Desmosomes
		Granulosum	Granular cell and transmigrating leukocytes	Desmosomes and gap junctions
		Spinosum	Prickle cell and Langerhans cell	
		Basale	Basal cell, Merkel cells and melanocyte	Gap junctions and hemidesmosomes
	Junctional epithelium	Suprabasal	Suprabasal cell	Hemidesmosomes and adherens junction
		Basale	Basal cell and transmigrating neutrophils	
	Dense irregular connective tissue	None	Fibroblast, mast cell, tissue macrophage, blood cells, plasma cell and T cells	None
Attached gingiva	Oral epithelium or keratinized stratified squamous epithelium	Corneum	Keratinized cell	Desmosomes
		Granulosum	Granular cell	Desmosomes and gap junctions
		Spinosum	Prickle cell and Langerhans cell	
		Basale	Basal cell, Merkel cells and melanocyte	Gap junctions and hemidesmosomes
Interdental gingiva	Nonkeratinized stratified squamous epithelium	Distendum	Flattened cell	Desmosomes and adherens junction
		Filamentosum	Polyhedral cell	Gap junctions and hemidesmosomes
		Basale	Basal cell, Merkel cells and melanocyte	
	Dense irregular connective tissue	None	Fibroblast, mast cell, tissue macrophage, blood cells and plasma cells	None

References: Autor & 4,6,8-10

Materials and Methods

For this observational research, three adult Wistar female rats (*Rattus norvegicus*) sourced from the Intermediate Laboratory of Preclinical Research at Universidad del Valle were utilized. The experiment received approval from the Biomedical Experimentation Animal Ethics Committee under the internal code 013-017. To achieve the purpose of the investigation, rats underwent perfusion with a saline solution and formaldehyde¹¹ prior to anesthesia. Hemicranium sagittal samples were obtained through surgical resection.¹² Samples decalcification was achieved using 10% ethylenediaminetetraacetic acid in which the dental enamel dissolves.¹³ Histological slices were acquired and cut at 4µm with a microtome. Slices underwent the classic hematoxylin and eosin (H&E) stain, and Goldner trichrome stain technique based on the Lee G. Luna protocol.¹⁴ Sagittal sections of the gingiva, around the molars, was observed using an optical microscope with camera (LaboMed LB-239; USA), and Scopelimage Advanced

Software (USA) was used for digital microphotography acquisition.

Results

Microphotography showed free, attached and interdental gingiva. Regarding the free gingiva and related to its coronal portion, the gingival groove can be seen as an apical tissue located towards the incisal/occlusal surface of the tooth. It is the transition between the keratinized stratified squamous epithelium and the parakeratinized stratified squamous epithelium; last one being adjacent to the enamel space. The intermediate portion of the free gingiva displays a lamina propria among the two prior epitheliums. Capillaries and defense cells, such as plasmacyte and lymphocytes are also present among the lamina propria tissue. The cervical portion of the free gingiva exhibits the gingival sulcus towards the tooth, where the junctional epithelium becomes attached to the dentin on the neck of the tooth (Figure 1).

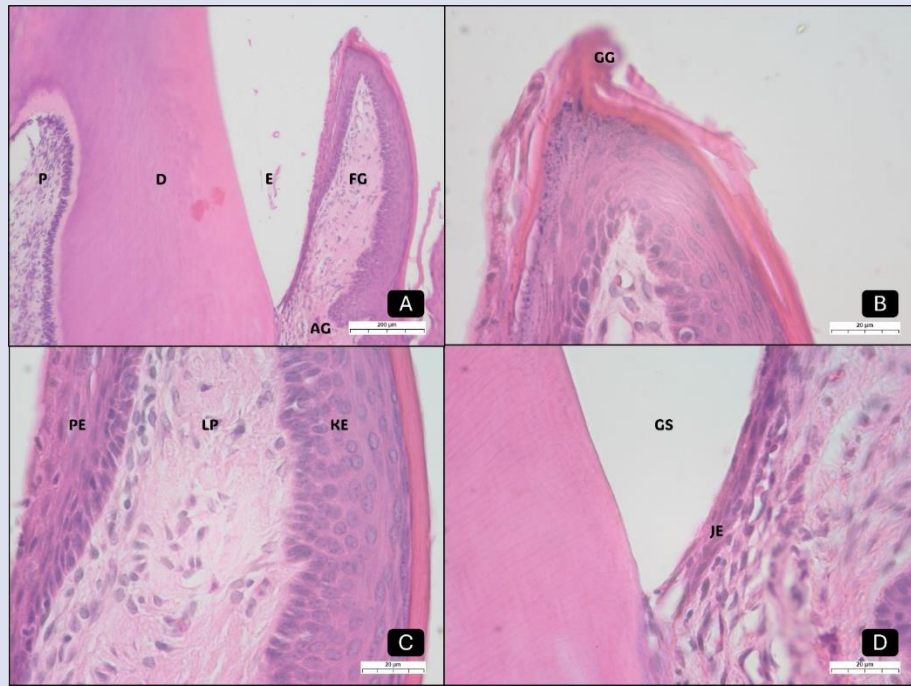


Figure 1. Gingiva with H&E stain. **A.** Tooth and gingiva at (X10). P: Dental pulp; D: Dentin; E: Enamel space; FG: Free gingiva; AG: Attached gingiva. **B.** Coronal portion of the free gingiva at (X40). GG: Free gingiva groove. **C.** Intermediate portion of the free gingiva at (X40). PE: Parakeratinized epithelium; LP: Lamina propria; KE: Keratinized epithelium. **D.** Cervical portion of the free gingiva at (X40). GS: Gingival sulcus; JE: Junctional epithelium.

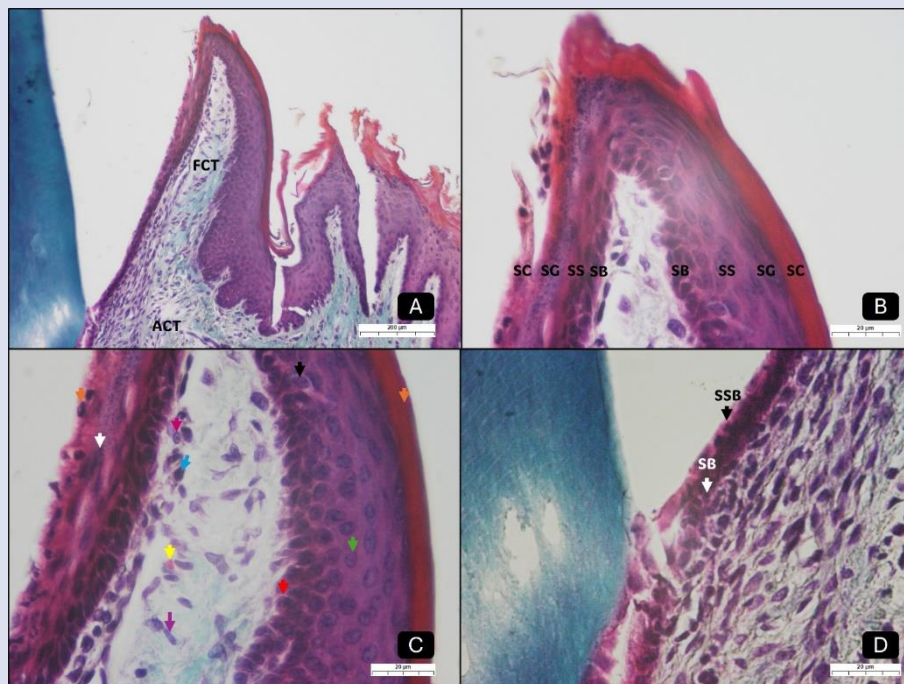


Figure 2. Gingiva with Goldner's trichrome stain. **A.** Gingiva at (X10). FCT: Free gingiva connective tissue; ACT: Attached gingiva connective tissue. **B.** Coronal portion of the free gingiva at (X40). SC: Stratum corneum; SG: Stratum granulosum; SS: Stratum spinosum; SB: Stratum basale. **C.** Intermediate portion of the free gingiva at (X40). Orange arrow: Keratinized cell; White arrow: Granular cell; Green arrow: Pickle cell; Black arrow: Langerhans cell; Red arrow: Basal cell; Pink arrow: Lymphocyte; Blue arrow: Plasma cell; Yellow arrow: Erythrocyte; Purple arrow: Fibroblast. **D.** Cervical portion of the free gingiva at (X40). SSB: Stratum suprabasal and suprabasal cell; SB: Stratum basale and basal cell.

The oral epithelium exhibits a keratinized stratified squamous epithelium with four stratum. The most outer stratum, stratum corneum, presented keratinized cell without cell nuclei and filled with keratin filaments. The stratum granulosum showed granular cells, and the stratum spinosum had prickles and Langerhans cells. The most inner stratum, stratum basale, features melanocytes and basal cells. The sulcular epithelium presented the same stratum as the oral epithelium. Cellularly, transmutating leukocytes were found on the stratum granulosum additionally to the resident granular cells. The keratin cell on the stratum corneum presented cell nuclei and highly condensed chromatin (Figure 2).

The cervical portion of the free gingiva presents the junctional epithelium. This is a less thick epithelium with only two stratum. The outer stratum, stratum suprabasale, has cells called after this layer. The same as for the stratum basale, which also contains transmutating neutrophils (Figure 2).

The lamina propria of the free and attached gingiva differs in location. Being the first the most coronal tissue,

and the second the most cervical one. They are composed of the same dense irregular connective tissue which displays collagen fibers, extracellular matrix proteins, small blood vessels and nerves, fibroblast, blood cells and immune system cells (Figure 1 and 2).

Concerning the interdental gingiva, it contains a nonkeratinized stratified squamous epithelium adjacent to both teeth. The coronal surface of this epithelium corresponded to the free gingiva groove. This epithelium presented the stratum basale as the inner stratum with basal cells, followed by the stratum filamentosum with polyhedral cells and the most apical stratum, stratum distensum with flattened cells. Basal to this epithelium a dense irregular connective tissue appears accompanied by many capillaries and postcapillary venules. Underneath, transseptal fibers which are collagen fibers, pass horizontally from the root of one molar, above the alveolar crest; to be inserted into the root of the adjacent molar. The bone on the alveolar crest showed an extracellular matrix and cells consistent with this special connective tissue (Figure 3).

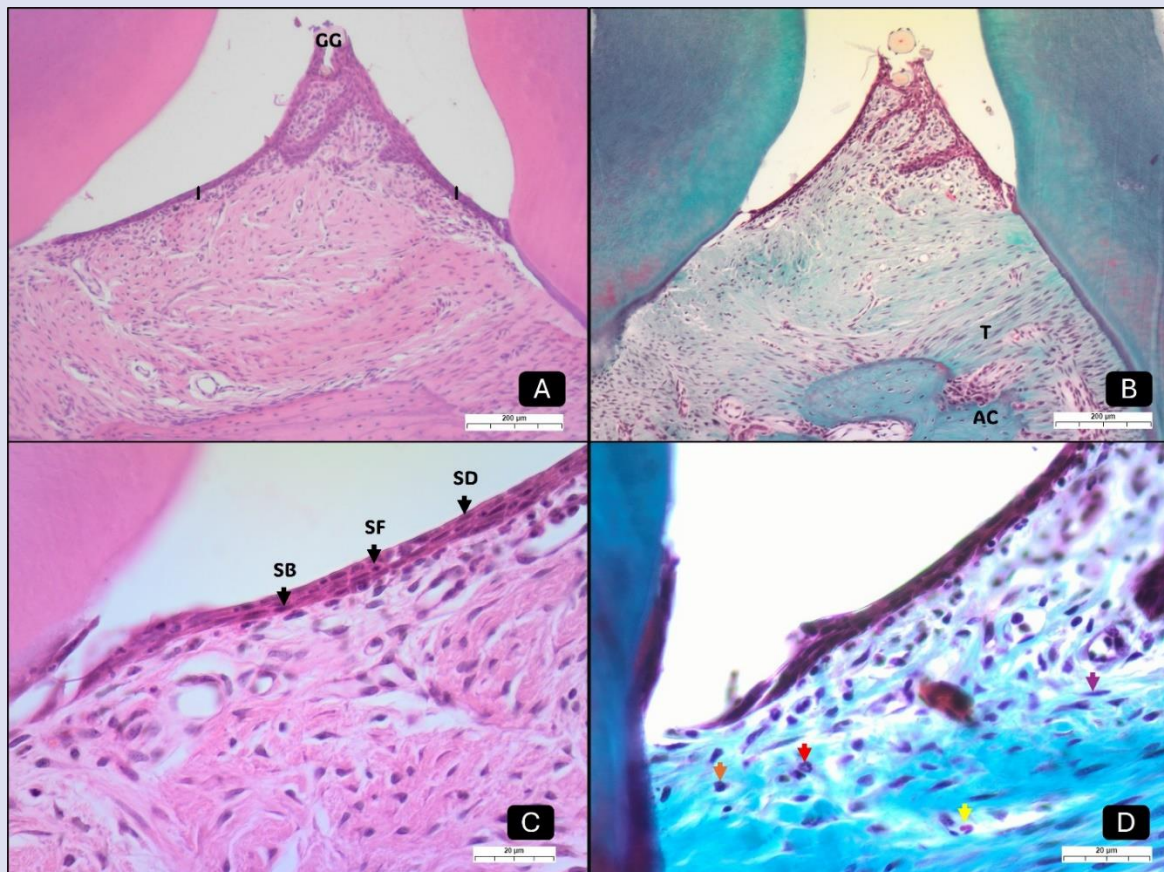


Figure 3. Interdental zone. **A.** Interdental gingiva with H&E stain at (X10). GG: Free gingiva groove; I: Interdental epithelium. **B.** Interdental gingiva with Goldner's trichrome stain at (X10). T: Transseptal group of gingival fibers; AC: Alveolar crest. **C.** Interdental gingiva with H&E stain at (X40). SD: Stratum distensum and flattened cell; SF: Stratum filamentosum and polyhedral cell; SB: Stratum basale and basal cell. **D.** Interdental gingiva with Goldner's trichrome stain at (X40). Red arrow: Lymphocyte; Orange arrow: Plasma cell; Yellow arrow: Erythrocyte; Purple arrow: Fibroblast.

Discussion

In anatomical and biomedical research, specifically morphologists are often in need of establishing the complex topographical relationships between tissues and structures in a body. Beyond that, under magnification, tissues and cells can be appreciated and thus describe their microanatomy in detail. Microscopy augmentation is essential to understand the organization of epitheliums, connective tissues, extracellular matrix fibers, all types of cells and arrangements such as bonding a certain tissue with another one.¹⁵ Therefore, histological techniques offered unique opportunities in dentistry research and in this case, oral mucosa description.

Nevertheless, Widbiller et al., proposed that the histological methods for dental tissues pose challenges, consequently to the proximity of various soft and mineralized tissues. Therefore, standard histological procedures had to be modified accordingly.¹⁶ Understanding the anatomy of the tooth, the gingiva and its intimate connection with the dentogingival junction was essential. And having in mind the purpose of this paper, the technical methods for this research were modified; which included hard tissues samples that underwent decalcification and paraffin embedded. Inevitable and due to decalcification, enamel was lost, however, the space of this tissue was preserved. Unlike what it reported by Panes et al., the trichrome stain on a decalcified sample, allowed the clear observation and description of the dentogingival junction.¹⁷

In relation to the histological stains, H&E is a broader used histological technique used on rat's oral mucosa.¹⁸ It consists of a nuclear stain obtained by an alum-mordanted hematoxylin and a cytoplasmic stain achieved with an alcoholic or aqueous solution of eosin Y.¹⁹ This stain results are a range of purple for nucleus or other basophilic structures, and a spectrum of pink shades for acidophilic cellular or extracellular components. And as Golbert et al., stated this histochemical method is not always sufficient.¹⁵ Therefore, special stains with higher substance selectivity became a valuable method in this specific research topic. In this regard and almost ninety years ago, Goldner presented a modification of Masson's trichrome stain. The author explains that the modification provides exceptional results on microphotography, better quality of detail and fewer color artifacts.²⁰ This staining method is more accurate to observe nuclear features on a range from brown to black colors. Cell cytoplasm and apical specializations such as keratin, appear in a gradient of red to orange. While tissues like connective ones, with the presence of collagen fiber turn out in green.¹⁵

Widbiller et al., on its dental histology research, and as it also resulted in the present investigation, H&E dyed nuclear chromatin on blue and purple shades. Eosin as its counterstaining helped visualize red blood cells in red, cell cytoplasm in pink, and collagen fibers in connective tissue and hard tissues, like the tooth and bone; in different saturations of pink.¹⁶ Furthermore, Panes et al., establish that the main goal of a trichrome stain is to allow visualization of different colors and shades. The authors also declared that any trichrome stain is perfect for the dyed of collagen fibers in the extracellular matrix, the main

component of connective tissues.¹⁷ Which results relevant for the gingival lamina propria description, or for other morphologist and researchers to quantify oral cavity tissues of different characteristics.

Panes et al., also affirmed that Goldner's trichrome histochemical stain allows the observation of the dental, lamellar bone and trabecular tissue architecture, together with the cellularity of these tissues.¹⁷ Likewise, the selected trichrome staining was used by Widbiller et al., with a very similar protocol to the one used for this research, authors stated that the specific stain was good to visualize the microanatomy, the collagen fibers and the cell perceptibility.¹⁶ This paper results showed that additionally to be a great stain for the already named tissues, it's a great dyed to showed the different strata and cells of the keratinized, parakeratinized and nonkeratinized epithelium.

As explained on the results section, histologically the rat gingiva displays different epitheliums and the same tissue on its lamina propria. Hassan et al., on its investigation with albino rats, agreed with these findings. Investigators explained that the gingival mucosa of this type of biomodels is covered with keratinized stratified squamous epithelium. Which showed short columnar basal cell layer resting on a well-defined basement membrane, polygonal prickle cells and flattened granular cell layer covered by thin and regular eosinophilic keratin layer, with a H&E stain. The same research also showed that some clear cells were detected within epithelium, corresponding with Langerhans cell. Additionally, the researchers made clear that the gingiva lamina propria appeared dense and fibrous. Long and slender connective tissue papillae and spindle shaped fibroblasts were observed²¹ similarly to this paper results with both histological techniques.

The results presented on this paper, contribute to the field of oral histology by showing how the gingiva in all its regions presents different types of epithelia, with their respective strata and associated cellularity. Furthermore, the comparison of both histological stains in the figures, enables the trichrome stain to showed its superiority for appreciating the morphological detail of the epithelial cells within the free and attached gingiva, as well as of the different connective tissues and their cells. Most importantly, it allowed a very detailed appreciation of the strata of the coronal portion of the free gingiva. Furthermore, in very thin tissues such as the epithelium of the interdental gingiva, the H&E technique allowed detailed observation showing the morphological detail of the cell nuclei and cytoplasm.

For future studies, the results shown with both stains can be extrapolated to research on gingiva in other species. Specifically, the use of trichrome staining could allow for detailed histological descriptions of human gingiva. It would be particularly useful for observing cellular differences in epithelia and connective tissues, since, unlike in rats, these tissues would be thicker.

The limitation of the study is that once sagittal sections of the hemiscranium were surgically obtained, coronal sections of the gingiva could not be acquired and therefore the histology in this anatomical position could not be described.

Conclusions

Rat gingiva histology was described with the classic hematoxylin and eosin stain and the less used, Goldner trichrome stain technique. Both histological stains showed cellular and tissue components of the free, attached and interdental gingiva. These parts of the oral mucosa have different epitheliums with multiple stratums and rich cellular morphology, which can be deeply appreciated with the trichrome stain.

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Conflicts of Interest Statement

The author declares no conflict of interest.

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A Bibliometric Analysis of the Top 100 Most-Cited Articles on the Use of Intraoral Scanners in Dental Implants

Hamiyet Güngör Erdoğan^{1,a,*}, Abdulhakim Kanlıdere^{2,b}

¹Department of Prosthetic Dentistry, Lokman Hekim University, Ankara, Türkiye.

²Department of Prosthetic Dentistry, Lokman Hekim University, Ankara, Türkiye.

*Corresponding author

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ABSTRACT

Objectives: The aim of this study is to conduct a bibliometric analysis of the studies obtained when searching with the keywords “intraoral scanner” and “dental implant”.

Materials and Methods: As a search strategy, a search was performed in the main categories of Web of Science (Emerging Sources Citation Index (ESCI), Social Science Citation Index (SSCI), Science Citation Index Expanded (SCI-Expanded)) with the terms “intraoral scanner (IOS)” and “dental implant”. The search was limited by document type to “articles” and “reviews” only and restricted to articles published until 2023. All articles were manually reviewed and standardized by 3 independent reviewers to avoid typos and duplication of author names or institutions.

Results: The 100 most cited articles were selected from 392 articles that met the criteria. There has been a significant increase in the number of published articles, especially in the last 10 years. The 3 most productive countries are the USA, Italy, and Spain. The continent with the highest number of publications is Europe. The most cited article on this topic has 401 citations, while the total number of articles with over 100 citations is 10.

Conclusions: IOSs are an important technology in terms of patient and dentist comfort, the use of which has increased over the years in dentistry. The use of IOSs with dental implants in prosthodontic treatment has become increasingly popular. In this bibliometric study, when the countries with the most publications were analyzed, it was determined that the USA, Spain, and Italy constituted the top 3 countries.

Keywords: Bibliometric analysis; Dental implant; Intraoral scanner

Dental Implantlarda Intraoral Tarayıcıların Kullanımıyla İlgili En Çok Atıf Alan İlk 100 Makalenin Bibliyometrik Analizi

Araştırma Makalesi

Süreç

Geliş: 27/01/2025

Kabul: 07/04/2025

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ÖZET

Amaç: Bu çalışmanın amacı, “intraoral scanner” ve “dental implant” anahtar sözcükleri ile arama yapıldığında elde edilen çalışmaların bibliyometrik analizini yapmaktır.

Gereç ve Yöntemler: Bir arama stratejisi olarak, Web of Science’in ana kategorilerinde (Emerging Sources Citation Index (ESCI), Social Science Citation Index (SSCI), Science Citation Index Expanded (SCI-Expanded)) “intraoral scanner (IOS)” ve “dental implant” terimleri ile arama yapıldı. Arama, belge türüne göre yalnızca “makaleler” ve “derlemeler” ile sınırlandırıldı ve 2023’e kadar yayınlanmış makalelerle sınırlandırıldı. Tüm makaleler, yazım hatalarından ve yazar adlarının veya kurumlarının tekrarından kaçınmak için 3 bağımsız değerlendirci tarafından manuel olarak incelendi ve standartlaştırıldı.

Bulgular: Kriterleri karşılayan 392 makale arasından en çok atıf alan 100 makale seçildi. Özellikle son 10 yılda yayınlanan makale sayısında önemli bir artış oldu. En üretken 3 ülke ABD, İtalya ve İspanya’dır. En fazla yayına sahip kıta Avrupa’dır. Bu konuda en çok atıf alan makale 401 atıfa sahipken, 100’den fazla atıf alan toplam makale sayısı 10’dur.

Sonuçlar: IOS’lar hasta ve diş hekim konforu açısından önemli bir teknolojidir ve diş hekimliğinde kullanımı yıllar geçtikçe artmıştır. Protetik diş hekimliğinde dental implantlarla birlikte IOS’ların kullanımı giderek daha popüler hale gelmiştir. Bu bibliyometrik çalışmada en fazla yayına sahip ülkeler incelendiğinde ilk 3 ülkeyi ABD, İspanya ve İtalya’nın oluşturduğu belirlenmiştir.

Anahtar Kelimeler: Bibliyometrik analiz; Dental implant; Ağız içi tarayıcı

^a gng.hamiyet@gmail.com

^b 0000-0001-7449-6297

^a akanlidere92@gmail.com

^b 0009-0006-5357-3154

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Introduction

The impression is a very important stage in implant dentistry.¹ The use of an intraoral scanner (IOS) allows instantaneous assessment of the scanned area; it also allows digital 3D models to be obtained, which can be transferred to a computer without casting a physical plaster model.²⁻⁴ For both the dentists and the patients, this saves considerable time and storage space and allows the scanned models to be easily emailed to the laboratory. It has been reported that it is very difficult to ensure absolute passive fit of the manufactured substructure in implant-supported prostheses.⁵

Due to the many steps involved in the clinical and laboratory process of implant-supported prostheses, it has been reported that it is difficult to prevent potential complications.^{6,7} Clinical situations, such as incorrect transfer of implant position, can lead to the production of maladjusted prostheses. And maladjusted prostheses are known to cause biological and mechanical complications.⁸ These complications include screw deformation and loosening, abutment fracture, bone resorption and even implant failure.^{9,10}

Digital impressions increase patient compliance with the treatment process, reduce the risk of deformation of impression materials, allow for three-dimensional design, reduce potential costs, and increase the clinical success of the prosthesis.¹¹ Digital impressions allow the dentist and the patient to virtually evaluate the implant prosthesis area before proceeding to the laboratory manufacturing stage for implant applications in dentistry. The use of digital impressions also enables the observation of the depth of the restoration interface and the configuration of the emergence profile.¹² There are studies reporting the clinical success of IOSs in single-tooth crowns and fixed partial dentures on implants.¹³ Reports indicate that in these two cases, the success of IOSs for implant-supported single crowns is better than for implant-supported fixed partial dentures and for cases with long edentulous spaces. An increase in edentulous areas is known to decrease the success of the scanner, primarily due to a decrease in the reference point.¹⁴

Research in the field of prosthodontics has greatly increased due to the demand for scientific knowledge about clinical procedures and materials used.¹⁵ This increase has been accompanied by an increase in the number of scientific journals publishing research in the field of prosthodontics.¹⁶ The importance of an article is demonstrated by citations by other researchers, changes in clinical practice, the controversy it generates, or by revealing new research directions.¹⁶ Bibliometric analysis studies are very important, showing the amount of published research in a particular field and providing an overview of research and scientific activity by calculating bibliometric indicators.¹⁷ On the other hand, the citation index is an important parameter used to measure relevance in a particular field of knowledge.^{15,16} The number of citations may not always reflect the quality or importance of an article or the importance of its authors, but frequently cited articles can lead to changes in clinical

practice, stimulate debate, and enable further research in a particular area.¹⁶

The aim of this bibliometric study is to determine the 100 most cited articles about dental implant and IOSs, track the course and trend of these studies from the past to the present, and help researchers with their future studies.

Materials and Methods

In this study, a search was carried out in the main categories of Web of Science: Emerging Sources Citation Index (ESCI), Social Science Citation Index (SSCI), Science Citation Index Expanded (SCI-Expanded). This database is widely used for bibliometric studies due to its broad subject coverage, the number of citations articles receive, and the ability to identify the institutions involved in each article. The search strategy was based on the keywords “intraoral scanner” and “dental implant”. The search was limited to articles and reviews as document types, and the download was done on October, 2024. The search was limited to articles published between 2012 and 2023. Before 2012, only one article was identified in 2001, and therefore this article was not included. Without any filtering, the search produced a total of 399 articles. Filtering by year and article type reduced this number of articles to 392. This bibliographic study focused on 100 highly cited articles from the 392 total articles. Three independent observers reviewed and verified these 100 articles.

The statistical analysis of the current study was analyzed with the Shapiro Wilk test for the assumption of normal distribution and with the Mann Whitney U test for the comparison of two independent groups when the normality assumption was not met. The Kruskal-Wallis test was used to compare three or more independent groups that did not have a normal distribution. Post-hoc correction Bonferroni tests were performed to reveal the group or groups that made the difference. Analyses were performed in IBM SPSS 25 and R version 4.4.0 programs.

Results

Table 1 shows the distribution of publications according to their characteristics. The distribution of publications by countries, continents, years of publication, open access status, WoS category, and WoS index was analyzed in this table. The highest number of publications by country is in the USA with 19%, followed by Spain and Italy with 11% (Table 1). Analyzing the distribution by continents reveals that Europe produced 48% of all publications, followed by Asia with a 30% publication rate (Table 1 and Figure 1).

When the distribution of continents is analyzed based on the average number of citations, European publications have the highest average amount of citations (62.17±68.52), followed by North American publications at 59.58±50.22 (Table 2 and Figure 2). Upon analyzing the years, we found that 2019 had the highest number of published articles, with 15 articles, and we have observed

both a horizontal trend and decreases since this year (Figure 3). It was determined that 38% of all publications were Open Access. These publications were mostly published in the Dentistry Oral Surgery Medicine category with a rate of 88%, while 90% of all articles had SCI-Expanded WoS Index (Table 2).

The Mann-Whitney U and ANOVA tests were performed for the comparison of the distribution of the number of citations (Table 2). As a result of the analyses, statistically significant differences were found between the number of citations according to continents and year of publication ($p < 0.05$). According to Bonferroni tests for continents, statistically significant differences were found between Asia, Europe, and North America ($p = 0.016$ and $p = 0.015$).

The number of citations in Europe and North America is higher than in Asia. The citation numbers of studies with

publication years 2012-2019 are higher than those with publication years 2020-2023. There were no statistically significant differences between the number of citations according to Open Access, WoS categories, and Web of Science indexes ($p < 0.05$).

The network analysis for the authors participating in the study is shown in Figure 4 for authors collaborating on the top 20 most cited articles. The size of the nodes indicates the productivity of the authors, and the thickness of the edges indicates the intensity of this scientific collaboration.

This bibliometric study reveals that the Journal of Prosthetic Dentistry published the most articles among the 100 most cited, with 21 publications, followed by the Journal of Clinical Oral Implants Research with 12 publications, and the International Journal of Oral Maxillofacial Implants with 9 publications (Table 3).

Table 1. The distribution of articles is based on their characteristics

		n	%
Country	Albania	1	1.0
	Brazil	4	4.0
	Canada	1	1.0
	China	8	8.0
	Germany	9	9.0
	Greece	1	1.0
	Hungary	1	1.0
	India	1	1.0
	Iran	2	2.0
	Italy	11	11.0
	Japan	3	3.0
	Lithuania	2	2.0
	Netherlands	1	1.0
	Norway	1	1.0
	Poland	1	1.0
	Russia	1	1.0
	Singapore	2	2.0
	South Korea	8	8.0
	Spain	11	11.0
	Sweden	1	1.0
	Switzerland	4	4.0
	Thailand	3	3.0
	Turkey	4	4.0
	Usa	19	19.0
Continent	Asia	30	30.0
	Europe	48	48.0
	North America	19	19.0
	South America	3	3.0
Publication Year	2012	1	1.0
	2013	3	3.0
	2014	3	3.0
	2015	9	9.0
	2016	4	4.0

Open Access	2017	10	10.0
	2018	10	10.0
	2019	15	15.0
	2020	12	12.0
	2021	12	12.0
	2022	13	13.0
	2023	8	8.0
	All Open Access	38	38.0
WoS Categories	Others	62	62.0
	Chemistry Physical	1	1.0
	Dentistry Oral Surgery Medicine	88	88.0
	Engineering Biomedical	1	1.0
Web of Science Index	Public Environmental Occupational Health	5	5.0
	Social Sciences Citation Index (SSCI)	6	6.0
	Emerging Sources Citation Index (ESCI)	4	4.0
	Science Citation Index Expanded (SCI-EXPANDED)	90	90.0

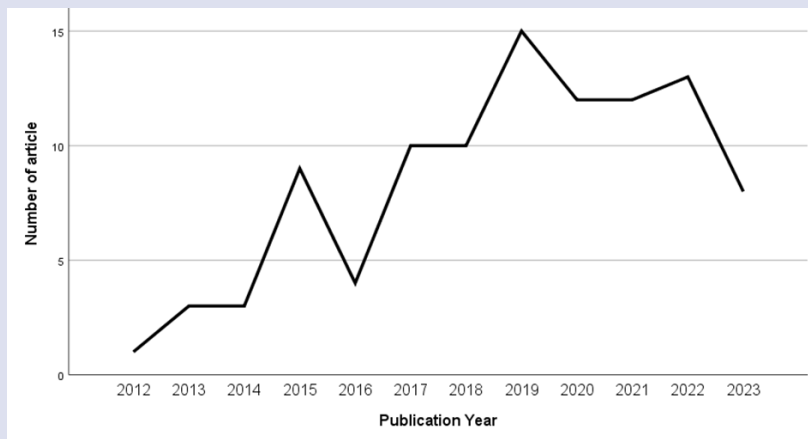


Figure 1. Distribution of articles in years

Table 2. The distribution and comparison of citation numbers are based on the characteristics of articles

		Min.- Max.	Mean±SD (Median)	Test Statistics	p-Value
Continent	Asia	14-82	32.47±20.58(26)	7.983	0.046*
	Europe	13-400	62.17±68.52(41.5)		
	North America	18-203	59.58±50.22(35)		
	South America	23-73	43.67±26.1(35)		
Publication Year	2012-2019	15-400	67.95±67.44(44)	-3.629	<0.001*
	2020-2023	13-116	32.98±22.11(25)		
Open Access	All Open Access	14-400	53.13±71.03(30)	-0.746	0.456
	Others	13-203	51.65±42.59(32.5)		
WoS Categories	Dentistry Oral Surgery	14-400	54.63±57.41(31)	-0.057	0.955
	Medicine				
	Others	20-94	43±27.45(33)		
Web of Science Index	Social Sciences Citation Index	14-94	37.5±29.36(27)	0.535	0.765
	Emerging Sources Citation Index	22-43	31.75±8.77(31)		
	Science Citation Index	13-400	54.1±57.04(31)		
	Expanded				

SD: Standart deviation, *p<0.05

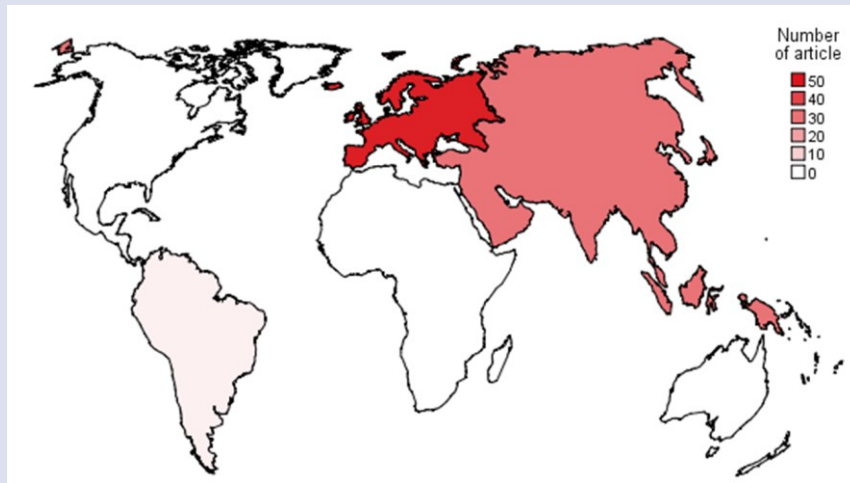


Figure 2. Distribution of number of articles by continent



Figure 3. Distribution of average citation numbers of publications by continent

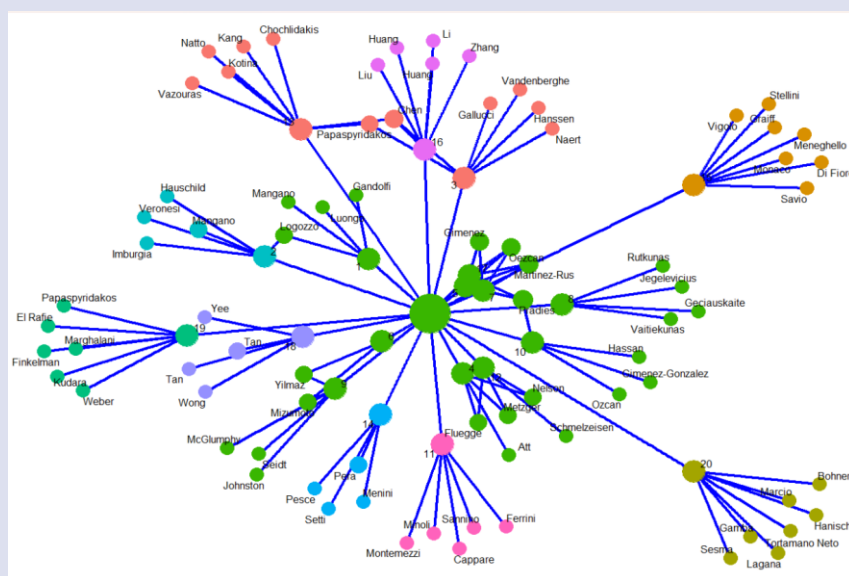


Figure 4. Author network analysis diagram for the first 20 articles

Table 3. Characteristics of the top 20 journals with the 100 most cited publications

Publication Title	Count	J.I.F	H-Index	Total Cited	Average per Cited
1- Journal of Prosthetic Dentistry	21	Q1	19	986	46.95
2- Clinical Oral Implants Research	12	Q1	12	603	50.25
3- International Journal of Oral Maxillofacial Implants	9	Q2	9	542	60.22
4- Journal of Dentistry	6	Q1	6	127	21.17
5- Journal of Prosthodontics Implant Esthetic and Reconstructive Dentistry	6	Q1	6	325	54.17
6- BMC Oral Health	5	Q1	5	759	15.8
7- International Journal of Environmental Research and Public Health	5	Q2	5	197	39.4
8- International Journal of Prosthodontics	4	Q2	4	331	82.75
9- Clinical Implant Dentistry And Related Research	3	Q1	3	242	80.67
10- Dentistry Journal	2	Q2	2	73	36.5
11- Implant Dentistry	2	Q2	2	52	26
12- International Journal of Implant Dentistry	2	Q1	2	48	24
13- International Journal of Oral Implantology	2	Q1	2	86	43
14- Journal of Advanced Prosthodontics	2	Q1	2	87	43.5
15- Journal of Oral and Maxillofacial Surgery	2	Q2	2	116	58
16- Journal of Oral Implantology	2	Q3	2	39	19.5
17- Journal of Prosthodontic Research	2	Q1	2	117	57.5
18- Clinical Epidemiology and Global Health	1	Q2	1	34	34
19- Clinical Oral Investigations	1	Q1	1	91	91
20- European Journal of Oral Implantology	1	Q2	1	137	137

J.I.F= Journal Impact Factor

Discussion

This study identified and analyzed the main features of the 100 most cited articles in the WoS-CC database by searching with the keywords “intraoral scanner” and “dental implant”. This type of analysis provides a perspective on the research area related to this topic. Moreover, analyzing the most influential articles can help researchers identify trends and deficiencies in the scientific

literature. The citations to an article indicate its academic importance and are also used to assess the impact of these articles on the scientific literature.¹⁸

For an article to be considered a classic, it must be cited at least 400 times.¹⁹ However, an article can also be considered classic in some smaller research areas if it has been cited more than 100 times. In the WoS-CC database on “intraoral scanner” and “dental implant”, 10 articles were cited more than 100 times and 1 article was cited more than 400 times. In the present study, the top 10 of the 100 most cited studies are classical and guiding in this field.

In studies on bibliometric analysis, WoS-CC, which is specifically designed based on citation analysis, is considered one of the most prestigious databases used to investigate scientific quality and impact.²⁰ While other databases may cite different sources, WoS and Scopus cite more articles published in selected peer-reviewed journals.^{21,22} Scopus receives more citations from non-English sources and reviews, while Web of Science focuses more on indexed journals and editorial content.²² Therefore, bibliometric analysis studies often use WoS-CC as the main database.²³ The Scopus database only measures citations from 1996 onwards. Also, the Google

Scholar database only sorts of citations by publication date or relevance and includes citations from documents such as books and theses, which can be limiting. And these documents lack blind peer review.²⁰ In this research, 90% of the articles were found to be in the SCI-Expanded WoS-CC category.

Examining previous bibliometric studies on dental implants in the literature reveals research in a variety of fields, including risk factors for peri-implantitis in implantology,²⁴ dental implants in diabetic patients,²⁵ dental implant failures,²⁶ aesthetics in implant dentistry,²⁷ prosthetic complications in dental implants,²⁸ and implant-supported whole arch restorations.²⁹ There is bibliometric study on the use of digital scanning in various dental practices, such as prosthodontics, restorative dentistry, orthodontics, and implantology.³⁰ The difference of the present study is that it aims to analyze the most cited publications about the use of the scanner in implant prosthodontics, not its general use in dentistry.

In the present bibliometric study, the geographical results show that the USA is the country with the highest number of publications. It can be concluded that there are authors in the USA who tend to overpublish and that the use of dental implants as a routine treatment option and the use of iOS is widespread in the institutions where these authors are located. This country is considered an early adopter of technology, with a higher access and use of technological devices in daily life compared to other countries.

Additionally, it may be considered that the institutions in the USA, Spain, and Italy, which are the countries with the highest number of publications, have policies that financially support scientific studies. Comparing the continents, the most

research has been done on the European region. Despite the USA producing the majority of publications, the European continent has many countries with similar levels of development, which accounts for the high number of publications there. These results are similar to the results of the bibliometric analysis conducted by Saini *et al.* in 2024.³⁰

In the present bibliometric analysis study, it was observed that the first publications on the use of IOS in dental implants were made in 2012.³¹ This situation shows us that the use of IOSs in the field of implantology has become widespread, and researchers are working on this subject. After 2019, the Covid-19 pandemic, which had a global impact on the decline, caused the closure of institutions, a decrease in the number of patients, and changes in the working conditions of dentists. These circumstances may have negatively affected the volume of publications in the field.

The direction of current scientific research and the trend of studies is to minimize the risk of the occurrence of the problem instead of solving the problem. For this purpose, advanced digital technologies such as IOSs have been used to produce more successful prosthetic restorations.

When the network analysis of the authors was examined, it was determined that the studies were both single-center and multi-center studies. It was observed that some authors had a relationship with certain institutions or authors. As a result, these authors collaborated on various studies together.

In the present study, it was determined that 21 of the 100 most cited articles were published in the Journal of Prosthetic Dentistry, one of the prestigious journals for prosthodontics. The journal has a Q value of Q1 and an h index of 19, and the number of citations per publication is 46.95. It is quite usual for researchers to prefer a prestigious journal to make their publications more visible. The high number of publications can be interpreted as proof that the Journal of Prosthetic Dentistry considers dental implants and IOS as a current, interesting, and developing field. The Q values of the 2nd and 3rd ranked journals (Clinic Oral Implant Research and International Journal of Oral Maxillofacial Implants) are Q1 and Q2, respectively. The h index is 12 and 9, respectively. Similarly, these journals focus on dental implants, track current developments, and typically publish high-quality publications.

Conclusions

The majority of the 100 most cited articles on IOSs and dental implants are original articles. The quantity of reviews is limited. Mostly published in the USA and continental Europe. WoS-CC is a database that lists publications that meet certain criteria. The fact that 10% of the publications have received 100 or more citations shows the success of the WoS-CC database. Almost a third of published articles are open access. With the developments in dental implant applications, it is thought that the use of IOS will not lose its popularity and will even continue to increase with ever-changing clinical scenarios.

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Comparison of Restoration Recommendation and Adjustment Time of AI Belong to Two Different CAD Software

Elif Tuba Akçin^{1,a,*}, Gökçe Bulut^{1,b}, Lale Karaağaçlıoğlu^{1,c}

¹Department of Prosthodontics, Faculty of Dentistry, Lokman Hekim University, Ankara, Turkey

*Corresponding author

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ABSTRACT

Objectives: The purpose of the in vitro study is to compare the restoration recommendation time and adjustment process of artificial intelligence (AI) belonging to two different digital design software.

Materials and Methods: The maxillary right first premolar tooth was prepared for zirconia all-ceramic crown restoration in a phantom model (n=26). Then, models were scanned using an intraoral scanner, and the opposing arch, and the right- and left-sided occlusions were also recorded. Data were transferred to two computer-aided design software programs (Group Exocad and Group 3Shape) and two design processes were used. In both systems, fully anatomical monolithic zirconia crown design processes were carried out in library mode. The time taken by the AI to recommend the restoration and the time the dental technician spent adjusting the restoration were recorded and were analyzed statistically, both separately and in comparison, to one another ($P<.05$).

Results: Statistically significant differences were found between the values of AI restoration recommendation time and dental technician restoration adjustment time according to the different software designs ($P<.05$). Group Exocad showed lower values than Group 3Shape ($P<.001$).

Conclusions: Exocad provides a faster and easier restoration design in comparison with the 3Shape Dental System.

Keywords: CAD/CAM, crown design, artificial intelligence

İki Farklı CAD Yazılımına Ait Yapay Zekanın Restorasyon Öneri ve Ayarlama Süresinin Karşılaştırılması

Araştırma Makalesi

Süreç

Geliş: 27/01/2025

Kabul: 12/05/2025

ÖZET

Amaç: Bu in vitro çalışmanın amacı, iki farklı dijital tasarım yazılımına ait yapay zekanın restorasyon önerme sürelerini ve uyumlama sürecini karşılaştırmaktır.

Gereç ve Yöntemler: Üst çene sağ birinci premolar diş, fantom modelde (n=26) zirkonyum tam seramik kron restorasyonu için prepare edildi. Daha sonra, modeller bir intraoral tarayıcı kullanılarak tarandı ve karşıt ark ve sağ ve sol taraflı oklüzyonlar da kaydedildi. Veriler iki farklı bilgisayar destekli tasarım yazılım programına (Grup Exocad ve Grup 3Shape) aktarıldı ve iki tasarım süreci yürütüldü. Her iki sistemde de, tamamen anatomik monolitik zirkonyum kron tasarım süreçleri kütüphane modunda gerçekleştirildi. Yapay zekanın restorasyonu önermek için harcadığı süre ve diş teknisyeninin restorasyonu uyumlamak için harcadığı süre kaydedildi ve hem ayrı ayrı hem de birbirleriyle karşılaştırılarak istatistiksel olarak analiz edildi ($P<.05$).

Bulgular: Yapay zekanın restorasyon öneri süresi ve diş teknisyeni restorasyon ayarlama süresi değerleri arasında farklı yazılımlara göre istatistiksel olarak anlamlı farklar bulundu ($P<.05$). Grup Exocad, Grup 3Shape'ten daha düşük değerler gösterdi ($P<.001$).

Sonuçlar: Exocad, 3Shape Dental Sistemine kıyasla daha hızlı ve kolay bir restorasyon tasarımı sağlar.

Anahtar Kelimeler: CAD/CAM, kron tasarımı, yapay zeka

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^a elifakcin88@gmail.com

^c lale.karaagaclioglu@lokmanhekim.edu.tr

^b gokcebulut28@gmail.com

^c gokcebulut28@gmail.com

^b gokcebulut28@gmail.com

^c gokcebulut28@gmail.com

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Introduction

Artificial Intelligence (AI) technology has made significant advancements across many sectors, including dentistry, where it plays a crucial role in processing and managing large volumes of patient data.^{1,2} It can be used in almost all areas of dentistry, such as oral, dental, and maxillofacial radiology, endodontics, implant surgery, restorative and prosthetic dentistry.^{2,3} The applications of AI are particularly important in prosthetic dentistry.⁴

Computer - aided design / computer - aided manufacturing (CAD/CAM) is increasing trend in designing and manufacturing fixed restorations^{5,6} and AI technologies are used in this systems.⁷

The primary trend in the design of CAD/CAM restorations is the library mode. In this method, the operator selects the design from the tooth data in the software and completes the restoration by adjusting it to the existing dentition.⁸⁻¹¹ Additionally, there is a correlation mode. The tooth is scanned before starting the tooth preparation, after which the prepared tooth is scanned with an intraoral scanner, and the initial scan data are superimposed. The crown is designed based on the initial scan data.⁸ The occlusal morphology of an intact tooth is directly transferred to the permanent restoration.¹² Correlation mode is more effective and time saving way to design the well-shaped crowns compared to library mode but it is used only the tooth structure is intact. Even so, in both modes of design, a certain amount of time is required for the dental technician to adjust and create the prosthesis.^{13,14} In addition, the time spent at the chairside during the prosthesis delivery stage is critical for both the patient and clinician.¹⁵ CAD/CAM technology, which greatly simplifies and accelerates the manufacturing process, offers a solution to this problem. However, the data existing in tooth libraries of software programs is still insufficient to design an excellent customized restoration, a significant amount of manual input is required.^{16,17}

Therefore, AI technology has been used to increase the effectiveness of CAD/CAM systems in clinical applications.^{18,19} The first intervention which integrates AI with CAD/CAM was occurred by Raith et al.¹⁸ to improve in chairside prosthetic application in 2017. With this intervention, digital restorations have gained new extent.^{16,20} Design software, powered by AI, have techniques like convolutional neural networks (CNNs) for creating tooth figures through deep learning (DL). It uses a lot of clinical cases existing in library of design software.^{21,22} AI obtains both easy to design restoration and prevention of human derived problems.²³⁻²⁵

The most significant advantage of AI is its ability to learn from new cases continually added to databases. It evaluates every situation and determines how successful restorations achieve optimal function based on ideal occlusion and appropriate marginal margins.²⁶ These developments make dentists and dental technicians turned towards automated restoration design made by AI. Various AI supported dental design software have been developed to meet this demand.^{27,28} While the precision of restorations designed by AI is acceptable in mimicking the shape of the original tooth, additional manual input is needed.^{13,16,29-31} Therefore, clinicians should focus on

collecting and entering correct data into databases. This will soon elevate the use of AI in dentistry to the highest level.⁴

The similarity ratio between the restorations designed by AI and those designed by dental technicians has not been researched. It is not clear if AI could overcome the all extreme cases in terms of digital prosthetic dentistry.³² Current AI technology can design basic prosthetic restorations such as inlays, single unit fixed partial dentures.³³ The comparison between the restoration designed by AI and those designed by experienced dental technicians is essential for advanced treatment plans.³⁴ Existing studies only evaluated the shape of teeth but they did not give information about fabrication of the restoration.¹⁵

Therefore, the abilities and effectiveness of AI in prosthetic restoration design remain unclear, and there is a lack of sufficient studies investigating this topic. This study investigated the time of restoration recommendation and adjustment process requirements of AI in two different digital dental design programs. The null hypothesis of this study was that there would be no difference between the AI recommendation time of the two design systems.

Material and Methods

The maxillary right first premolar tooth was prepared for zirconia all-ceramic crown restoration in a phantom model (ANA-4, Frasco GmbH, Tettang, Germany) by the same operator (G.B.) using a high-speed instrument (PanaAir FX, NSK, Kanuma, Japan) and diamond burs (314 S SG 881 012, 314 S SG 811 033, 314 G SG 859 018, DiaSwiss, Nyon, Switzerland) under water cooling. One mm circular shoulder was chosen for the preparation of the finish line. A 2-mm functional cusp reduction in the palatal tubercle and a 1.5 mm non-functional cusp reduction in the buccal tubercle were applied. Cusp bevels were formed in the middle triad on buccal surface and occlusal triad on both the buccal and palatal surface of the preparation.³⁵ The sample size for per group was determined as n=26 as a result of the Power Analysis performed with a significance of $P<.05$ and 90%. After teeth preparation, the phantom models were scanned using an intraoral scanner (IOS) (TRIOS 3 (T3), Cart version 1.4.7.5, 3Shape, Copenhagen, Denmark) by 10 years IOS experienced operator (L.K.) (Figs. 1A, B). The mandibular phantom model was then scanned as the opposing arch, and the right- and left-sided occlusions were recorded. After the final processing, the files were exported in stereolithography (STL) format. Data were transferred to two different computer-aided dental software programs: Group Exocad (version 3.0, Exocad DentalCAD, Exocad GmbH, Darmstadt, Germany) and Group 3Shape (3Shape Dental Manager, version 88.1.9, 3Shape Dental System, Copenhagen, Denmark), and two design processes were carried out by a dental technician (Ç.E.) with 10 years of experience. In both systems, a fully anatomical monolithic zirconia crown was selected for the maxillary right first premolar tooth; the minimum material thickness was set to 0.4 mm, and the cement gap was set to 0.2 mm (Fig. 2). The designs for both systems were created in library mode, and the time required for the restoration, as suggested by the AI software, was recorded using a digital chronometer. After that, the restorations

were adjusted and the adjustment time was also recorded. Tooth preparations, intraoral scanning procedures, and designing of the restorations were carried out separate operators who are blinded about the aim of the study. The time taken by the AI to recommend the restoration, the time the dental technician spent adjusting the restoration, and the time the dental technician spent on adjustments in two different dental design programs were analyzed statistically, both separately and in comparison, to one another.

Descriptive statistics of the data (number, percentage, mean, standard deviation, median, minimum, and maximum) were evaluated. The reliabilities of the scales used in this study were also assessed. The normality assumption was checked using the Shapiro-Wilk test as the first step of statistical analysis. The Mann-Whitney U test was employed to compare two independent groups that did not have a normal distribution. All data were analyzed using a software program (IBM SPSS Statistics v22.0; IBM Corp, New York, United States). A value of $P < .05$ was considered significantly different.



Figure 1A. The occlusal view of digital impression of the prepared right maxillary first premolar tooth scanned with intraoral scanner

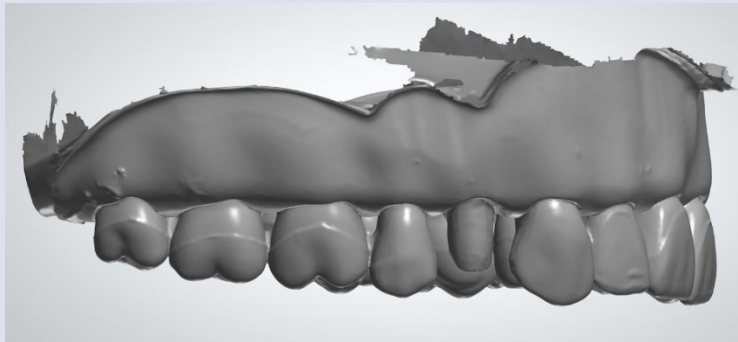


Figure 1B. The buccal view of digital impression of the prepared right maxillary first premolar tooth scanned with intraoral scanner

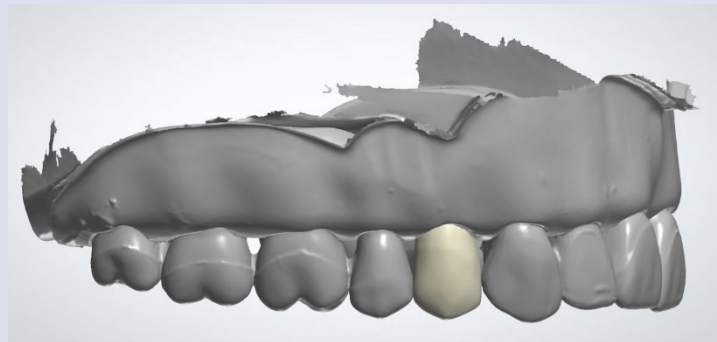


Figure 2. Design of fully anatomical zirconia crown

Results

According to the measurement methods, the recommendation time of the AI, the dental technician's restoration adjustment time, and the distribution of the differences between these two metrics are presented in Table 1. The time distribution graphs are shown in Fig. 3.

Statistically significant differences were found between the values of AI restoration recommendation time and dental technician restoration adjustment time according to the different software designs ($P<.05$). For all the parameters subjected to statistical analyses, Group Exocad showed lower values than those of Group 3Shape ($P<.001$).

Table 1. Comparison of artificial intelligence restoration recommendation time, dental technician restoration adjustment time and dental technician-system time according to the different design softwares

Time (sec)	Groups	Min-Max	Median \pm SD	Test Statistics	P^*
Artificial intelligence restoration recommendation time	Exocad	3.21-4.21	3.93 \pm 0.22(3.96)	64.50	<.001*
	3Shape	2.85-6.90	4.97 \pm 1.05(5.17)		
Dental technician restoration adjustment time	Exocad	4.00-23.00	10.09 \pm 4.76(9.4)	0.000	<.001*
	3Shape	28.90-47.50	35.96 \pm 6.69(32.29)		

SD: Standard deviation.

* $P<.05$

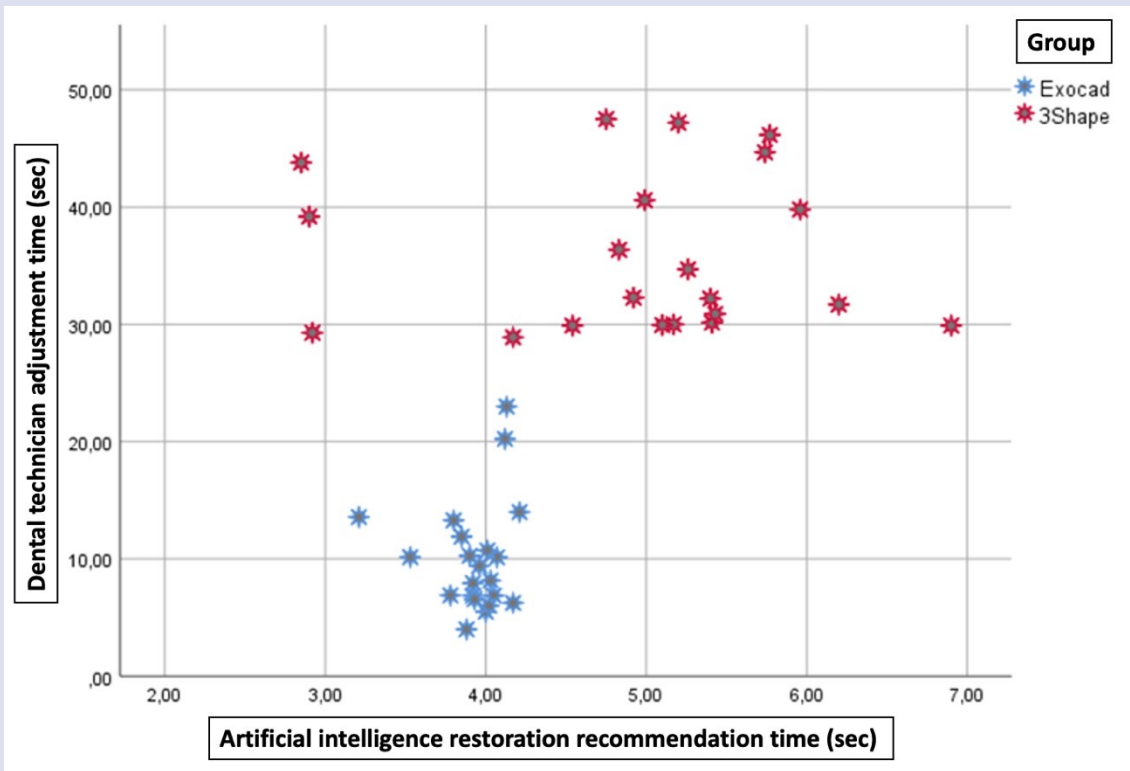


Figure 3. Distribution of artificial intelligence restoration recommendation time and technician adjustment time according to design

Discussion

In this study, the full anatomical crown recommendation time of Exocad and 3Shape Dental System software were compared. The findings revealed significant differences in the recommendation time of the full anatomical crown between the two systems. Statistical analysis showed that the 3Shape Dental System required a longer time to propose a fully anatomical crown and for the technician to adjust it. Based on the results of this study, the hypothesis that there would be

no difference between the AI recommendation time of the two design systems was rejected.

The library mode is the generally preferred method in dental design programs. In this approach, the restoration is selected from the system library, and necessary adjustments are made by an operator.^{8,9} Several studies compare the correlation mode and library mode of CAD designs.^{8,9,30} When the structural integrity of the tooth to be restored is preserved, designing in correlation mode should be the first choice. Conversely, for teeth that have

experienced tissue loss owing to caries or trauma, it is recommended to use the library mode.⁸ In our study, scanning was not performed before tooth preparation, and crown design was not conducted in the correlation mode. After preparation, the models were scanned with an intraoral scanner, and crowns were designed in library mode.

Wang et al.⁸ compared the precision of crowns manufactured using different design theories and three CAD software programs. Four types of tooth deficiencies were created to mimic the different tooth deficiency. Full anatomical crowns were designed for the mandibular left first molar tooth prepared on plaster models obtained from patients using library and correlation modes in the 3Shape, CEREC and Exocad programs. Morphological deviations between the crowns designed automatically by the software and the original teeth were evaluated using a 3D matching system. According to the results of the study, crowns produced with the 3Shape and CEREC showed better results than those produced with the Exocad in case of tooth information loss. The CEREC showed higher stability than the 3Shape and Exocad software programs. When designing restorations, the CEREC and 3Shape systems create a line by determining the set of prominent points on the biological characteristic curves. In the Exocad system, a series of interaction points must be added to create biological curves.³⁶ This may explain the difference between automatically designed restorations. However, in the standard group, for which all data were provided, the Exocad system designed the best restorations. Consistent with the results of this study, because all teeth adjacent and opposite to the designed tooth were present in our study, the restoration recommendation skill of the Exocad system was better than that of the 3Shape system.

Recently, the sensory information in AI has developed significantly and it made the machines understand complex data. Two AI methods are commonly used for this purpose. The first method uses handcrafted features defined by mathematical equations that allow data to be quantified using computer programs. In the second method, DL algorithms learn by navigating the data space directly, which gives them superior problem-solving capabilities.³⁷ Despite the use of AI in dental design, expert intervention and additional processes are still required.³⁰ DL can be strengthened by inputting additional patient data into databases. Thus, faster and easier service can be provided to patients with restorations directly designed and created using AI.

Liu et al.¹⁵ compared the design process of the full anatomical molar crown performed by AI and experienced dental technicians. They found that, AI had reduced the design time by %400 compared to dental technicians. Also, it was reported in another study that, the design time of the restoration proposed by systems powered by AI are lower statistically than the time of experienced dental technicians.¹⁴ AI can decrease time required for the design of the dental crowns.^{11,27,33} In the present study, the all designs, proposed by AI belong to two

different software, were adjusted by the 10-year-experienced dental technician and comparisons were performed.

Programs that enable more detailed and precise restoration designs may negatively impact the automatic restoration recommendation time and the time required for technician adjustments. In the present study, the differences in the restoration design time between the Exocad and 3Shape dental systems may be attributed to the details of the design programs or differences in the databases. The feasibility of single crowns designed by AI is showed by Chau et al.¹⁶ and they concluded the accuracy of dentures designed by AI can be developed by optimization. Excellent crown restoration designs and patients' comfort can be achieved by further research in AI and DL.^{38,39} The more cases loaded into the system in advance, the larger is the database of the program. This can impact the design time in detailed systems. In the present study, the 3Shape Dental System suggested restorations in a longer time than the Exocad. It also took longer for the technician to adjust it to the existing dentition. A longer time may be required because the 3Shape Dental System allows for more precise details. Although there are many design programs, limited studies have evaluated the differences between them; thus, further studies are needed.⁴⁰

The methodology of the present study that, firstly AI belong to two different design software had proposed the restorations after that all restorations were adjusted by 10-year experienced dental technicians. The proposing time and the adjustment time of the restorations were compared each other. AI designs and dental technician's design were not compared. It is a limitation of the present study. Another limitation of the study, the morphology and the accuracy of the restorations were not evaluated with a 3D assessment program reported in previous studies.^{11,14,15,27} Also, the restorations were not manufactured and a comparison of manufactured restorations was not performed. Future in vitro and clinical studies are required.

Conclusions

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

1. The restoration recommendation time of the AI in the Exocad system was lower than that of the 3Shape Dental System. Exocad recommends restoration within a significantly shorter time.
2. The time required for the technician to adjust the crown suggested by the AI of the Exocad system to the existing dentition was found to be significantly lower than that of the 3Shape Dental system.
3. Exocad provides a faster and easier restoration design compared to the 3Shape Dental System. In clinical practice, Exocad system is more suitable to deliver definitive prostheses quickly.

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Evaluation of the Performance of Different Chatbots' Responses to Restorative Dentistry-Related Questions

Cansu Yıkıcı Çöl^{1,a}, Merve Nezir^{2,b,*}, Suat Özcan^{2,c}

¹Panorama Ankara Oral and Dental Health Clinic, Çankaya, Ankara, Türkiye.

²Department of Restorative Dentistry, Faculty of Dentistry, Gazi University, Çankaya, Ankara, Türkiye.

*Corresponding author

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ABSTRACT

Objectives: To evaluate and compare the performance of the responses given by three different chatbots to questions related to the field of restorative dentistry for undergraduate education, specialist education, and which are considered controversial currently.

Materials and Methods: Thirty-five questions total was created by two dentists. In these questions, many different topics such as terminology, treatment procedures, technical details, material and application procedure, post-procedure care, indications, contraindications, approach in the presence of medical problems are touched upon. Three different chatbots (Copilot, Gemini and ChatGPT) were used in the study. Evaluation was done using a 5-point Likert Scale. The statistical significance level was determined as 0.05.

Results: When the correlation of the sub-dimensions among themselves is evaluated, there is a very strong positive statistically significant correlation between the questions about undergraduate education and the questions about specialist education ($p < 0.001$). Out of a total of 105 responses, Copilot produced 48 valid responses and 57 invalid responses. While Gemini produced 54 valid and 51 invalid responses, ChatGPT produced 58 valid and 47 invalid responses.

Conclusions: We think that this study may provide ideas for further studies in terms of evaluating the responses to various questions, including especially controversial questions regarding different areas of dentistry.

Keywords: Artificial intelligence, ChatGPT, Copilot, Gemini, Restorative Dentistry.

Restoratif Diş Hekimliği ile İlgili Sorulara Verilen Farklı Sohbet Botu Yanıtlarının Performansının Değerlendirilmesi

Araştırma Makalesi

Süreç

Geliş: 06/02/2025

Kabul: 06/03/2025

ÖZET

Amaç: Lisans eğitimi, uzmanlık eğitimi ve günümüzde tartışmalı kabul edilen restoratif diş hekimliği alanıyla ilgili sorulara üç farklı chatbot tarafından verilen yanıtların performansını değerlendirmek ve karşılaştırmak.

Gereç ve Yöntemler: Toplam 35 soru iki diş hekimi tarafından oluşturuldu. Bu sorularda terminoloji, tedavi prosedürleri, teknik detaylar, materyal ve uygulama prosedürü, işlem sonrası bakım, endikasyonlar, kontrendikasyonlar, tıbbi sorunlar varlığında yaklaşım gibi birçok farklı konuya değinilmektedir. Çalışmada üç farklı chatbot (Copilot, Gemini ve ChatGPT) kullanıldı. Değerlendirme 5 puanlık Likert Ölçeği kullanılarak yapıldı. İstatistiksel anlamlılık düzeyi 0,05 olarak belirlendi.

Bulgular: Alt boyutların kendi aralarındaki korelasyonu değerlendirildiğinde lisans eğitimiyle ilgili sorularla uzmanlık eğitimiyle ilgili sorular arasında çok güçlü pozitif istatistiksel olarak anlamlı bir korelasyon vardır ($p < 0,001$). Toplam 105 yanıtta Copilot 48 geçerli yanıt ve 57 geçersiz yanıt üretti. Gemini 54 geçerli ve 51 geçersiz yanıt üretirken, ChatGPT 58 geçerli ve 47 geçersiz yanıt üretti.

Sonuçlar: Bu çalışmanın, özellikle diş hekimliğinin farklı alanlarıyla ilgili tartışmalı sorular da dahil olmak üzere çeşitli sorulara verilen yanıtları değerlendirmek açısından daha ileri çalışmalar için fikir sağlayabileceğini düşünüyoruz.

Anahtar Kelimeler: Yapay zeka, ChatGPT, Copilot, Gemini, Restoratif Diş Hekimliği.

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^a cansu.yikici@gmail.com

^c suatozcan@gazi.edu.tr

^{ID} 0000-0001-8855-7417

^{ID} 0000-0001-8782-2899

^b mervenezir@gazi.edu.tr

^{ID} 0000-0001-8902-5471

Introduction

These days, artificial intelligence (AI) chatbots have completely changed digital communication by sharing knowledge and giving people the chance to ask tailored questions and get answers that are both original and targeted. Chatbots have the potential to enhance their answers over time, owing to their ability to extract information from large amounts of data thanks to deep learning algorithms.¹ In late 2022, there was a groundbreaking advancement in artificial intelligence technology: OpenAI Inc. ChatGPT program offered by (San Francisco, CA, USA) has been introduced. This chatbot reached a staggering 100 million new users in the first 3 months. Over the past few years, the field of dentistry has also experienced remarkable growth in artificial intelligence applications and tools.² With the use of computational linguistics and vast amounts of data, ChatGPT is an artificial intelligence computer software that can mimic human speech in response to user requests, hence enhancing responsiveness and communication skills. Through text-based interfaces, methods like machine learning and deep learning are applied. ChatGPT is a huge language model that generates human-like replies to natural language questions using deep learning AI techniques. For patients, healthcare professionals, and educators alike, ChatGPT offers a wide range of services. For instance, it may help students with their homework and tutoring by providing explanations and answers to help them understand complicated concepts. Additionally, by serving as a teaching tool, it has the power to fundamentally alter how students study biomedical science. Healthcare professionals working in dentistry and other medical fields can benefit from ChatGPT's many services, which include improved decision-making support, digital data recording, diagnosis, disease prevention, image analysis, treatment, fewer treatment interruptions, and research and discovery opportunities.³

Apart from ChatGPT, artificial intelligence robots also include applications such as Google Gemini and Microsoft Copilot. The healthcare sector is paying close attention to AI models, and initial research has shown positive results. AI programs excel at emulating human speech patterns and generating answers to spoken text that seem natural. The application of ChatGPT and related models in healthcare services has piqued the interest of many individuals. AIs will probably be utilized, in particular, to assist physicians and patients in understanding how to interpret laboratory results and use clinical laboratory services.⁴ However, the dangers of misuse, including the spread of misinformation, ethical concerns, and factual errors, should all be considered in writing for academia and healthcare practices. Human intelligence (HI) is more adaptable than artificial intelligence due to its natural evolutionary history, versatility, creativity, psychological intelligence, and capacity to understand complex abstract ideas.⁵ In the light of all this information, this study aimed to evaluate and compare the performance of the responses given by three different chatbots (Microsoft Copilot, Google Gemini and ChatGPT 3.5) to questions that are considered controversial today for undergraduate students and specialists in the field of restorative dentistry. The first null hypothesis of this study was that the responses given by different chatbots to the questions are consistent

with each other. The second null hypothesis is that each of the three responses to the same questions is consistent with each other.

Materials and Methods

No ethics committee approval is required for this study.

There was not an appeal for ethical approval because the research was done using data that was freely accessible online. Two practitioners in restorative dentistry produced a comprehensive set of questions about education for the field. Thirty questions total was created by two dentists (C.Y.C. and M.N.), who are full-time specialists in restorative dentistry working by both public and private institutions. Twenty-five questions were designed undergraduate education, five questions for specialist education, and five questions associated with controversial issues (Figure 1). Table 1 displays the list of questions that the restorative dentistry specialist chosen. In these questions, many different topics such as terminology, treatment procedures, technical details, material and application procedure, post-procedure care, indications, contraindications, approach in the presence of medical problems are touched upon. In this study, the responses given to questions by three different chatbots were evaluated. The chatbots evaluated are summarized in Table 2. A new e-mail account was created to avoid being affected by past activity. All search history and cookies on the computer have been cleared. Three different chatbots were used in the study. These are summarized in Table 2. Accounts were opened with new e-mail addresses in all three applications. A total of 35 questions were asked to each chatbot on the same day (22.03.2024). In order to evaluate its reliability, each question was repeated 3 times and a total of 270 responses were obtained. Before asking questions for each answer, a 'new topic' or 'new chat' was opened. All responses received were recorded in a separate file. Evaluation was done using a 5-point Likert Scale Scores^{6,7} from 1 to 5 are given on the scale (Table 3).

The responses received were evaluated independently by two restorative dentistry specialists. Two raters then reviewed the responses. Differences were discussed based on evidence, and disagreements were resolved by consulting a third evaluator (S.Ö.). All responses were noted in a separate excel file. Descriptive statistics were used to describe continuous variables (mean, standard deviation, minimum, median, and maximum). Frequency and percentage data were acquired for descriptive statistics pertaining to categorical variables. Fleiss Kappa agreement overall test was used to compare the evaluations of chatbots on a categorical feature on a question basis and in subcategories with randomness and to measure the fit that is above or below randomness according to the category. To investigate the link between quantitative data that differ from the normal distribution, the Spearman's rho correlation test was used. When evaluating the validity of the responses, the threshold value was accepted as 4. Questions that received 4 or more points on a question basis and in subcategories were considered valid.¹ The reliability and internal consistency of each Chatbot were evaluated using Spearman-Brown Coefficient, Cronbach Alpha, and Guttman Split Half Coefficient coefficients. The statistical significance level was determined as 0.05.

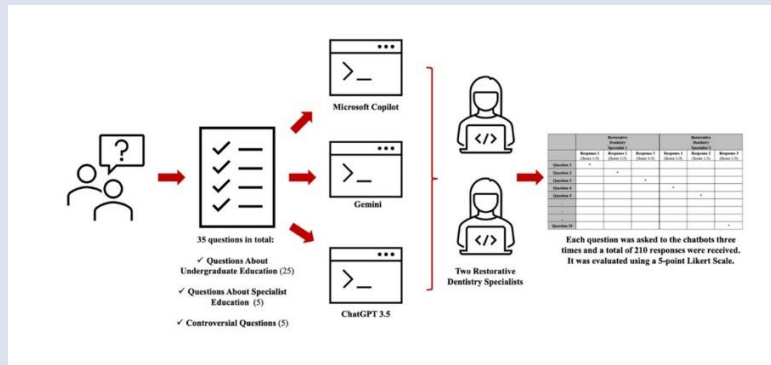


Figure 1. Study design

Table 1. List of questions asked to the chatbots

Category of Questions	Questions Asked to Chatbots
Questions About Undergraduate Education	U1. What type of composite resin material should be used in restorations of front and back teeth? U2. What should be taken into consideration when applying dental bonding agent? U3. Why is matrix band applied to the tooth when filling? U4. What are the types of dental matrix band? U5. Why is wedge application used when filling teeth? U6. What are the application stages of amalgam restoration? U7. What are the application stages of composite resin restoration? U8. What should be taken into consideration in composite resin polymerization? U9. How should the finishing and polishing of composite restorations be done? U10. What advice should be given to patients after amalgam restoration application? U11. What advice should be given to patients after composite resin restoration application? U12. What should be taken into consideration during dental treatment in a patient with diabetes? U13. What should be taken into consideration during dental treatment in a patient with heart problems? U14. What should be taken into consideration during dental treatment in a patient with rheumatic disease? U15. What should be taken into consideration during dental treatment in pregnant women? U16. In which patients should antibiotic prophylaxis be applied? U17. How is antibiotic prophylaxis performed? U18. What is vital bleaching and how is it applied? U19. What is devital bleaching and how is it applied? U20. What should be taken into consideration in patients who will undergo tooth whitening treatment? U21. What should be recommended to patients after teeth whitening treatment? U22. When should filling be applied after teeth whitening treatment? U23. What is indirect pulp capping treatment and how is it applied? U24. What is direct pulp capping treatment and how is it applied? U25. What is atraumatic restorative treatment and why is it used?
Questions About Specialist Education	S1. What is the gold standard dental bonding agent? S2. Which inorganic filler type shows the lowest wear on the tooth structure in dental composites? S3. Why and how to apply chlorhexidine after dental cavity preparation? S4. How to do deep margin elevation? S5. What are the advantages of the ethanol based etch and rinse system?
Controversial Questions	C1. Can teeth whitening be applied to pregnant women? C2. Is whitening treatment harmful to health? C3. Should fluoride applications be recommended to patients? C4. Can we recommend fluoride toothpaste to pregnant patients? C5. Which patients should not have amalgam fillings?

Table 2. The attributes of the chatbots used in the study

Chatbots	Developer	Language model	Versions	Free/paid versions	Version used in the study
Microsoft Copilot	Microsoft	GPT-4 and DALLÉ	Copilot Pro, Copilot for Microsoft 365, Free Microsoft Copilot	Copilot, Copilot Pro	Copilot
Gemini	Google AI	LaMDA	Nano, Pro and Ultra	Gemini, Gemini Advanced	Gemini
ChatGPT	OpenAI	GPT-4, GPT-3 and DALLÉ	GPT-1 GPT-2 GPT-3 GPT-4	ChatGPT, ChatGPT plus	ChatGPT 3.5

Table 3. 5-point Likert Scale

Score	Meaning
Score 5 (Strongly Agree)	The answer is correct, and the content is comprehensive.
Score 4 (Agree)	The answer is correct and most of the content is correct, but it lacks information, or contains incorrect information.
Score 3 (Neutral)	The answer is somewhat correct, but details are primarily incorrect, missing, or irrelevant.
Score 2 (Disagree)	The answer is incorrect, but the content includes some correct elements.
Score 1 (Strongly Disagree)	The answer and the entire content are incorrect or irrelevant.

The Fleiss Kappa overall agreement test was used to compare the evaluations of more than two observers on a categorical feature at the same time with randomness and to measure the agreement that was above or below randomness according to the category. Spearman's rho correlation test was used to examine the relationship between quantitative variables that do not comply with normal distribution. The statistical significance level was determined as 0.05.

Results

When the consistency between 3 different ChatBots is evaluated on a question basis, there is a strong statistically significant consistency in 13 out of 35 questions (37%) in total $p < 0.001$. These questions are distributed as 8 out of 25 (32%) in questions about undergraduate education, 1 out of 5 (20%) in questions related to specialist Education, and 4 out of 5 (80%) in controversial questions. For the question 'How to do deep margin elevation (S4)', there is a moderate negative statistically significant agreement between the AI tools ($p < 0.05$). When compared on the basis of sub-dimensions, no statistically significant consistency was found between the chatbots. ($p > 0.05$). Table 4 summarizes the compatibility between ChatBots according to questions and sub-dimensions.

When the correlation of the sub-dimensions among themselves is evaluated, there is a very strong positive statistically significant correlation between the questions

about undergraduate education and the questions about specialist education ($p < 0.001$).

When evaluating the validity of the responses, the threshold value was accepted as 4. Questions that received 4 or more points on a question basis and in subcategories were considered valid.¹

When the validity of the responses was evaluated, a total of 35 questions were repeated 3 times, so 105 responses were received from each chatbot. Out of a total of 105 responses, Copilot produced 48 valid responses (45%) and 57 invalid responses (54%). While Gemini produced 54 valid (51%) and 51 invalid (48%) responses, ChatGPT produced 58 valid (55%) and 47 invalid (44%) responses.

When the valid/invalid responses of the sub-dimensions were evaluated in general, all three chatbots produced wrong responses in questions about undergraduate education and questions about specialist education. On the contrary, it was determined that all three chatbots produced correct responses on controversial issues.

When the internal consistency and reliability of the chatbots were analyzed, Copilot and Gemini showed good reliability and good internal consistency. ChatGPT demonstrated good internal consistency and good-moderate reliability. Cronbach's Alpha, Spearman-Brown and Guttman Split-Half Coefficients of chatbots are shown in Figure 2.

Table 4. Compatibility between chatbots by question and for sub-dimensions

	Question	Copilot_mean	Gemini_mean	ChatGPT_mean	Kappa kp
Questions About Undergraduate Education	What type of composite resin material should be used in restorations of front and back teeth?	2.33±0.58 2- (2-3)	2±0 2- (2-2)	3.33±1.15 4- (2-4)	-0.350 0.173
	What should be taken into consideration when applying dental bonding agent?	3±0 3- (3-3)	3±0 3- (3-3)	3.67±0.58 4- (3-4)	-0.286 0.391
	Why is matrix band applied to the tooth when filling?	5±0 5- (5-5)	5±0 5- (5-5)	5±0 5- (5-5)	1.000 <0.001
	What are the types of dental matrix band?	3±0 3- (3-3)	4±0 4- (4-4)	3±0 3- (3-3)	-0.500 0.134
	Why is wedge application used when filling teeth?	4±0 4- (4-4)	3±0 3- (3-3)	4.33±0.58 4- (4-5)	-0.370 0.158
	What are the application stages of amalgam restoration?	3±0 3- (3-3)	3±0 3- (3-3)	3±0 3- (3-3)	1.000 <0.001
	What are the application stages of composite resin restoration?	3±0 3- (3-3)	3±0 3- (3-3)	3.33±0.58 3- (3-4)	-0.125 0.708
	What should be taken into consideration in composite resin polymerization?	3±0 3- (3-3)	3±0 3- (3-3)	4±0 4- (4-4)	-0.500 0.134
	How should the finishing and polishing of composite restorations be done?	2±0 2- (2-2)	4±0 4- (4-4)	4±0 4- (4-4)	-0.500 0.134
	What advice should be given to patients after amalgam restoration application?	3±0 3- (3-3)	3±0 3- (3-3)	3.33±0.58 3- (3-4)	-0.125 0.708
	What advice should be given to patients after composite resin restoration application?	4±0 4- (4-4)	3±0 3- (3-3)	4±0 4- (4-4)	-0.500 0.134
	What should be taken into consideration during dental treatment in a patient with diabetes?	4±0 4- (4-4)	4±0 4- (4-4)	5±0 5- (5-5)	-0.500 0.134
	What should be taken into consideration during dental treatment in a patient with heart problems?	4±0 4- (4-4)	4±0 4- (4-4)	4±0 4- (4-4)	1.000 <0.001
	What should be taken into consideration during dental treatment in a patient with rheumatic disease?	3±0 3- (3-3)	3±0 3- (3-3)	4±0 4- (4-4)	-0.500 0.134
	What should be taken into consideration during dental treatment in pregnant women?	3.67±0.58 4- (3-4)	3.67±0.58 4- (3-4)	4±0 4- (4-4)	0.357 0.284
	In which patients should antibiotic prophylaxis be applied?	4±0 4- (4-4)	3±0 3- (3-3)	3±0 3- (3-3)	-0.500 0.134
	How is antibiotic prophylaxis performed?	3±0 3- (3-3)	3±0 3- (3-3)	3±0 3- (3-3)	1.000 <0.001
	What is vital bleaching and how is it applied?	3±0 3- (3-3)	3±0 3- (3-3)	3±0 3- (3-3)	1.000 <0.001
	What is devital bleaching and how is it applied?	3.33±0.58 3- (3-4)	3±0 3- (3-3)	3±0 3- (3-3)	-0.125 0.708
	What should be taken into consideration in patients who will undergo tooth whitening treatment?	3±0 3- (3-3)	3±0 3- (3-3)	3±0 3- (3-3)	1.000 <0.001
	What should be recommended to patients	4±0 4- (4-4)	4.33±0.58 4- (4-5)	4.33±0.58 4- (4-5)	-0.286 0.391

Questions About Specialist Education	after teeth whitening treatment?				
	When should filling be applied after teeth whitening treatment?	4±0 4- (4-4)	4±0 4- (4-4)	3.33±0.58 3- (3-4)	-0.286 0.391
	What is indirect pulp capping treatment and how is it applied?	3±0 3- (3-3)	3±0 3- (3-3)	3±0 3- (3-3)	1.000 <0.001
	What is direct pulp capping treatment and how is it applied?	3±0 3- (3-3)	3±0 3- (3-3)	3±0 3- (3-3)	1.000 <0.001
	What is atraumatic restorative treatment and why is it used?	3±0 3- (3-3)	3±0 3- (3-3)	3.67±0.58 4- (3-4)	-0.286 0.391
	What is the gold standard dental bonding agent?	1±0 1- (1-1)	1±0 1- (1-1)	1±0 1- (1-1)	1.000 <0.001
	Which inorganic filler type shows the lowest wear on the tooth structure in dental composites?	4±0 4- (4-4)	3.33±0.58 3- (3-4)	4±0 4- (4-4)	-0.286 0.391
	Why and how to apply chlorhexidine after dental cavity preparation?	3±0 3- (3-3)	4±0 4- (4-4)	4±1 4- (3-5)	-0.312 0.236
	How to do deep margin elevation?	3±0 3- (3-3)	4±0 4- (4-4)	1±0 1- (1-1)	-0.500 0.034
	What are the advantages of the ethanol based etch and rinse system?	4±0 4- (4-4)	3±0 3- (3-3)	3.67±2.31 5- (1-5)	-0.397 0.052
Controversial Questions	Can teeth whitening be applied to pregnant women?	4±0 4- (4-4)	4.33±0.58 4- (4-5)	4.67±0.58 5- (4-5)	-0.500 0.134
	Is whitening treatment harmful to health?	4±0 4- (4-4)	4±0 4- (4-4)	4±0 4- (4-4)	1.000 <0.001
	Should fluoride applications be recommended to patients?	4±0 4- (4-4)	4±0 4- (4-4)	4±0 4- (4-4)	1.000 <0.001
	Can we recommend fluoride toothpaste to pregnant patients?	4±0 4- (4-4)	4±0 4- (4-4)	4±0 4- (4-4)	1.000 <0.001
	Which patients should not have amalgam fillings?	4±0 4- (4-4)	4±0 4- (4-4)	4±0 4- (4-4)	1.000 <0.001

Fleiss Kappa Agreement

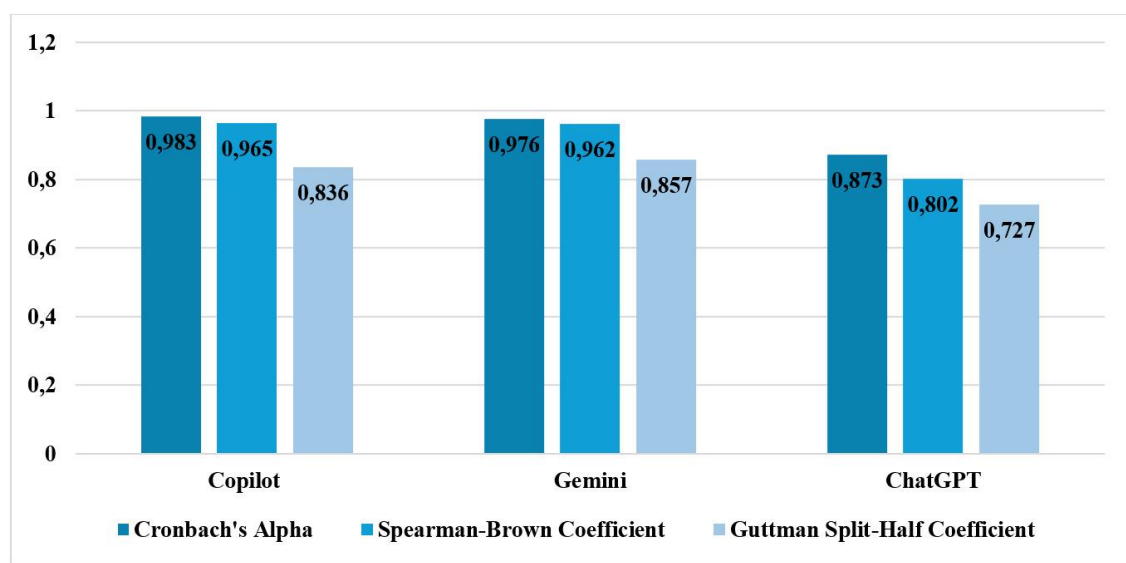


Figure 2. Cronbach's Alpha, Spearman-Brown and Guttman Split-Half Coefficients of chatbots

Discussion

Artificial intelligence is an interdisciplinary field that draws on logic, cybernetics, statistics, decision theory, cognitive psychology, linguistics, neuroscience, and computer engineering to create computer algorithms that simulate intelligent behavior with little human intervention. Information retrieval, speech and image recognition, robotics, sensor technologies, and cognitive decision support systems are just a few of the applications of artificial intelligence that employ machine learning as their primary technology. Artificial intelligence is already having an influence on the whole world and is quickly changing every aspect of contemporary life, including business, social media, healthcare, space technology, and many government responsibilities.⁸ Additionally, artificial intelligence chatbots, which have recently started to attract a lot of attention, can also play an active role in ensuring that people obtain the detailed information they want to learn in various fields. AI systems are capable of perceiving and reacting to objects, events, and phenomena similarly to how humans do. technology is becoming more and more crucial to comprehend how AI is seen and used as technology continues to enter every part of daily life. AI is being used extensively in dentistry, especially in fields like clinical prediction, practice management, implantology, caries detection, teledentistry, and x-ray and diagnostics.⁹

AI-based chatbots have a great deal of promise to advance dental clinical practice. Through thorough analysis, their right usage may facilitate the formulation of precision and customized medical goals, as well as help with diagnostic and treatment planning.⁷ This study evaluated and compared the performance of the responses given by three different chatbots to questions related to the field of restorative dentistry for undergraduate students and specialist students and which are considered controversial currently.

In this study, when the consistency between three different chat robots was evaluated on a question-by-question basis, it was observed that there was consistency in 13 out of 35 questions. Consequently, the first null hypothesis of the study was rejected. According to researchs, a number of factors, such as the underlying technology, the particular algorithms employed, the datasets used for training, and the objectives the chatbot is intended to accomplish, might be responsible for variations in the replies provided by chatbots. The accuracy, fluency, and responsiveness of the chatbot can be impacted by significant variations in the quantity, quality, and diversity of training data. The variety of chatbot responses might be caused by these variables.⁷

Chatbot technology can create a more personalized and interesting learning environment for students. The chatbot facilitates real-time interaction by comprehending and identifying user questions, constructing contextually appropriate sentences, and responding instantly.¹⁰ Studies have focused on chatbot technology, especially its application in education.¹¹⁻¹³ ChatGPT is well-versed in a wide range of undergraduate

subjects, including biology, engineering, and health sciences. It could provide answers to a variety of queries that kids might have both within and outside of the classroom. He is especially skilled at writing code and is proficient in a number of programming languages. In a successful example, the relevant code can be created in the desired programming language. It can help with teaching by drawing students' attention with entertaining techniques like question-answer games in all subject areas. However, ChatGPT may not be sufficient for visual outputs. Furthermore, it has been noted that ChatGPT does a good job at answering exam questions. It can precisely respond to both verbal and numeric questions without omitting any information or cautions. Given that it is a text-based model, its ability to answer test questions can be enhanced by addressing any limitations in graphical representation or interpretation. It is evident that ChatGPT is utilized in undergraduate courses, particularly for tests administered remotely.¹⁴ Questions about undergraduate education and questions about specialist education were found to have a very high positive association in this study. Chatbots can be reliable in answering various questions regarding both undergraduate and specialty education in dentistry. However, it should not be forgotten that visual outputs are also of great importance, especially in dentistry education, where manual dexterity is of great importance. We believe that in the future, developing chatbots with visual outputs may increase their use in the field of dentistry. However, these responses must be verified by professional and expert dentists.

The ability of large language models (LLMs) like ChatGPT¹⁵, Gemini¹⁶, and Microsoft Copilot¹⁷ to comprehend and generate text that is human-like has completely changed the field of artificial intelligence. These chatbot models learn a great deal of knowledge and linguistic subtleties through training on a variety of online datasets. LLMs are useful instruments for information distribution and decision assistance in a number of fields since they can handle a wide range of activities, from responding to inquiries to creating logical and contextually relevant answers.¹⁸ In this study, it was observed that the chatbot that gave the most valid responses to the questions was ChatGPT. The fact that ChatGPT provides a conversational interactive platform for users and answers questions directly instead of sending them to different websites is one of its biggest advantages over conventional online search engines. ChatGPT allows users to analyze and query the veracity and sources of information. ChatGPT has the ability to create new content during real-time conversations. To answer user questions, ChatGPT employs a variety of AI models that have been trained on a vast quantity of textual data. Provides conversational responses to user queries. It is capable of remembering user input and its own response to the conversation thread, and builds its previous outputs with subsequent queries. With the use of a conversational interface, ChatGPT enables users to carry out a wide range of text-based operations at a never-

before-seen scale, including answering queries, producing codes, translating text, and producing original content. ChatGPT provides an intelligent learning platform that enhances student learning by allowing learning materials to be tailored to each student's needs. It seems like a good idea to use ChatGPT as a learning platform, and there are no issues with it. In each web search, there is always a chance of finding false information. This is also true of ChatGPT, which ensures that users double-check information when unsure.⁸

The number of studies evaluating the accuracy, consistency and reliability of chatbots, a new and popular source of information, is quite limited.^{1,19} It appears that issues related to restorative dentistry have not yet been researched. Therefore, this study aimed to evaluate the accuracy, consistency, validity, and recommendability of the responses given to frequently asked questions in the field of restorative dentistry by chat robots, which have become very popular recently. When the internal consistency and reliability of the chatbots were analyzed, Copilot and Gemini were found to show good internal consistency and good reliability. ChatGPT, on the other hand, was found to show good internal consistency and good-moderate reliability. Therefore, the second null hypothesis of the study was rejected. However, all three chatbots gave incorrect responses to questions about undergraduate education and questions about specialty education. On the contrary, it was determined that all three chatbots produced correct responses on controversial issues. The accuracy of the responses given to controversial questions is very important. We think that this study may provide ideas for further studies in terms of evaluating the responses to various questions, including especially controversial questions regarding different areas of dentistry.

Limitations of this study include the constant updating and improvement of existing versions of the chatbots used. It is very important to keep up with artificial intelligence technology, which is renewed and developed every day. This study focused on questions related to the field of restorative dentistry, one of the fields of dentistry. We think that evaluating questions related to other fields of dentistry with further studies and possibly the most up-to-date chat robots will make valuable contributions to the literature.

Conclusions

Within the limitations of this current study, it was concluded that: There is a strong statistically significant consistency in 13 out of 35 total questions (37%) within each chatbot. There is a very strong positive statistically significant correlation between the questions about undergraduate education and the questions about specialist education. Out of a total of 105 responses, Copilot produced 48 valid responses (45%) and 57 invalid responses (54%). While Gemini produced 54 valid (51%) and 51 invalid (48%) responses, ChatGPT produced 58 valid (55%) and 47 invalid (44%) responses. However, these responses must be verified by professional and

expert dentists. We think that this study may provide ideas for further studies in terms of evaluating the responses to various questions, including especially controversial questions regarding different areas of dentistry.

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Not applicable.

Conflicts of Interest Statement

Not applicable.

Authorship Contributions

Conceptualization, C.Y.Ç., M.N., and S.Ö.; methodology, C.Y.Ç., M.N., and S.Ö.; validation, C.Y.Ç., M.N., and S.Ö.; formal analysis, C.Y.Ç., M.N., and S.Ö.; investigation, C.Y.Ç., M.N., and S.Ö.; writing—original draft preparation, C.Y.Ç., M.N., and S.Ö.; writing—review and editing, C.Y.Ç., M.N., and S.Ö.; supervision, C.Y.Ç., M.N., and S.Ö.; project administration, C.Y.Ç., M.N., and S.Ö. All authors have read and agreed to the published version of the manuscript.

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Effect of Er:YAG Laser on Scaling and Root Planning and Usage of i-Platelet Rich Fibrin as a Biomodifier

Necip Fazıl Gün^{1,a}, Meltem Karsiyaka Hendek^{1,b,*}, Ebru Olgun^{1,c}

¹Department of Periodontology, Faculty of Dentistry, Kirikkale University, Kirikkale, Türkiye.

*Corresponding author

Research Article

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ABSTRACT

Objectives: The purpose of this study was to compare scaling and root planning (SRP) with Er:YAG laser and Gracey curettes and the effectiveness of using injectable platelet-rich fibrin (i-PRF) as a biomodifier was also investigated.

Materials and Methods: There were 4 groups of extracted human teeth: Gracey Group (n=9): SRP with Gracey curettes; Gracey + i-PRF Group (n=9): SRP with Gracey curettes followed by application of i-PRF to the root surface; Er:YAG Group (n=9): SRP with Er:YAG laser; Er:YAG + i-PRF Group (n=9): SRP with Er:YAG laser followed by application of i-PRF to the root surface. The width of dentin tubules and the presence/absence of smear layer were examined using scanning electron microscopy (SEM).

Results: There was significantly less smear layer in the Er:YAG group compared to the Gracey group (p=0.001). The width of dentin tubules was found to be significantly higher in the Er:YAG and Er:YAG+i-PRF groups compared to the Gracey group (respectively; p=0.015; p<0.001). The width of dentin tubules in the Er:YAG+i-PRF group was profoundly higher than in the Gracey+i-PRF group (p=0.026).

Conclusions: Er:YAG laser was found to be more effective than Gracey curettes, which are the gold standard in root surface cleaning. Especially when combined with Er:YAG laser, i-PRF resulted in wider dentin tubules.

Keywords: Er:YAG laser, i-PRF, in vitro, root biomodification

Er:YAG Lazerin Diş Yüzeyi Temizliği ve Kök Yüzeyi Düzleştirme Üzerindeki Etkisi ve Biyomodifiye Edici Olarak e-Trombositten Zengin Fibrinin Kullanımı

Araştırma Makalesi

Süreç

Geliş: 10/02/2025

Kabul: 01/06/2025

ÖZET

Amaç: Bu çalışmanın amacı, Er:YAG lazer ve Gracey küretleri ile diş yüzeyi temizliği ve kök yüzeyi düzleştirme (KYD) prosedürünü karşılaştırmak ve biyomodifiye edici olarak enjekte edilebilir-trombositten zengin fibrin (e-TZF) kullanımının etkinliğini araştırmaktır.

Gereç ve Yöntemler: Çekilen insan dişleri 4 gruba ayrıldı: Gracey Grubu (n=9): Gracey küretleri ile KYD; Gracey + e-TZF Grubu (n=9): Gracey küretleri ile KYD ve ardından kök yüzeyine e-TZF uygulanması; Er:YAG Grubu (n=9): Er:YAG lazeri ile KYD; Er:YAG + e-TZF Grubu (n=9): Er:YAG lazeri ile KYD ve ardından kök yüzeyine e-TZF uygulanması. Dentin tübüllerinin genişliği ve smear tabakasının varlığı/yokluğu taramalı elektron mikroskobu kullanılarak incelendi.

Bulgular: Er:YAG grubunda Gracey grubuna kıyasla önemli ölçüde daha az smear tabakası vardı (p=0,001). Dentin tübüllerinin genişliğinin Er:YAG ve Er:YAG+e-TZF gruplarında Gracey grubuna kıyasla önemli ölçüde daha yüksek olduğu bulundu (sırasıyla; p=0,015; p<0,001). Er:YAG+e-TZF grubundaki dentin tübüllerinin genişliği Gracey+e-TZF grubuna kıyasla belirgin şekilde daha yüksekti (p=0,026).

Sonuçlar: Er:YAG lazerin, diş yüzeyi temizliğinde altın standart olan Gracey küretlerinden daha etkili olduğu bulundu. Özellikle Er:YAG lazerle birleştirildiğinde, e-TZF daha geniş dentin tübülleriyle sonuçlandı.

Anahtar Kelimeler: Er:YAG lazer, e-TZF, in vitro, kök biyomodifikasyonu

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^a necibgun@gmail.com

^c ebuerdemir@hotmail.com

^b 0000-0002-7955-3497

0000-0001-7298-8589

^b mltmkrskryk@yahoo.com

0000-0003-1518-4159

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Introduction

Regenerating the lost periodontium and transforming the root surface into a biologically suitable substrate for the attachment of epithelial and connective tissue cells is one of the goals of periodontal treatment.¹ The mechanical debridement of root surfaces affected by periodontitis focuses on eliminating the etiological factors of periodontal disease and facilitating the attachment of periodontal tissues to restore biological compatibility.² The mechanical debridement of deposits on the root surface is considered the gold standard in the treatment of this disease.³

Root biomodification refers to procedures aimed at detoxifying, decontaminating, and demineralizing the root surface in order to remove the smear layer and expose the collagen matrix of the dentin and cementum.⁴ Various agents are used for root surface biomodification, including mechanical agents (hand instruments/ultrasonics and lasers), chemical agents, and growth factors (biostimulants).⁵

The hemostatic effects, selective calculus ablation, and bactericidal activity are among the specific characteristics of lasers that are worth considering. In this way, it can be observed that appropriate laser application may provide an alternative to mechanical or modified root debridement.⁶ The mechanism of action of laser application is based on thermomechanical ablation, which relies on the high radiation absorption by surface water and hydroxyapatite groups.⁷ Meanwhile, working at the surface level does not cause thermal damage to the underlying tissues. Additionally, it has reported that high-intensity lasers have a significant bactericidal effect on periodontal pathogenic bacteria.⁸ The reason for this is thought to be that the laser radiation promotes the evaporation of water in the bacterial cell cytoplasm, leading to cell rupture,⁹ or it may directly melt or coagulate the bacterial cells.⁸

Er:YAG lasers are lasers that pulse freely while operating and can be used on both soft and hard tissues without causing any damage. The most important feature of this type of laser is that they have very good water absorption. Due to this feature, they can be used safely on both soft and hard tissues. Due to the good ablation feature of Er:YAG lasers, they can be used safely in periodontics; soft tissue surgery, scaling and root planing (SRP), disinfection and detoxification applications.¹⁰ It has been shown that Er:YAG lasers have high bactericidal effects on periodontopathogenic bacteria at low energy levels and have a detoxifying effect on toxins such as lipopolysaccharides diffused to the root surface.^{10,11} In addition, Er:YAG laser does not cause denaturation in periodontal tissues and positively affects the adhesion and proliferation of fibroblasts.¹²

Autogenous platelet-derived products obtained from the patient's own blood have increasingly been used in regenerative applications in recent years, yielding positive results both clinically and histologically. Clot formation and stabilization play a crucial role in regenerative healing during the healing process. Platelets are the major cells of the coagulation cascade and contain signaling molecules

essential for healing.¹³ Considering these characteristics, platelet-rich concentrations have become the preferred blood products for inducing regeneration in dentistry for over thirty years. Research has reported that platelet-rich plasma (PRP) and platelet-rich fibrin (PRF) stimulate cell proliferation and differentiation, thereby supporting tissue regeneration. Another distinguishing feature that separates PRF from PRP is its production without the use of anticoagulants. Reported modified advantages include faster wound healing, quicker angiogenesis, and lower cost.¹⁴ Researchers have periodically made various protocol modifications to evaluate the developable properties of PRF.¹⁵ By using low centrifugation speeds and shorter centrifugation times, a liquid form of PRF has been obtained, and this product is referred to as injectable PRF (i-PRF). Injectable PRF, which has the capacity to act as a biomodifier on root surfaces, possesses noteworthy properties due to its enhancing effects on gingival fibroblast attachment and wound healing, making it worthy of further investigation. The liquid fibrin, as described by J. Choukroun, contains no anticoagulants or any additives and is used in its liquid form.¹⁶

In light of all this information, the aim of this study is to compare Er:YAG laser, SRP with Gracey curettes, and to evaluate the effectiveness of i-PRF as a biomodifier. The hypothesis of the study is that surfaces treated with Er:YAG laser and i-PRF will exhibit better surface roughness, leave less smear layer, and have wider dentinal tubules compared to the control groups.

Materials and Methods

This study was approved by Kırıkkale University Clinical Research Ethics Committee (No: 17/01 Date: 14.10.2021).

The study included single-rooted teeth of patients referred to the Department of Periodontology at Kırıkkale University Faculty of Dentistry with indications for extraction. Teeth included in the study were defined as follows: i) teeth with hopeless prognosis, ii) teeth with probing depths greater than 8 mm, iii) teeth without root canal treatment, iv) teeth with the presence of dental calculus on the root surfaces, and v) teeth that had not undergone SRP procedures within the last 6 months. Teeth with caries or restorations under the enamel-cementum junction, teeth with shape/size anomalies and teeth with root fractures were excluded from the study. The teeth were stored in phosphate-buffered sterile saline at 4°C until the procedures were performed.

The included teeth were divided into four groups according to the following criteria:

1. Gracey Group: SRP performed with Gracey curettes
2. Gracey + i-PRF Group: SRP performed with Gracey curettes followed by application of i-PRF to the root surface
3. Er:YAG Group: SRP performed with Er:YAG laser
4. Er:YAG + i-PRF Group: SRP performed with Er:YAG laser followed by application of i-PRF to the root surface

The surfaces where the procedures would be applied were marked with a marker pen, 1 mm apical to the enamel-cementum junction coronally and 3 mm coronal

to the root apex apically. To obtain i-PRF, blood was collected from one volunteer aged 18 or older, non-tobacco-user, without any systemic diseases and who had not taken any medication affecting coagulation in the last 3 months. Two tubes of blood were centrifuged at room temperature for 3 minutes at 700 rpm using a Duo centrifuge device (Process for PRF, Nice, France).

In the Gracey group, SRP was performed with only Gracey 3-4 curettes (Hu-Friedy, Frankfurt, Germany) until a flat and smooth surface was obtained. In the Gracey + i-PRF group, after SRP with Gracey curettes, i-PRF was applied to the root surfaces immediately after it was obtained for 5 minutes. In the Er:YAG group, SRP was performed using a chisel tip R14 tip (R14 Perio Tip, Fidelis, Fotona, Slovenia) at approximately 20°-30° angle from the tooth surface, 2 mm away, at settings of 120 mJ and 10 Hz, with 70% air and 30% distilled water cooling. In the Er:YAG + i-PRF group, after SRP with Er:YAG laser, i-PRF was applied to the root surfaces immediately after it was obtained for 5 minutes. Subsequently, blocks in disk shape were obtained from the marked areas using trephine burs with a diameter of 4 mm under water cooling and prepared for scanning electron microscopy (SEM) examination. All procedures were performed by a single researcher (NFG).

SEM Procedures

SEM (JSM 5600 LV; JEOL, Tokyo, Japan) was used to examine the surface morphology of the obtained samples. To eliminate possible external contaminations, the tooth samples were washed with ethanol before SEM examination. After the washing process, a 30-minute air drying process at room temperature was carried out to remove any remaining moisture. To enhance the conductivity of the samples during analysis, as well as to obtain higher resolution images, their surfaces were coated with a thin layer of Gold/Palladium using a gold plating device (Polaron SC7620, Kent, UK). SEM images were obtained at magnifications of 1000x and 5000x. A blinded investigator graded the images and assigned a score in accordance with the Sampaio index.¹⁷

The criteria for this index are as follows:

Score 1: The initial score is attributed to the presence of a root surface devoid of smear layer, with the dentinal tubules exhibiting complete openness and an absence of smear layer within them.

Score 2: The presence of a smear layer at the entrance of the dentin tubules was observed, whilst the root surface was found to be devoid of such a layer. The dentin tubules were found to be fully open.

Score 3: The root surface exhibited partially open dentin tubules, devoid of a smear layer.

Score 4: The root surface is characterized by the presence of partially open dentin tubules, which are covered by a uniform smear layer.

Score 5: The root surface was found to be covered with a uniform smear layer, and no open tubules were observed in the dentin.

Score 6: The root surface was found to be covered with an irregular smear layer, and there was evidence of grooves and/or scattered debris.

Additionally, the diameters of dentin tubules seen at 5000x magnification were measured.

Statistical Analysis

To achieve 80% power (effect size, $f = 0.3$) and detect differences among groups, 36 extracted teeth were required. Statistical analyses of the data from our study were performed with the use of the SPSS software package. (Version 22.0, SPSS Inc., Chicago, IL, USA). Descriptive statistics of numerical data were reported as median (minimum-maximum) and mean \pm standard deviation (SD) depending on the normal distribution of the data. Normal distribution of the data obtained was assessed using the Shapiro-Wilk test and homogeneity of variances using the Levene test. The Kruskal-Wallis test was used to compare data that did not follow a normal distribution. After this test, the Dunn-Bonferroni post-hoc test was used for pairwise comparisons to identify the groups responsible for the statistically significant differences. A p-value of <0.05 was considered to be statistically significant.

Results

Statistical findings regarding the comparison of scores between groups are presented in Table 1. The scores among groups were statistically significantly different ($p < 0.001$). It was found that the scores of the Gracey group were significantly higher than those of the Er:YAG group ($p = 0.001$). There was no statistically significant difference to be found between the scores of the other groups. ($p > 0.05$).

Statistical findings regarding the comparison of the width of dentin tubules among research groups are presented in Table 2. The widths of dentin tubules among groups were statistically significantly different ($p < 0.001$). It was determined that the widths of dentin tubules in the Er:YAG and Er:YAG + i-PRF groups were significantly higher than those in the Gracey group ($p = 0.015$; $p < 0.001$, respectively). Additionally, it was found that the width of dentin tubules in the Er:YAG + i-PRF group was significantly higher than that in the Gracey + i-PRF group ($p = 0.026$). There was no indicated difference which is significant found in the width of dentin tubules among the other groups ($p > 0.05$).

Table 1. Smear Layer Scores According to Sampaio Index in Groups

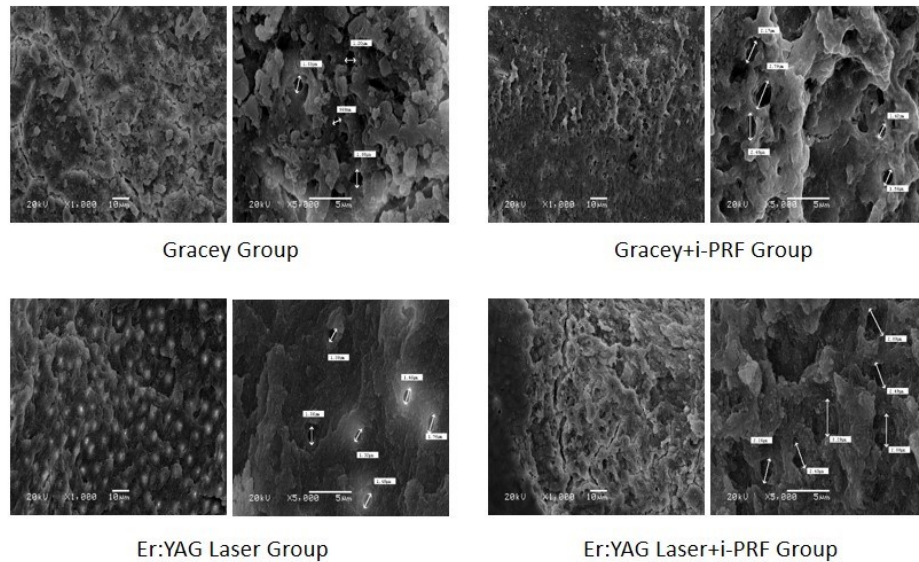
Groups	n	Median (min-max)	Mean \pm SD	P value	Post hoc P value
Gracey	9	4.5 (4 - 6)	4.67 \pm 0.82	0.002*	1-2: 0.430**
Gracey+i-PRF	9	3.5 (3 - 4)	3.50 \pm 0.55		1-3: 0.001**
Er:YAG	9	2.5 (2 - 3)	2.50 \pm 0.55		1-4: 0.087**
					2-3: 0.322**
Er:YAG+i-PRF	9	3 (2 - 4)	3.17 \pm 0.75		2-4: 1.000**
					3-4: 1.000**

* Kruskal-Wallis test, ** Dunn-Bonferroni post-hoc test

Table 2. Dentinal Tubule Diameters and Widths in Groups

Groups	n	Median (min-max)	Mean \pm SD	P value	Post hoc P value
Gracey	9	1.25 (1.10 – 1.62)	1.29 \pm 0.18	<0.001*	1-2: 0.991**
Gracey+i-PRF	9	2.01 (1.61 – 2.06)	1.95 \pm 0.17		1-3: 0.015**
Er:YAG	9	2.72 (2.29 – 2.82)	2.62 \pm 0.24		1-4: <0.001**
Er:YAG+i-PRF	9	3.15 (2.70 – 3.23)	3.04 \pm 0.22		2-3: 0.615**
					2-4: 0.026**
					3-4: 1.000**

* Kruskal-Wallis test, ** Dunn-Bonferroni post-hoc test

**Figure 1.** SEM images in four groups**SEM Results**

Gracey Group: In the SEM micrographs of the group where only SRP was applied, a typical smear layer appearance was observed at 1000x magnification. Dentin tubules were partially open. The images obtained at 5000x magnification showed fewer and rather narrow dentin tubules compared to the other groups (Figure 1).

Gracey + i-PRF Group: Compared to the gracey group, it was observed that the oral parts of dentin tubules were more prominently opened at 1000x magnification. In the images obtained at 5000x magnification in this group, wider and more distinct dentin tubules were observed compared to the first group (Figure 1).

Er:YAG Group: In the 1000x micrographs of this group, a higher number and relatively prominent dentin tubules were observed compared to the two groups where SRP

was performed with a gracey curette. Smear layers were very rarely observed at tubule openings, and the smear layer on the root surface was also recorded to be less than in the gracey groups. At 5000x magnification, fewer smear layers were observed, and wider dentin tubules were seen (Figure 1).

Er:YAG + i-PRF Group: Similar images to the Er:YAG laser group were recorded in terms of the visibility of dentin tubules and the amount of smear layer. Less amount of smear layer and more prominent dentin tubules were observed compared to the gracey groups. In the images obtained at 5000x magnification where dentin tubule diameters were measured, it was determined that no smear layer was observed at the tubule openings. Larger tubules were seen in terms of their width compared to the gracey groups (Figure 1).

Discussion

The primary goal in periodontal therapy is based on the removal of bacteria and calcified structures such as dental calculus within the biofilm, disruption of the mechanical integrity of the biofilm structure on the cementum surface, and removal of contaminated cementum and endotoxins. The elimination of the smear layer formed on the contaminated root surface, detoxification of the root surface, exposure of collagen fibers, and obtaining a root surface close to the original for the adhesion of the clot, which is the first step in wound healing, are being investigated for alternative methods. For this purpose, the effectiveness of many chemical and physical agents such as citric acid, tetracycline, ethylene diamine tetra acetic acid (EDTA), platelet-derived growth factor (PDGF), fibronectin, and lasers (Nd:YAG, CO₂, Er:YAG) on the root surface has been evaluated.¹⁸⁻²⁰ The lack of an optimised protocol for root surface modification and the lack of complete knowledge of the effectiveness of the Er:YAG laser, which has been increasingly used in recent years to overcome the disadvantages of the conventional SRP method used as the gold standard treatment, highlight the need for new studies.

If employed at low energy levels, Er:YAG laser does not cause protein denaturation on root surfaces and other tissues, instead, it exposes collagen fibrils or amino acids, creating a chemotactic effect for fibroblasts. Thus, it has been shown to positively affect fibroblast adhesion and proliferation.^{12,21-23} Rossa *et al.*²⁴ reported that root surfaces treated with conventional SRP alone did not tend to adhere and proliferate. In contrast, samples treated with the Er:YAG laser showed predominantly flat cells on their surfaces. This was independent of the energy level or pulse rate. Laser-treated root surfaces showed more spindle-shaped cells compared to samples after mechanical SRP. In their study, Karthikeyan *et al.*²⁵ examined the morphological and chemical changes on the root surface following Er:YAG and Nd:YAG laser applications using SEM and infrared spectroscopy. Their findings from infrared spectroscopy analysis reported no changes in the inorganic substances on the root surface with Er:YAG laser. In our study, samples treated with laser-assisted SRP significantly produced less smear layer compared to conventional SRP samples. The ability to expose wider dentinal tubules and leave less smear layer behind carries the potential for clinical effectiveness. It is believed that after cleaning the infected root surface with this method, fibroblasts' adhesion to the root surface will be positively influenced. Additionally, the well-known stimulating effect of lasers on healing could manifest in the surrounding soft tissues during periodontal treatment.

The particular advantage of i-PRF is its longer-term release of growth factors such as transforming growth factor-beta (TGF- β), PDGF and vascular endothelial growth factor (VEGF), stimulating local angiogenesis, increasing adhesion of stem cells, modulating the immune system of the area, and enhancing epithelial mitogenesis.¹⁶ A study examining the effect of i-PRF on the

proliferation and osteogenic differentiation of gingival mesenchymal stem cells reported that a 5% i-PRF culture significantly increased cell proliferation after 7 days, while a 10% i-PRF culture significantly decreased cell proliferation. In the same study, it was also reported that the expression of all osteogenic genes for gingival mesenchymal stem cells decreased in i-PRF cultures.²⁶ In studies evaluating the effect of i-PRF on human periodontal ligament cells, it was reported that cell proliferation, cell migration, biological differentiation and mineralization increased after biomodification with i-PRF.^{27,28} Another study compared the effects of i-PRF and PRP on human gingival fibroblasts cultured in vitro on titanium implant surfaces.²⁹ Given studies reported that compared to PRP, i-PRF could significantly influence the proliferation, differentiation, and migration of human osteoblasts, affecting osteoblast behavior more prominently. i-PRF exhibited significantly higher mRNA, PDGF, TGF- β , fibronectin, and type 1 collagen compared to PRP. An in vitro study by Okuda *et al.*³⁰ evaluated the efficacy of topical application of PRP on gingival fibroblasts. It was reported that PDGF and TGF- β are growth factors found in high concentrations and that platelet-rich blood products may be a source of these factors. In addition, it has been noted that PRP induces cell proliferation in a cell type-specific manner and that its ability to suppress epithelial cell proliferation is beneficial for regeneration. In light of all this information, it was thought that the addition of i-PRF, known to contain TGF- β , to the root surface affected by periodontitis and the external supplementation of this growth factor could be effective in this study. Aydinlyurt *et al.*³¹ compared the results of SRP, SRP + i-PRF and i-PRF-only applications in experimental periodontitis treatment in rats. The findings suggested that i-PRF might significantly contribute to bone mineralization by influencing osteoblast behavior. It was reported that root surface biomodification with i-PRF supported root coverage and increased the formation of new gingival tissue in a study investigating the effect of i-PRF on root coverage in free gingival grafting.³² In another study, the effect of the use of i-PRF in combination with a connective tissue graft in gingival recession surgery on root closure results was investigated and it has been shown that the incorporation of i-PRF into the graft material results in a significant reduction in the depth of recession and an increase in the height of keratinized tissue in comparison to a connective tissue graft alone. However, no significant difference was found between the two treatment procedures after six months in terms of pocket depths, clinical attachment levels, recession width, gingival thickness, mean and complete root coverage.³³ Albonni *et al.*³⁴ evaluated the clinical effectiveness of i-PRF as a subgingival irrigation adjunct to SRP in 15 periodontitis patients with pockets (>5mm) in at least two teeth bilaterally. In their study, it was reported that the use of i-PRF in addition to SRP did not show a significant difference in clinical periodontal parameter values over a three-month period.

In conclusion, there is still no consensus on the effect of i-PRF on periodontal parameters evaluated *in vivo*, although *in vitro* studies have shown promising results for the periodontal regenerative potential of i-PRF. Based on the results of our study, i-PRF did not show a significant effect in removing the smear layer. i-PRF appears to be effective at the cellular level but ineffective at the morphological level. The emergence of wider dentin tubules may serve as evidence for its cellular-level effects. This could be attributed to a mechanism where the growth factors contained in i-PRF penetrate more easily into the increased amount of collagen structure and wider dentin tubules exposed after laser application.

Conclusions

In conclusion, the application of Er:YAG laser appears to induce beneficial changes at both the cellular and morphological levels compared to conventional methods. Specifically, the combination of Er:YAG laser with i-PRF has yielded significant morphological results. Further animal studies and clinical trials are needed to explore the combined use of Er:YAG and i-PRF. The applications of Er:YAG laser and i-PRF hold promising evidence for clinical practice in facilitating periodontal regeneration, potentially eliminating the need for exogenous materials with evolving and advancing technology.

Author contributions

NFG, MKH, EO participated in designing the study. NFG participated in generating the data for the study. NFG, EO participated in gathering the data for the study. NFG and EO participated in the analysis of the data. NFG, MKH, EO participated in writing the paper. NFG, MKH, EO has had access to all raw data of the study. EO has reviewed the pertinent raw data on which the results and conclusions of this study are based. NFG, MKH, EO have approved the final version of this paper. MKH guarantees that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

Conflict of Interest Statement

The authors declared that they have no conflict of interest.

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Effect of Polishing and Aging on Surface Properties of Permanent Restorative Materials Used in the Posterior Region

Şura Boyraz^{1,a,*}, Emine Şirin Karaarslan^{2,b}, Hüseyin Hatırlı^{2,c}

¹Department of Restorative Dentistry, Faculty of Dentistry, Yozgat Bozok University, Yozgat, Türkiye.

²Department of Restorative Dentistry, Faculty of Dentistry, Tokat Gaziosmanpaşa University, Tokat, Türkiye.

*Corresponding author

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ABSTRACT

Objectives: The aim of this *in vitro* study was to evaluate the effects of polishing and aging on the surface properties of different restorative materials used in the posterior region.

Materials and Methods: In this study, a total of 576 samples were prepared by using 6 different composite resin (Filtek Z250-Z250, Filtek One Bulk Fill-FOB, Sonic Fill 2-SFB, Zenit Nano Ceramic-ZNC, Gradia Plus İndirekt-GPI, Estelite Bulk Fill Flow-EBF), a giomer composite resin (Beautifil Flow Plus-BFP) a glass ionomer cement (Equia Forte HT Fil -EQF) and a hybrid ceramic (Vita Enamic-VE). Sixty-four cylindrical specimens (8 mm diameter and 2 mm thickness) were prepared for each restorative material. The specimens were divided into two groups according to whether or not polishing was applied and further solution subgroups (n= 8). Surface roughness of the samples were measured with a contact-type profilometer before and after immersed in different solutions and thermal aging, and average roughness values were recorded. Statistical analysis was performed using the three-way analysis of variance test (p<0.05).

Results: It was determined that the material type, polishing method and immersing solution had a significant effect on the roughness change (p<0.05). Among the restorative materials, the highest roughness change (ΔRa) was found in Equia Forte HT, the lowest ΔRa value was found in EBF, GPI and Z250 groups (p<0.05). The highest roughness change was caused by cola and the lowest roughness change was observed in distilled water groups (p<0.05).

Conclusions: It was determined that the type of restorative material, polishing and aging and immersion solution had a significant effect on the roughness change.

Keywords: Restorative material; polishing method; thermal cycles; acidic drinks; surface roughness.

Posterior Bölgede Kullanılan Daimî Dolgu Materyallerinin Yaşlandırma Sonrası Yüzey Özelliklerinin Karşılaştırılması

Araştırma Makalesi

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ÖZET

Amaç: Bu çalışmanın amacı posterior bölgede kullanılan farklı restoratif materyallerin yüzey özelliklerine farklı polisaj sistemleri ve yaşlandırmanın etkisinin *in vitro* olarak değerlendirilmesidir.

Gereç ve Yöntemler: Bu çalışmada 6 farklı kompozit (Filtek Z250-Z250, Filtek One Bulk Fill-FOB, Sonic Fill 2-SFB, Zenit Nano Seramik-ZNC, Gradia Plus İndirekt-GPI, Estelite Bulk Fill Flow-EBF), 2 farklı cam iyonomer siman (Equia Forte HT Fil -EQF, Beautifil Flow Plus-BFP), 1 hibrit seramik (Vita Enamic-VE) kullanılarak toplamda 576 adet örnek hazırlandı (n=8). Her bir restoratif materyalden 64 adet silindirik örnek elde edildi (çap: 8mm, kalınlık: 2mm). Örnekler 2 farklı polisaj yöntemi (Matris Bandı-MB, Kerr Occlubrush-KOB) ve sonrasında 4 farklı yaşlandırma solüsyonuna (distile su, kola, vişne suyu, soğuk çay) göre alt gruplara ayrıldı. Örneklerin yüzey pürüzlülüğü ölçümleri, farklı solüsyonlarda ve termalsiklusa bekletme öncesinde ve sonrasında profilometre cihazı ile yapıldı ve ortalama pürüzlülük değerleri kaydedildi. Çalışma sonucunda elde edilen verilerin istatistiksel analizi Dört Yönlü-ANOVA ile yapıldı.

Bulgular: Materyal türü, polisaj yöntemi ve bekleme solüsyonunun pürüzlülük değişiminde anlamlı etkisi olduğu belirlendi (p<0,05). Restoratif materyaller arasında en yüksek pürüzlülük değişimi (ΔRa) Equia Forte HT'de, en düşük ΔRa değeri ise Estelite Bulk Fill, Gradia Plus İndirekt ve Filtek Z250 gruplarında görüldü (p<0,05). İçecek grupları değerlendirildiğinde ise pürüzlülük değişimine en fazla kola, en az ise distile suyun neden olduğu görüldü (p<0,05).

Sonuçlar: Bu çalışmanın sonucunda restoratif materyallerin yüzey pürüzlülüğünü; restoratif materyalin cinsi, kullanılan polisaj yöntemleri ve asitli içeceklerin etkileyebileceği belirlendi.

Anahtar Kelimeler: Restoratif materyal; polisaj yöntemi; termalsiklus; asitli içecekler; yüzey pürüzlülüğü

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^a sura.boyraz@yobu.edu.tr
^c huseyinhatirli@gmail.com

^b karaarslan.emine@gmail.com
^c huseyinhatirli@gmail.com

^b karaarslan.emine@gmail.com ^c huseyinhatirli@gmail.com

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Introduction

The main aim of dentistry is to restore the patient's lost tooth tissue functionally and aesthetically with successful restorations. Today, many materials have been developed that give doctors and patients the opportunity to choose restorative materials. The selection of restorative materials depends on factors such as duration of use in the mouth, wear resistance, solubility, volumetric stability, color stability, location of the mouth area where it is applied, size and localization of the cavity or preparation, chewing habits, dietary habits, oral hygiene, amount of saliva and systemic disorders.^{1,2}

With the development of glass ionomer cements in 1972, these materials have become generally preferred restorative materials because they provide adhesion to dental tissue and are compatible with biological tissues. However, the low wear resistance, solubility and aesthetic properties of cements are not as good as composites, which has limited the clinical use of cements.^{3,4} High viscosity glass ionomer has been developed to increase the wear resistance of glass ionomer cements and reduce their moisture sensitivity, allowing them to be used in areas where chewing stress is high.⁵

Although they were initially used in the restoration of anterior teeth, their micromechanical adhesion to dental tissues, superior aesthetic properties and higher wear resistance compared to other restorative materials have expanded the usage areas of composite resins. However, despite the positive properties of composite resins, they also have some disadvantages that affect the long-term clinical performance of the material. Placing composites with the incremental technique during the restoration of deep cavities causes loss of time for both the doctor and the patient. There is also a risk of air bubbles remaining between the layers and moisture contamination. To eliminate these disadvantages and reduce the processing cost, bulk fill composite resins that can be applied in a single layer up to 4-5 mm thick have been developed in recent years.⁶

In recent years, as a result of research conducted to combine the positive properties of composite resins and ceramics, CAD/CAM hybrid blocks have been introduced to the market. These hybrid blocks provide advantages such as easier processability, superior edge compatibility and high fracture resistance, thanks to their dual-phase structure that combines the positive properties of ceramic and composite resins.⁷

Finishing and polishing processes are the processes applied to restorative materials to harmonize the edges of the restoration and to obtain brighter and smoother surfaces by giving appropriate contours to the restoration.^{8,9} When the finishing and polishing process is done properly, it is an important step that affects the aesthetics and permanence of the restorations.¹⁰ It has been reported that the roughness of the restoration surfaces causes bacterial plaque to adhere, thus increasing the formation of periodontal diseases and secondary caries and causing patient dissatisfaction.¹⁰⁻¹² Evaluation of surface roughness is done with devices such as optical and mechanical profilometers, AFM and SEM.¹³

Restorative materials used in dentistry are intermittently exposed to chemical drinks frequently consumed in daily life.¹⁴ It has been reported that carbonated drinks and drinks with acidic potential, which are frequently consumed today, cause morphological changes on restorative materials.^{15,16}

The purpose of this study to compare the surface properties of permanent restorative materials with different properties used in the posterior region after cyclic aging. The null hypotheses of this study are;

1. There is no difference in surface roughness among the restorative materials.
2. There is no difference in surface roughness between the polishing methods applied to restorative materials.
3. There is no difference in the surface roughness change of the restorative materials between the soaking solutions.

Materials and Methods

Specimen Preparation

In this study, micro hybrid composite (Filtek Z250), nanohybrid composite (Zenit Nano-Ceramic), indirect composite (GC), bulk fill composite (Tokuyama Estelite Bulk, Filtek One Bulk fill, Sonic Fill), hybrid composite (Giomer), hybrid glass ionomer cement (Equia Fort) and hybrid ceramic (Vita Enamic) restorative materials were used. The restorative materials and polishing systems used in this study are shown in Table 1.

The G*Power (G*Power Ver. 3.0.10, Franz Faul, Universität Kiel, Germany) package program was used to determine the number of samples to be tested in the study. In order to determine the effect difference of $F = 0.30$ (moderate) with 80% power, at least 64 samples for each group were needed at the type I error level of $\alpha=0.05$. For each of the eight restorative materials, 64 cylindrical specimens were prepared using a metal mold with a central hole of 8 mm in diameter and 2 mm in thickness. Composite resins were filled into a metal mold. Then, the surface of the materials was covered with mylar strip on the top and bottom and placed between two glasses. The glass surfaces were pressed with finger pressure to remove excess composite resin and eliminate pores. Composite resins were cured at a standard intensity of 1.000 mW/cm² for 20 seconds from the bottom and top with LED polymerization light from a distance of 1 mm. Each composite resin group was randomly assigned to two subgroups for finishing and polishing procedures. Gradia Plus, an indirect composite resin, was polymerized for another 60 seconds using its own polymerization system (Labolight DUO, GC Corporation, Japan). The hybrid ceramic block was cut vertically with a diamond cutting disc (Microcut201, Metkon, Bursa, Turkey) with a thickness of 2 mm and a rectangular prism was obtained. After Equia Forte HT Fill hardened in the molds, Equia Forte Coat was applied to the sample surfaces and cured with light. Sixty-four specimens of each restorative materials were randomly assigned to one of the two finishing and polishing techniques.

Table 1: Compositions and manufacturer details of the tested materials

Materials (Abbreviation)	Material Category	Composition	Manufacturer
Estelite Bulk-Fill Flow (EBF)	Bulk-Fill Composite	Organic matrix: Bis-GMA, TEGDMA, Bis-MPEPP, Mequinol, and Dibutyl hydroxyl toluene Filler: Spherical silica-zirconia filler(wt%/vol%: 70 / 56)	Tokuyama Dental, Tokyo, JAPAN
Filtek One Bulk Fill (FOB)	Bulk-Fill Composite	Organic matrix: AFM (dynamic stress-relieving monomer), AUDMA, UDMA, and 1,12-dodecane-DMA Fillers: 20-nm silica filler, 4- to 11-nm zirconia filler, an aggregated zirconia/silica cluster filler (comprised of 20-nm silica and 4- to 11-nm zirconia particles), and a ytterbium trifluoride filler consisting of agglomerate 100-nm particles. (wt%/vol%: 76.5 / 58.5)	3M ESPE, St. Paul, USA
Sonic Fill 2 (SFB)	Bulk-Fill Composite	Glass, oxide, chemicals (10–30%), 3-trimethoxysilylpropyl methacrylate (10–30%), silicon dioxide (5–10%), ethoxylated bisphenol A dimethacrylate (1–5%), bisphenol A bis(2-hydroxy-3-methacryloxypropyl) ether (1–5%), and triethylene glycol dimethacrylate (1–5%)	Kerr Orange CA, USA
Gradia Plus Indirect (GPI)	Nanohibrit Composite	Organic matrix: : UDMA, dimethacry- late Fillers: SiO ₂ , fumed SiO ₂ , Sr and lanthanoid F, Al F silicate (prepolymer- ized) Inorganic fillers (wt%: 71)	GC Corporation, JAPAN
Zenith Nano Ceramic (ZNC)	Nanohibrit Composite	glass filler, pyrogenic silica, agglomerated nanoparticles, Diurethane dimethacrylate, butanediol dimethacrylate, isopropylidene-bis [2(3-hydroxy-3(2)-(4-phenoxy) propyl] bismethacrylate	President Dental, München, GERMANY
Filtek Z250 (Z250)	Micrahibrit Composite	Organic matrix: Triethyleneglycol dimetacrylate (TEGDMA) < 1–5%; Bisphenol-A-glycidylmethacrylate (Bis-GMA) < 1–5%; Bisphenol-A polyethyleneglycol dietherdimethacrylate (Bis-EMA) 5–10%; Urethane dimethacrylate (UDMA) 5–10% Filler: Zirconia/silica; 60 vol% inorganic fillers; Particle size 0.01 to 3.5 m	3M ESPE St., Paul, MN, USA
Equia Forte HT Fill (EQF)	High Viscosity Glass Ionomer	Powder: 95% strontium fluoroaluminosilicate glass (including highly reactive small particles) + 5% polyacrylic acid Liquid: 40% aqueous polyacrylic acid	GC, Tokyo, JAPAN
Beautifil-Bulk Restorative (BBF)	Giomer	Organic matrix: Bis-GMA, UDMA, Bis MPEPP, TEGDMA Fillers: S-PRG filler based on Fluoroboroaluminosilicate glass and nano filler (10- 20nm) (wt%/vol%: 87 / 74.5)	Shofu Inc., Kyoto, Japan
Vita Enamic (VE)	Hybrid Ceramic	Porous structure-sintered ceramic matrix infiltrated with polymer material. Inorganic ceramic 86 wt%: fine-structure feldspar ceramic enriched with aluminum oxide (silicon dioxide 58–63%, aluminum oxide 20–23%, sodium oxide 9–11%, potassium oxide 4–6%, boron trioxide 0.5–2%, zirconia < 1%, calcium oxide <1%). Organic polymer 14 wt% (urethane dimethacrylate, triethylene glycol dimethacrylate).	Vita Zahnfabrik, Bad Säckingen, GERMANY
Kerr Occlubrush (KOB)	4.0±0.5 mm thick	Silicon carbide particles impregnated in fiber bristles	Kerr Orange, CA, USA

Polishing procedures

All samples were divided into 2 subgroups, group 1 and group 2.

Group 1, unpolished (mylar strip): This group comprised the specimens that were left untreated, not submitted to finishing and polishing procedures.

Group 2, Kerr Occlubrush polishing system: The samples were treated with 600, 800 and 1000 grit silicon carbide paper to ensure standardization between samples before the application of the polishing systems. The samples were polished with KERR Occlubrush in dry conditions with light hand pressure at 10.000 rpm for 45 seconds in the order specified by the manufacturer.¹⁷ After each polishing step, the samples were rinsed thoroughly with water for 10 seconds and air dried for 5 seconds until the next step and final polishing.

All samples were polished on a flat surface by the same operator. Specimens were then stored in distilled water at 37° C for 24 hours for rehydration and completion of the polymerisation.

Aging Procedure

Immersion of Specimens in Solutions

Each restorative material and polishing process was divided into four subgroups: cola (pH:2.53, The Coca-Cola Company, USA), ice tea (pH:3.71, Lipton Company, USA), cherry juice (pH:2.86, Dimes Company, TURKEY) and distilled water (pH:6.67) (n = 8). After the surface measurements, samples were kept in a water bath at 5±2 °C and 55±2 °C for 30 seconds and 10 seconds outside in a thermal cycle device (SD Mechatronik Thermocycler, SD Mechatronik GMBH, Westerham) in order to imitate the thermal changes in the oral environment for 2000 cycles.

The samples were kept in beverages such as distilled water, cola, cherry juice and iced tea for 3 days, 4 hours a day. This process corresponds to the exposure time of restorative materials to acidic drinks for 2 minutes per day for 1 year.^{18,19}

During the study, samples were kept in sealed bottles and drinks were renewed daily. At the end of 3 days, the samples were subjected to thermal aging again 2000 times. This process was continued as a cycle until a total of 10,000 cycles were completed. Before surface roughness measurements, the samples were rinsed with deionized water for 60 seconds and dried with blotting paper.

Measurement of Surface Roughness

The surface roughness of specimens were measured before and after immersion in the solutions in three different areas using a surface profilometer (Surtronic 25, Taylor Hobson, Leicester, UK). The profilometer was calibrated according to the manufacturer's instructions before each measuring session. Surface roughness measurements were performed with a cut-off value of 0.25 mm, a transverse length of 1.25 mm, and a stylus speed of 0.1 mm/second near the center of each

specimen. The average surface roughness value (Ra) and the surface roughness change (Δ ra) of each specimen were recorded separately.

Statistical Analysis

Statistical analyses were performed using SPSS software (SPSS 22.0 Chicago, IL, ABD). Descriptive analyzes were performed on the general characteristics of the data of the study groups. Data of continuous variables are given as mean \pm standard deviation. The Shapiro-Wilk test was used to test normality of the variables. When the means of quantitative variables were compared between groups, two and three-way analysis of variance was used for repeated measurements ($p < 0.05$).

Results

The results of three-way ANOVA test revealed significant differences among materials, solutions, polishing methods, materials*polishing methods, and solutions*polishing methods interactions ($p < 0.05$) ANOVA tables of the samples before and after aging are included in Tables 2 and 3.

Table 2: Results of Two-Way Variance Analysis Between Groups in Terms of Roughness Values of Restorative Materials Before Aging

Source	Type III SS	df	Mean square	F	p value
Intercept	47.639	1	47.639	20503.091	0.000
Material	32.169	8	4.021	1730.623	0.000
Polishing	0.521	1	0.521	224.108	0.000
Material * Polishing	0.369	8	0.046	19.876	0.000

Table 3: Three-Way Variance Analysis Results Between Groups in Terms of Roughness Change Values of Restorative Materials After Aging

Source	Type III SS	df	Mean square	F	p value
Intercept	1.127	1	1.127	264.302	0.000
Material	0.378	8	0.047	11.067	0.000
polishing	0.035	1	0.035	8.152	0.004
solution	0.075	3	0.025	5.888	0.001
Material * Polishing	0.229	8	0.029	6.720	0.000
Material * Solution	0.041	24	0.002	0.405	0.995
Polishing * Solution	0.001	3	0.000	0.055	0.983
Material * Polishing * Solution	0.039	24	0.002	0.381	0.997

Evaluation of Surface Roughness of Restorative Materials Before Aging

The average and standard deviations (μ m) of the initial surface roughness values obtained as a result of the mylar strip and KOB polishing of the restorative materials in the study are shown in Table 4. Accordingly, the values of KOB were recorded significantly higher than the mylar strip ($p < 0.05$).

It was observed that the average Ra values, except for EQF and VE, were below the threshold value (threshold value: 0.2 μ m) in the groups prepared under the mylar strip. The lowest surface Ra value for all groups was obtained with the EBF group. There is a significant difference between EBF and all other restorative material groups ($p < 0.05$). The highest surface Ra value was obtained with the VE group. At the same time, a significant difference was noted between VE and other groups

($p < 0.05$). However, there was no significant difference between BFP and GPI, SFB and Z250 groups ($p > 0.05$) (Table 4).

It was observed that the Ra values of the materials prepared with KOB, except for EQF, were below the threshold value (threshold value: 0.2 μ m). It was noted that EBF group had the lowest surface roughness among all groups and there was a significant difference between EBF and all other restorative material groups ($p < 0.05$). While the highest surface roughness was observed in the VE group, a significant difference was noted between the other groups ($p < 0.05$) (Table 4).

Evaluation of Surface Roughness of Restorative Materials After Cyclic Aging

The average and standard deviations (μ m) of the surface roughness values of the restorative materials after aging in the

study are shown in Table 5. When the mylar strip groups were evaluated after aging, it was seen that the lowest Ra value was in the EBF group, and there was no significant difference between the EBF and GPI and Z250 groups ($p>0.05$). A significant difference was observed between the EQF and VE groups, whose roughness was above the threshold value, and the other restorative material groups ($p<0.05$) (Table 5).

When the KOB groups were evaluated after aging, a significant difference was noted between VE, whose roughness was above the threshold value (threshold value: $0.2 \mu\text{m}$), and the other groups ($p<0.05$). It was observed that there was no significant difference between EQF, whose roughness was above the threshold value, and other BFP and SFB groups ($p>0.05$). It was observed that the lowest surface roughness was in the EBF group and there was no significant difference between the EBF and ZNC and Z250 groups ($p>0.05$) (Table 5).

Except for the EQF restorative material after aging, the roughness values of the KOB group were recorded higher than the values of the mylar strip group. Ra values of the mylar strip were obtained higher for the EQF restorative material than for the KOB group ($p<0.05$). For FOB restorative material, no difference was noted between polishing systems (Table 5).

The most significant roughness change between finished under mylar strip and groups cyclically aged in cola was found in EQF. A significant difference was observed between this group and other restorative materials ($p<0.05$). Among the materials polished with KOB and subjected to cyclic aging in cola, the highest roughness change was seen in the BFP group and there

was no significant difference between it and the other groups ($p>0.05$). The lowest value was seen in the GPI group and this difference was not statistically significant ($p>0.05$) (Table 5).

Among the materials finished under mylar strip and subjected to cyclic aging in cherry juice, the highest roughness change was seen in the EQF group and there was no significant difference with the BFP group ($p>0.05$). The lowest change was seen in the EBF, GPI, Z250 groups and a significant difference was observed with EQF ($p<0.05$). Among the materials polished with KOB and subjected to cyclic aging in cherry juice, the highest roughness change was in the BFP group, and the lowest value was in the GPI and VE groups ($p<0.05$) (Table 5).

Among the materials finished with mylar strip and subjected to cyclic aging in cold tea, the highest roughness change was seen in the EQF group, and the lowest change was seen in the EBF, Z250 groups. Among the materials polished with KOB and subjected to cyclic aging in cold tea, the highest roughness change was in the BFP group, and the lowest change was in GPI, EBF, ZNC and VE groups ($p>0.05$) (Table 5).

Among the materials finished under mylar strip and subjected to cyclic aging in water, the highest roughness change was seen in the EQF group, and the lowest change was seen in the EBF, Z250 groups ($p>0.05$). Among the materials polished with KOB and subjected to cyclic aging in water, the highest roughness change was in the BFP group and the lowest roughness change was in the GPI, EBF, Z250, ZNC and VE groups ($p>0.05$) (Table 5).

Table 4: Comparison of initial surface roughness values between groups

MATERIALS	INITIAL RA VALUES	
	Mylar Strip	Kerr Occlubrush
Equia Forte HT Fill (EQF)	0.209 ± 0.01 ^(A)	0.235 ± 0.02 ^(B)
Estelite Bulk-Fill Flow (EBF)	0.047 ± 0.007 ^(A)	0.079 ± 0.01 ^(B)
Filtek One Bulk Fill (FOB)	0.121 ± 0.03 ^(A)	0.135 ± 0.017 ^(B,b)
Beautifil-Bulk (BBF)	0.082 ± 0.017 ^(A,a)	0.153 ± 0.025 ^(B,c)
Gradia Plus Indirect (GPI)	0.085 ± 0.015 ^(A,a)	0.152 ± 0.017 ^(B,c)
Vita Enamic (VE)	0.606 ± 0.025 ^(A)	0.674 ± 0.025 ^(B)
Sonic Fill 2 (SFB)	0.094 ± 0.017 ^(A,a)	0.189 ± 0.025 ^(B)
Filtek Z250 (Z250)	0.091 ± 0.012 ^(A,a)	0.113 ± 0.01 ^(B,d)
Zenith Nano Ceramic (ZNC)	0.066 ± 0.007 ^(A)	0.124 ± 0.01 ^(B,bd)

A,B: Indicates differences between lines in capital letters ($p<0.05$).

a,b,c,d: Differences in lowercase letter between columns ($p<0.05$).

Table 5: Surface roughness values according to different beverages after cyclic aging

Ra Values in Groups After Cyclic Aging			
Restorative Materials	Solution	Mylar Strip	Kerr Occlubrush
EQF	Cola	0.4 ± 0.18 ^(A,a)	0.26 ± 0.01 ^(B)
	Cherry Juice	0.4 ± 0.20 ^(A,a)	0.27 ± 0.01 ^(B)
	Ice Tea	0.34 ± 0.22 ^(A,ab)	0.27 ± 0.02 ^(B)
	Distilled Water	0.3 ± 0.11 ^(A,b)	0.26 ± 0.02
EBF	Cola	0.06 ± 0.01	0.11 ± 0.01
	Cherry Juice	0.06 ± 0	0.11 ± 0.01
	Ice Tea	0.06 ± 0.01	0.1 ± 0.01
	Distilled Water	0.06 ± 0.01	0.09 ± 0.01
FOB	Cola	0.16 ± 0.02	0.18 ± 0.04
	Cherry Juice	0.17 ± 0.03	0.17 ± 0.02

BFP	Ice Tea	0.17±0.02	0.17±0.01
	Distilled Water	0.17±0.03	0.17±0.03
	Cola	0.17±0.03 ^(A)	0.26±0.02 ^(B)
	Cherry Juice	0.2±0.03 ^(A)	0.28±0.02 ^(B)
GPI	Ice Tea	0.18±0.01 ^(A)	0.24±0.02 ^(B)
	Distilled Water	0.12±0.02 ^(A)	0.21±0.01 ^(B)
	Cola	0.14±0.01	0.18±0.02
	Cherry Juice	0.11±0.02	0.17±0.01
VE	Ice Tea	0.1±0.01 ^(A)	0.18±0.02 ^(B)
	Distilled Water	0.1±0.02	0.16±0.02
	Cola	0.65±0.05 ^(A)	0.73±0.04 ^(B)
	Cherry Juice	0.64±0.03	0.69±0.02
SFB	Ice Tea	0.63±0.03	0.69±0.02
	Distilled Water	0.63±0.03	0.68±0.02
	Cola	0.15±0.03 ^(A)	0.25±0.02 ^(B)
	Cherry Juice	0.14±0.02 ^(A)	0.25±0.02 ^(B)
Z250	Ice Tea	0.15±0.03 ^(A)	0.22±0.01 ^(B)
	Distilled Water	0.13±0.02 ^(A)	0.2±0.02 ^(B)
	Cola	0.11±0.01	0.16±0.02
	Cherry Juice	0.11±0.01	0.16±0.02
ZNC	Ice Tea	0.1±0.01	0.15±0.02
	Distilled Water	0.1±0.01	0.13±0.02
	Cola	0.12±0.02	0.17±0.01
	Cherry Juice	0.12±0.01	0.16±0.01
	Ice Tea	0.12±0.01	0.15±0.02
	Distilled Water	0.11±0.01	0.14±0.01

A,B: Indicates differences between lines in capital letters ($p<0.05$).

a,b,c,d: Differences in lowercase letter between columns ($p<0.05$).

Discussion

Surface roughness, which is one of the important factors affecting the clinical success of restorations, affects the aesthetic properties due to its tendency to discoloration, while it also affects the biological properties because it increases the retention of dental plaque.^{20,22} At the same time, a well-done polishing process will increase patient comfort and satisfaction. For these reasons, the effectiveness of finishing and polishing processes is very important for the surface properties of restorative materials.

It has been shown that the smoothest surfaces in direct composite resins occur under the mylar strip.¹⁷ However, the surfaces created under the mylar strip are rich in resin and need to be removed because they have poor mechanical properties.^{23,24} In this study, the effect of a single-stage polishing brush (Occlubrush, KERR), which can be used in polishing both direct and indirect restorative materials, on the surface roughness of current restorative materials after waiting in acidic beverages was compared.

In terms of the findings of this study, null hypothesis 1 was rejected because there was a significant difference in initial surface roughness between the restorative materials evaluated. While the roughness was significantly lower in the EBF group than in all other restorative materials, the highest surface roughness was

observed in the VE group. However, the fact that the roughness values in the VE group, which is an indirect restorative material, is higher than the other groups is thought to be due to the brush used as the polishing system being insufficient in terms of polishing the hybrid ceramic surfaces. Furthermore, the lower surface roughness observed in the EBF group is due to the high resin content and low filler rates of the flowable composites.

Although there is no consensus on the threshold value for the surface roughness of restorations, it is stated that restorations with a surface roughness of less than 0.2 μm are acceptable in terms of compatibility with oral tissues, and a surface roughness of more than 0.2 μm may cause plaque accumulation.²⁰ In addition, Jones *et al.* reported that the patient could detect roughness values above 0.5 μm with the tip of the tongue.²⁵ Considering the findings of this study, the second null hypothesis was also rejected. While a roughness value below 0.5 μm was observed in all groups of evaluated direct restorative materials finished under transparent tape and polished with a brush, roughness values below 0.2 μm were observed in all direct restorative materials except the high viscosity glass ionomer (EQF) group. Finishing and polishing processes of glass ionomer-containing restorative materials are more difficult due to their heterogeneous structure. During

polishing, their softer matrix is easily eroded, leaving behind hard glass particles.^{26,27}

Özarslan *et al.* Vita Enamic CAD/CAM blocks; They compared the roughness values of the groups that were not polished and those that were finished and polished with the Vita Enamic Polishing Set and reported that the groups finished with the Vita Enamic Polishing Set exhibited less roughness values.²⁸ However, as a result of this study, the highest roughness values were obtained in the VE group polished with KOB. KOB is an indicated polishing material for all restorative materials tested in the study; however, since the Vita Enamic polishing set is the material's own set, it is very likely to provide effective polishing.

The etching effect of acidic beverages on restorative materials has been evaluated in many studies, and it is known that beverages with low pH have a greater erosive effect on restorative materials.²⁹⁻³¹ In these studies, it was determined that the surface roughness of restorative materials varies depending on the type of aging solution and restorative material content.

In this study, a significant difference was observed between the restorative materials kept in cola, cherry juice, iced tea and water and the 3rd null hypothesis was also rejected. Sarı *et al.* reported that a significant increase in surface roughness values of restorative materials was observed after soaking in orange juice and cola.^{32,33} While apple juice contains maleic acid, orange juice primarily contains citric acid. Fruit acids containing carboxylic acids such as these can chelate with calcium ions in the glass ionomer structure and form a structure that is soluble in water.³⁰ On the other hand, when the phosphoric acid in cola chelates with calcium, a water-insoluble structure is formed. The pH value of sour cherry juice used in this study is 2.86 and it contains citric acid in its structure. Among the restorative materials we subjected to cyclic aging in cherry juice, the highest roughness change was found in the BFP group and the lowest roughness change was found in the GPI group. It is thought that exposure of the BFP group to solutions causes a significant increase in roughness on the surface, as the size of the voids formed as a result of the removal of the S-PRG fillers in its structure from the surface is much larger.³⁴ We think that the lower roughness change in GPI is due to the fact that it has smaller filler particles.

This study evaluated the effects of different polishing procedures and solutions on surface roughness of permanent restorative materials used in the posterior region. The limitations of this study were the continuous immersion periods and lack of the cleaning effect of saliva and oral hygiene procedures. Although this study could not simulate intraoral conditions, the deleterious effects of commonly consumed drinks on restorative materials were confirmed.

Conclusions

Within the limitations of this study:

1. Although initially smoother surfaces were obtained in the groups finished under mylar strip, it was

determined that the surface roughness after immersion in solutions was less in the groups polished with a single-stage brush.

2. Restorative materials showed varying rates of roughness change after aging and immersion in different solutions. It was determined that the type of restorative material, polishing and aging had a significant effect on the roughness change. Among the tested materials, high-viscosity glass ionomer exhibited the greatest increase in surface roughness after immersion in different solutions, whereas the flowable bulk-fill composite showed the least change.

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Conflicts of Interest Statement

There is no conflict of interest in this study.

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The Validation of the Dental Undergraduates' Preparedness Assessment Scale (Du-Pas) and The Evaluation of the Effect of Integrated Clinical Practices on the Knowledge and Experience of Final Year Dental Students Using Du-Pas

Halenur Altan^{1,a}, Müzeyyen Dilşah Demiray^{1,b,*}, Büşra Almas^{1,c}, Ahmet Altan^{2,d}, Ali Rıza Tunçdemir^{3,e}

¹Department of Pediatric Dentistry, Faculty of Dentistry, Necmettin Erbakan University, Konya, Türkiye.

²Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Necmettin Erbakan University, Konya, Türkiye.

³Department of Prosthetic Dentistry, Faculty of Dentistry, Necmettin Erbakan University, Konya, Türkiye.

*Corresponding author

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ABSTRACT

Objectives: The Dental Undergraduates Preparedness Assessment Scale (DU-PAS) is a 50-item, two-part tool designed to assess final-year dental students' knowledge, attitudes, and skills. This study aimed to validate the Turkish version of DU-PAS and evaluate the impact of traditional versus integrated clinical education on students' knowledge, experience, and self-confidence.

Materials and Methods: This study was conducted in two phases. In the first phase, the Turkish adaptation and validation of DU-PAS were completed by administering the scale to 272 final-year dental students via Google Forms. In the second phase, 53 students from Necmettin Erbakan University Faculty of Dentistry completed DU-PAS before and after their integrated clinical internship. Additionally, the Akin Self-Confidence Scale was administered before the internship, and the data were analyzed in relation to DU-PAS scores. Internal consistency was assessed using Cronbach's alpha and item-total correlation coefficients. Paired t-tests were used to compare DU-PAS scores before and after the internship.

Results: Items with factor loading differences below 0.1 or loading on multiple factors were excluded from the scale. Specifically, items 6, 7, 12, 17, 18, 26, 29, 31, 46, and 50 were removed. Items 13 and 15 were excluded as they formed a single-item factor. Items 27 and 28 were also removed due to low internal consistency. After item removal, the final validated version consisted of 35 items. A positive correlation was found between students' DU-PAS and self-confidence scores.

Conclusions: The Turkish version of the Dental Undergraduates Preparedness Assessment Scale was validated following item removal. The original 50-item scale was reduced to 35 items. It was observed that the self-confidence levels of final-year dental students were lower before the integrated internship compared to after its completion. The findings suggest that the integrated clinical internship positively contributed to students' self-confidence.

Keywords: Dentistry, final-year student, preparedness, self confidence, validation

Diş Hekimliği Öğrencileri- Hazırbulunuşluk Değerlendirme Ölçeğinin (DU-PAS) Türkçe Validasyonu ve Entegre Klinik Uygulamalarının Son Sınıf Diş Hekimliği Öğrencilerinin Bilgi ve Deneyim Düzeylerine Etkisinin DU-PAS Ölçeği ile Değerlendirilmesi

Araştırma Makalesi

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International License

^a halenuronat@gmail.com
^b balmas48@gmail.com
^c alirizatumdemir@gmail.com

ÖZET

Amaç: Diş Hekimliği Lisans Öğrencilerinin Hazırlık Değerlendirme Ölçeği (DU-PAS) son sınıf öğrencilerin bilgi, tutum ve becerilerini değerlendirmek için kullanılan iki bölümlü, eli sorudan oluşan bir psikometrik ölçektir. Çalışmamızda Diş Hekimliği Öğrencileri- Hazırbulunuşluk Değerlendirme Ölçeği'nin (DU-PAS) Türkçe geçerliliği doğrulanacak; geçerliliği doğrulanan DU-PAS kullanılarak geleneksel ve entegre klinik eğitim modelinin diş hekimliği son sınıf öğrencilerinin bilgi, deneyim ve özgüvenlerine etkisi karşılaştırılacaktır.

Gereç ve Yöntemler: Çalışmamız iki basamakta gerçekleştirildi. Birinci basamakta DU-PAS ölçeğinin geçerlilik-güvenirliği, kültürel adaptasyonu yapılan ölçeğin 272 son sınıf öğrencisine Google Form üzerinden uygulanmasıyla gerçekleştirildi. İkinci aşama ise Necmettin Erbakan üniversitesi diş hekimliği fakültesi öğrencilerin entegre stajı öncesi ve sonrası özgüvenleri ve DU-PAS ilişkisi ölçüldü. Ayrıca, entegre staj öncesinde Akın Öz Güven Ölçeği uygulanmış ve elde edilen veriler DU-PAS ile ilişkilendirildi. Ölçeğin iç tutarlılığını analiz etmek için Cronbach alfa katsayısı ve madde-toplam korelasyon katsayıları kullanıldı. DU-PAS puanlarının staj öncesi ve sonrası karşılaştırılması için bağımlı t-testi uygulandı.

Bulgular: İlk analiz sonucunda bir maddenin iki farklı faktör altında yer alması faktör analizi için kabul edilebilir bir durum olmadığından ve bir maddenin farklı faktörler altındaki değerleri arasındaki farkın 0,1'den küçük olması durumuna ölçekten çıkartılması gerekmektedir. M6, 12, 17, 18, 26, 29, 31, 46, 50,7 maddeleri birden fazla faktör altından yer aldığı için ölçekten çıkarılmıştır. Madde 13 ve madde 15 ise tek maddeli bir faktör oluşturdıkları için ve tek maddeli bir faktör olamayacağından ölçekten çıkarılmıştır. Madde 28 ve madde 27 ise ikisi birlikte bir faktör oluşturmakta ve oluşan faktörün Cronbach's alfası düşük güvenirlikte olduğu için bu maddelerde ölçekten çıkarılmıştır. Özgüven ile hazırbulunuşluk arasında pozitif korelasyon vardır.

Sonuçlar: Diş Hekimliği Öğrencileri- Hazırbulunuşluk Değerlendirme Ölçeği madde çıkarma yapılarak Türkçe diline valide edilmiştir. 50 maddede olan ölçek 35 maddeli şekilde kullanılabilir. Diş hekimliği son sınıf öğrencilerinin entegre stajı öncesi özgüvenleri entegre stajı sonrasında daha düşük olduğu görülmüştür. Entegre stajının özgüveni olumlu yönde etkilediği elde ettiğimiz sonuçlar arasındadır.

Anahtar Kelimeler: Diş hekimliği, hazırbulunuşluk, özgüven, son sınıf öğrencisi, validasyon.

^b demiraydilsah@gmail.com
^d dt.ahmetaltan@gmail.com

^{ID} 0000-0002-5683-3314
^{ID} 0000-0003-2041-6364

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Introduction

Because of its unique structure, dental applications encompass various aspects such as teaching and learning, instructor-student relationships, patient expectations, clinical outcomes, and complex materials and methods.¹ Every dentist strives to deliver painless dental treatments with minimal discomfort for their patients. Experts in the field agree that dentistry entails irreversible procedures and the management of patients' emotional behaviors. Unlike other healthcare professions, dental students often confront invasive and irreversible procedures.²

Graduate dentists need not only clinical competence but also strong adaptive skills suited for the 21st century to effectively serve society. Clinical, scientific, and environmental skills form essential components of the dental curriculum, as they enable students to engage with their patients empathetically, allowing them to better understand their oral health status and needs.³ Research indicates that when healthcare providers possess effective communication skills, patient satisfaction increases, adherence to treatment recommendations improves, and patient anxiety and complaints related to malpractice decrease.⁴⁻⁶ Therefore, it is essential to incorporate courses and internships into the

curriculum that focus on enhancing dental students communication skills with patients.

Deficiencies in graduates' critical thinking skills have been observed, with reports indicating that students struggle to explain treatment options to their patients. This issue is believed to stem from a lack of experience and an inability to integrate their knowledge gained in dental clinics.^{7,8} Additionally, the presence of various departmental clinics within dental faculties, each with its own evaluation criteria and conditions, restricts students' treatment planning skills.⁹

Dental curricula today differ in design, utilizing traditional, integrated, or a combination of both approaches. The traditional curriculum focuses on pre-clinical basic sciences and clinical experiences, offering practical training in later years.¹⁰ However, this model primarily relies on lectures, which can make it difficult for students to grasp the interconnectedness of subjects within a discipline-based education.

In contrast, the integrated curriculum combines various disciplines according to related fields and subjects. In our country, different educational models are being developed to enhance dental education.¹¹ The traditional model may not adequately address the new educational needs arising from rapid changes in the field. Since many challenges encountered in dental treatment span multiple disciplines, there is a

growing trend towards an integrated approach in both theoretical and clinical education. The goal of this integration is to help students view the larger picture, rather than just learning isolated aspects of their studies.

Health services aim to solve the problems of healthy/sick individuals in the shortest time, which is one of the obligations to have problem-solving skills. In this way, how the problem-solving process will be realized in order to provide quality care and achieve the intended goals as soon as possible should be provided to dental students. When the literature was examined, no study was found to evaluate the self-confidence and professional knowledge skills of final dental students trained with the integrated clinical model.

Self-confidence is one of the essential factors for communicating successfully with patients. Akin introduced the Akin Self-Confidence scale to the literature because of his study with 796 high school students to evaluate students' self-confidence levels validly and reliably.¹² The General Dental Council has developed standards for the appropriate and transparent assessment of dental undergraduate education. The Dental Undergraduates Preparedness Assessment Scale (DU-PAS) is a two-part, fifty-question psychometric scale used to assess final students' knowledge, attitudes, and skills.^{13,14} With our study, we aim to introduce the DU-PAS scale to the Turkish literature and to measure the effect of the integrated clinical model on the practical deficiency and the acquisition of communication skills by the Akin Self-Confidence Scale.

Material and Method

Our study, conducted at Necmettin Erbakan University Faculty of Dentistry, Department of Pedodontics, was approved by Necmettin Erbakan University Faculty of Dentistry, Ethics Committee for Non-Drug and Non-Medical Device Research (2022/17-124), and was conducted by the principles specified in the Declaration of Helsinki.

Study Design

This study is a prospective scale study. The study was conducted in two steps; first step is cultural adaptation and cultural validation of DU-PAS and second step is the effects of the integrated clinical education model on the knowledge, experience and self-confidence scale is on the final-year dentistry students participants will be administered using the Turkish validated DU-PAS and Akin self-confidence scale. Permission to use and adapt the Dental Undergraduates Preparedness Assessment Scale (DU-PAS) was obtained from the author prior to conducting the study.

In adapting a scale to another culture, a group at least 5-10 times larger than the number of scale items should be reached.¹⁵ In this study, the number of scale items was 50. In validating the DU-PAS, the aim was to adapt the 50 items in the scale to at least 250 final year dental students, with 5 samples for each item. The first-step validation of the DU-PAS scale was conducted with a total of 272 final-year dental students who completed the survey via Google Forms.

Two dentist experts (endodontics and restorative dentistry) with an advanced level of English translated the English version of the scale into Turkish. The scale translated into Turkish was translated back into English and re-evaluated by two experts (pediatric dentist and endodontics). The final version was edited by three dentists and applied to 30 students for comprehensibility (Table 1). Following the pilot administration of the DU-PAS scale to 30 students, minor modifications were made to improve clarity and cultural relevance. These changes were incorporated into the final version used in the main study. The study was completed with 272 final-year dental students. For cultural validation, this number includes all students who completed the scale, excluding those from Necmettin Erbakan University Faculty of Dentistry. Therefore, the sample represents a convenience group of final dental students from various faculties, except for the researchers' own institution. The 30 students who participated in the pilot study were not included in the final analysis sample to avoid potential bias arising from prior exposure to the scale.

Table 1: Final Version of the Cultural Adaptation, Validation, and Reliability of Turkish Version DU-PAS

Questions	0	1	2	3
PART A				
1 Hastalarımın eksiksiz anamnez alabiliyorum.				
2 Kapsamlı klinik ağız muayenesi yapabiliyorum.				
3 Uygun dental radyografileri belirleyebiliyorum.				
4 Periapikal radyografi çekebiliyorum.				
5 Bite-wing radyografi çekebiliyorum.				
6 Dental radyografilerdeki standart bulguları yorumlayabiliyorum.				
7 Ortodonti gerektiren hastaların tedavi ihtiyaçlarını değerlendirebiliyorum				
8 Hastalarımın tüm tedavi ihtiyaçlarını karşılayan kapsamlı bir tedavi planı oluşturabiliyorum.				
9 Hastalarımın bireysel koşullarına göre bir dizi tedavi seçeneği sağlayabiliyorum.				
10 Hastalarımın farklı tedavi seçeneklerinin avantaj ve dezavantajlarını açıklayabiliyorum.				
11 Herhangi bir tedaviye başlamadan önce hastalarımın geçerli bir onam alabiliyorum.				

12	Hastaların tedavi seanslarını uygun bir sırayla gerçekleştirebiliyorum.				
13	Hastalarımı uygun şekilde ilaç reçete edebiliyorum.				
14	Inferior alveol sinir bloğunu etkili bir şekilde uygulayabiliyorum.				
15	Uygun yöntemlerle ameliyat gerektirmeyen periodontal tedavi uygulayabiliyorum.				
16	Diş çürüklerini etkili bir şekilde temizleyebiliyorum.				
17	Dişleri diş rengi dolgularla uygun şekilde restore edebiliyorum.				
18	Dişleri amalgam dolgularla uygun şekilde restore edebiliyorum.				
19	Tek köklü dişlerde endodontik tedaviyi uygun şekilde yapabiliyorum.				
20	Çok köklü dişlerde endodontik tedaviyi uygun şekilde yapabiliyorum.				
21	Diş koruma prensiplerini kullanarak uygun kron tedavisi sağlayabiliyorum.				
22	Mekanik olarak sağlam bölümlü protezler sağlayabiliyorum				
23	Mekanik olarak sağlam protezler sağlayabiliyorum.				
24	Ameliyat gerektirmeyen diş çekimlerini uygun şekilde yapabiliyorum.				
	PART B	0	1	2	3
25	İnsanların tedavilerinden beklentilerini yönetebileceğimi hissediyorum.				
26	Hastalarımı dental ihtiyaçları için öz bakımı teşvik etmeye motive edebileceğimi hissediyorum.				
27	Tedavilerimde kişisel sınırlarımın farkındayım.				
28	Gerektiğinde akademik danışman ve meslektaşlarımdan yardım istemek konusunda kendimi rahat hissediyorum.				
29	Karmaşık tedavi ihtiyaçları olan hastaları uygun şekilde sevk edebiliyorum.				
30	Ağız kanserlerinden şüphelenilen hastaları sevk etme konusunda kendime güveniyorum.				
31	Öğrenme ihtiyaçlarımı karşılamak için klinik uygulamalarım üzerinde düşünürüm.				
32	Diş hekimliği pratiğimi destekleyen bilimsel ilkeler hakkında yeterli bilgiye sahibim.				
33	Kanıtı dayalı bir yaklaşım kullanarak yeni dental materyalleri ve ürünleri değerlendirmek konusunda kendime güveniyorum.				
34	Uygulamamı etkileyebilecek araştırma sonuçlarını yorumlama konusunda kendime güveniyorum.				
35	Klinik pratiğimde kanıtı dayalı bir yaklaşım kullanıyorum.				
36	Hastalarımı etkili bir iletişim kurabileceğimi hissediyorum.				
37	Hastalarımın diş tedavisinden beklentilerini ifade etmeleri için fırsat veriyorum.				
38	Hastalarla etkili iletişimin önündeki engelleri uygun şekilde ele almak konusunda kendime güveniyorum.				
39	Girişimsel işlemlerin potansiyel risklerini hastalara anlatmak konusunda kendime güveniyorum.				
40	Meslektaşlarımla uygun şekilde iletişim kurmak konusunda kendime güveniyorum.				
41	Endişeli hastaları uygun davranış teknikleri ile yönetme konusunda kendime güveniyorum.				
42	Uygun diş tedavisi sağlamak için çocukların davranışlarını yönetebiliyorum.				
43	Diş hekimliği ekibinin etkin bir üyesi olarak sorumluluklarımı yerine getirebiliyorum.				
44	Klinik notlarımın kayıtlarını eksiksiz tutarım.				
45	Klinik randevu planlamasının kısıtlamaları dahilinde çalışabilirim.				
46	Devam eden mesleki gelişimim için sorumluluk alıyorum				
47	Diş hekimi olarak yasal sorumluluklarımın farkındayım.				
48	Hastalarımın ilişkilerimi profesyonel düzeyde tutarım.				
49	Meslektaşlarımdan uygunsuz davranışları hakkında endişelerimi dile getirebileceğimi hissediyorum.				
50	Hasta gizliliğini korumak için uygun önlemleri alıyorum.				

Administration of DU-PAS Scale and Akin Self-Confidence to Final Dental Students

In the second step, the final dentistry students who did their internship in the integrated clinic of Necmettin Erbakan University Faculty of Dentistry. Fifty-three final-year students were included in this study, and informed consent forms were obtained. The DU-PAS were administered twice: once immediately before the start of the integrated clinical internship (6 weeks) and again immediately after its completion. The Akin self confidence scale was used before the integrated internship. Both administrations were conducted online via Google Forms, consistent with the procedure used in the first step of the study.

The participants were asked to complete the demographic information form, including age, gender, and educational status. Then, each of them was administered the 33-item Akin Self-Confidence Scale developed by Akin¹⁴ consisting of 2 subcategories: intrinsic self-confidence and extrinsic self-confidence (Appendix 1). The items of this scale are written in the form of a 5-point Likert: (1) never, (2) occasionally, (3) often, (4) usually, (5) always) type rating scale. By dividing the total score obtained from the scale by the number of items, a conclusion can be reached about the self-confidence level of the individual. On the Akin Self-Confidence Scale, a score below 2.5 indicates low self-confidence, between 2.5 and 3.5 indicates moderate self-confidence and 3.5 and above indicates high self-confidence. It was determined that the items in the first factor of the scale (17 items) were primarily

related to the self-confidence of individuals towards themselves. This factor was handled under the name of internal self-confidence. Since the items loaded on the second factor (16 items) were mainly related to individuals' self-confidence towards their external environment and social life, this factor was called external self-confidence (Appendix 1).

The validated Dental Undergraduates Preparedness Assessment Scale was applied to learn and evaluate their thoughts about their professional competencies. The scale consists of two subgroups: Part A (24 items) investigating preparedness for clinical procedures and Part B (26 items) investigating preparedness related to cognition, communication, and professionalism skills. For part A, I have no experience (0-Zero); I can do it with verbal or practical input from a colleague (1-One); I can do it on my own, independently (2-Two). For part B, I have no experience (0-Zero); mostly (1-One); always (2-Two). The total DU-PAS score was calculated by summing the scores of all items in both parts of the scale. Each item was scored on an ordinal scale, and higher scores indicated greater preparedness.

2.3. Statistical Analysis. The scale structures were analyzed using explanatory factor analysis. In exploratory factor analysis, the principal component analysis method was used for factor extraction, and the Varimax method was used for rotation. Cronbach's alpha and item-total correlation coefficients were used to analyze the scale's internal consistency. The paired-t test was used to compare the before and after DU-PAS scores.

Appendix 1. Akin Self-Confidence Scale

Bu anketlerden elde edilen sonuçlar bilimsel bir çalışmada kullanılacaktır. Sizden istenilen bu ifadeleri okuduktan sonra kendinizi değerlendirmeniz ve sizin için en uygun seçeneğin karşısına çarpı (X) işareti koymanızdır. Her sorunun karşısında bulunan;(1) Hiçbir zaman (2) Nadiren (3) Sık sık (4) Genellikle ve (5) Her zaman anlamına gelmektedir. Lütfen her ifadeye mutlaka TEK yanıt veriniz ve kesinlikle BOŞ bırakmayınız. En uygun yanıtları vereceğinizi ümit eder katkılarınız için teşekkür ederim.		Hiçbir Zaman	Nadiren	Sık Sık	Genellikle	Her Zaman
1	Kendimi başarılı bir insan olarak görürüm.	1	2	3	4	5
2	Başkalarının yanında heyecanımı kontrol edebilirim.	1	2	3	4	5
3	Seçimlerimde başkalarına bağımlı değilimdir.	1	2	3	4	5
4	Yaşamdaki zorluklarla baş edebilirim.	1	2	3	4	5
5	Benim için aşılamayacak sorun yoktur.	1	2	3	4	5
6	Başkalarının görüşlerine saygı gösteririm.	1	2	3	4	5
7	Problemlerimin üstesinden gelebileceğime inanırım.	1	2	3	4	5
8	Sosyal etkinliklere katılmaktan çekinmem.	1	2	3	4	5
9	Verdiğim kararların arkasında dururum.	1	2	3	4	5
10	Kendi kendime yetebileceğime inanırım.	1	2	3	4	5
11	Aktif birisi olduğumu düşünürüm.	1	2	3	4	5
12	Öz-eleştiri yapabilirim.	1	2	3	4	5
13	Anlamadığım konularda başkalarına soru sorabilirim.	1	2	3	4	5
14	Yeni girdiğim ortamlara uyum sağlarım.	1	2	3	4	5
15	Kendimle barışık bir insanım.	1	2	3	4	5
16	Gerektiğinde sonuna kadar hakkımı savunurum.	1	2	3	4	5
17	İstediğim şeyleri elde etmek için mücadele edebilirim.	1	2	3	4	5
18	Kendimi rahat bir şekilde ifade edebilirim.	1	2	3	4	5
19	Kendimi ve başkalarını olduğu gibi kabul ederim.	1	2	3	4	5

20	Çevremde yeteri kadar güvenilebileceğim insan vardır.	1	2	3	4	5
21	Sorumluluk almaktan çekinmem.	1	2	3	4	5
22	Diğer insanların eleştirilerini anlayışla karşılayabilirim.	1	2	3	4	5
23	Sıkıntılı anlarımda bile olumlu düşünmeye çalışırım.	1	2	3	4	5
24	Ön plana çıkmaktan korkmam.	1	2	3	4	5
25	Başarısız olduğumda hemen pes etmem.	1	2	3	4	5
26	Başka insanlarla kolaylıkla iletişim kurabilirim.	1	2	3	4	5
27	Değerli birisi olduğuma inanırım.	1	2	3	4	5
28	Kolay arkadaş edinebilirim.	1	2	3	4	5
29	Düşüncelerimi ifade ederken başkalarından çekinmem.	1	2	3	4	5
30	Kolay karar verebilirim.	1	2	3	4	5
31	Sosyal bir insan olduğuma inanırım.	1	2	3	4	5
32	Kendimi severim.	1	2	3	4	5
33	Başka insanların övgülerini hak ettiğime inanırım.	1	2	3	4	5

Results

The Dental Undergraduates Preparedness Assessment Scale has 50 items in total. The validation results consists of two parts: descriptive statistics and the total correlation of each item. Descriptive statistics and item-total correlation coefficients of the items of the scale are presented in Table 2. Cronbach's alpha value of the scale was 0.925, and the scale was obtained with high reliability. In addition, item-total correlations should be 0.2 and above. When the item total correlation coefficients were analyzed, item 5 was removed from the scale because its item total correlation coefficient was below 0.2.

In exploratory factor analysis, the principal component analysis method was used for factor extraction, and the Varimax method was used for rotation. As a result of the first analysis, it is unacceptable for an item to be included under two factors for factor analysis. If the difference between the values of an item under different factors is less than 0.1, it should be removed from the scale. Items M6, 12, 17, 18, 26, 29, 31, 46, 50, 7 were removed from the scale because they were under more than one factor. Item 13 and item 15 were removed from the scale because they formed a single-item factor, and there cannot be a single-item factor. Item 28 and item 27 together form a factor, and the Cronbach's alpha of the factor formed is low reliability, so these items were removed from the scale. The results obtained from the repeated analyses after a total of 15 items were removed from the scale together with the item analysis are presented in Table 3. After removing these items, the CMR value was 0.880, and Bartlett's test chi-square value was 3980.290 ($p < 0.001$). These values reveal the suitability of the data set for factor analysis. In the 35-item scale, it was found that all of the extraction values were 0.3 and above, and all of the diagonal values in the anti-image correlation matrix were above 0.5. As a result of the analysis, a seven factor structure was revealed. With seven factors, 58.58% of the total variance is explained.

All item-total correlations of the scale items were obtained as 0.3 and above. Cronbach's alpha of factor 1 was 0.880, factor 2 was 0,795, factor 3 was 0,835, factor 4 was 0,81, factor 5 was 0,751, factor 6 was 0,663, and factor 7 was 0,615.

According to the obtained Cronbach's alpha coefficients, factor 1, 3, and 4 sub-dimensions were highly reliable. Factors 2, 5, 6, and 7 were highly reliable (Table 4).

According to Tukey's summability test, it was analyzed whether the scale was summable or not, and as a result of the test, it was found that the scale was not in a summable structure ($F=252,016$; $p < 0.001$). It is understood that each dimension should be evaluated within itself, and there is no general evaluation. According to Hotelling's T2 test, it is understood that the items in the scale form different sub-dimensions. In other words, it is understood that it is not a one-dimensional scale ($F=31.878$; $p < 0.001$).

In the second step, 53 Necmettin Erbakan University (NEU) Faculty of Dentistry final-year students were administered the DU-PAS and Akin Self-Confidence Scale. The comparison of pre- and post-intervention DU-PAS scores revealed a statistically significant increase in students' clinical preparedness. The mean DU-PAS score before the internship was 125 ± 19.1 (Min-Max: 70–140), whereas the mean score after the internship increased to 134 ± 13.2 (Min-Max: 78–149) (Table 5). The reduction in standard deviation in the post-test also suggests a more consistent level of preparedness among students, which may reflect the unifying effect of structured clinical exposure. A paired-sample t-test revealed a statistically significant increase in readiness scores following the intervention ($p = 0.002$), indicating that the training had a positive effect on students' readiness.

Figure 1 illustrates the individual changes in readiness scores of final-year dental students before and after the integrated clinical internship, stratified by self-confidence levels. The majority of students demonstrated an increase in their readiness scores following the training. This upward trend was observed across all confidence levels, though the degree of improvement varied. Students with high self-confidence (blue lines) generally started with higher baseline scores and showed consistent improvements. Moderate-confidence students (orange lines) exhibited a wider range of improvement, with several individuals showing substantial gains. The few students with low self-confidence (red lines) displayed limited change, and in some cases, minimal or no increase.

Table 2. Item Analysis and Reliability Results of DU-PAS

	Mean	S.D.	Item-total correlation	Cronbach's Alpha (α) if item deleted	Cronbach's Alpha (α)
m1	1.931	0.295	0.278	0.925	0.925
m2	1.775	0.436	0.361	0.924	
m3	1.672	0.494	0.307	0.925	
m4	1.901	0.347	0.294	0.925	
m5	1.473	0.824	0.124	0.928	
m6	1.798	0.421	0.370	0.924	
m7	1.088	0.658	0.349	0.925	
m8	1.386	0.533	0.489	0.923	
m9	1.573	0.533	0.537	0.923	
m10	1.733	0.460	0.446	0.924	
m11	1.928	0.288	0.301	0.925	
m12	1.805	0.425	0.465	0.924	
m13	1.183	0.578	0.377	0.924	
m14	1.912	0.309	0.307	0.925	
m15	1.809	0.448	0.277	0.925	
m16	1.928	0.288	0.426	0.924	
m17	1.878	0.372	0.425	0.924	
m18	0.870	0.905	0.258	0.927	
m19	1.912	0.309	0.410	0.924	
m20	1.374	0.671	0.373	0.924	
m21	1.599	0.584	0.435	0.924	
m22	1.298	0.657	0.449	0.924	
m23	1.386	0.613	0.444	0.924	
m24	1.794	0.424	0.342	0.924	
m25	1.382	0.525	0.566	0.923	
m26	1.550	0.506	0.444	0.924	
m27	1.672	0.486	0.522	0.923	
m28	1.508	0.566	0.348	0.924	
m29	1.302	0.623	0.519	0.923	
m30	0.683	0.750	0.497	0.923	
m31	1.550	0.536	0.574	0.922	
m32	1.118	0.530	0.521	0.923	
m33	0.859	0.694	0.473	0.923	
m34	1.042	0.651	0.526	0.923	
m35	1.195	0.610	0.525	0.923	
m36	1.691	0.471	0.570	0.923	
m37	1.748	0.452	0.524	0.923	
m38	1.626	0.500	0.602	0.922	
m39	1.592	0.508	0.626	0.922	
m40	1.691	0.487	0.527	0.923	
m41	1.527	0.530	0.563	0.923	
m42	1.309	0.510	0.526	0.923	
m43	1.592	0.523	0.506	0.923	
m44	1.382	0.573	0.468	0.923	
m45	1.366	0.583	0.510	0.923	
m46	1.573	0.540	0.561	0.923	
m47	1.374	0.617	0.432	0.924	
m48	1.546	0.514	0.440	0.924	
m49	1.263	0.669	0.431	0.924	
m50	1.630	0.529	0.398	0.924	

Table 3. Explanatory Factor Analysis Results of DU-PAS

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Extraction	Anti-image correlation coefficient
m38	0.822							0.724	0.918
m36	0.775							0.674	0.921

m41	0.734							0.638	0.918
m40	0.674							0.540	0.907
m39	0.673							0.578	0.924
m37	0.643							0.504	0.914
m43	0.540							0.430	0.941
m42	0.531							0.479	0.927
m25	0.482							0.508	0.922
m11		0.737						0.628	0.810
m14		0.735						0.601	0.809
m16		0.710						0.612	0.904
m1		0.677						0.574	0.806
m4		0.599						0.566	0.755
m19		0.597						0.541	0.907
m24		0.478						0.358	0.887
m33			0.805					0.702	0.851
m34			0.795					0.735	0.856
m32			0.704					0.596	0.898
m30			0.668					0.579	0.915
m35			0.637					0.588	0.923
m23				0.858				0.786	0.753
m22				0.839				0.767	0.766
m20				0.680				0.528	0.823
m21				0.678				0.578	0.901
m8					0.652			0.575	0.875
m9					0.644			0.582	0.921
m2					0.633			0.537	0.844
m10					0.616			0.547	0.887
m3					0.585			0.407	0.900
m44						0.750		0.695	0.859
m45						0.636		0.604	0.884
m47						0.558		0.511	0.903
m49							0.691	0.619	0.875
m48							0.652	0.613	0.849
Eigen value	4.893	3.467	3.267	2.870	2.568	1.811	1.627		
VER	13.979	9.907	9.333	8.200	7.338	5.173	4.650		
CEVR	13.979	23.886	33.220	41.419	48.757	53.930	58.580		

VER: Variance Explanation Ratio, CEVR: Cumulative Explained Variance Ratio Kaiser-Meyer-Olkin: K-M-O=0.880; Bartlett's Test (X²=3980.290; p<0.001)

Table 4. Reliability Result of DU-PAS

		Mean	S.D.	Item-Total correlation	Cronbach's Alpha (α) if item deleted	Cronbach's Alpha (α)
Factor 1	m25	1.378	0.523	0.531	0.875	0.880
	m36	1.700	0.467	0.687	0.862	
	m37	1.756	0.447	0.585	0.870	
	m38	1.626	0.500	0.749	0.856	
	m39	1.593	0.507	0.661	0.864	
	m40	1.693	0.486	0.613	0.868	
	m41	1.522	0.529	0.699	0.860	
	m42	1.304	0.507	0.566	0.872	
	m43	1.596	0.521	0.543	0.874	
	m1	1.930	0.295	0.534	0.768	
Factor 2	m4	1.901	0.345	0.469	0.780	0.795
	m11	1.930	0.282	0.601	0.758	
	m14	1.916	0.304	0.622	0.752	
	m16	1.930	0.282	0.645	0.750	
	m19	1.912	0.309	0.505	0.773	
Factor 3	m24	1.795	0.422	0.404	0.805	0.835
	m30	0.680	0.747	0.594	0.818	

Factor 4	m32	1.118	0.523	0.618	0.810	0.817
	m33	0.864	0.693	0.695	0.784	
	m34	1.037	0.653	0.713	0.780	
	m35	1.195	0.603	0.591	0.814	
	m20	1.372	0.679	0.489	0.842	
	m21	1.606	0.579	0.583	0.794	
	m22	1.296	0.655	0.738	0.719	
Factor 5	m23	1.380	0.613	0.767	0.709	0.751
	m2	1.777	0.434	0.498	0.714	
	m3	1.679	0.491	0.417	0.742	
	m8	1.394	0.533	0.528	0.703	
Factor 6	m9	1.580	0.530	0.606	0.671	0.663
	m10	1.730	0.461	0.544	0.698	
	m44	1.380	0.570	0.508	0.523	
Factor 7	m45	1.369	0.581	0.495	0.539	0.615
	m47	1.388	0.616	0.423	0.639	
	m48	1.554	0.513	0.460	---	
	m49	1.277	0.667	0.460	---	

S.D. : Standard Deviation, Hotelling's T(2) test ($F=31.878$; $p<0.001$), Tukey's additivity test ($F=252.016$; $p<0.001$), Genel Cronbach's alfa=0.909

Table 5. Comparison of DU-PAS Scores Before and After Integrated Internship

DU-PAS (Before)		DU-PAS(After)		p
Mean±S.D	Min-Max	Mean±S.D	Min-Max	
125±19.1	70-140	134±13.2	78-149	
				0.002*,x

S.D Standart Deviation, *Statistically significant, x Paired t-test

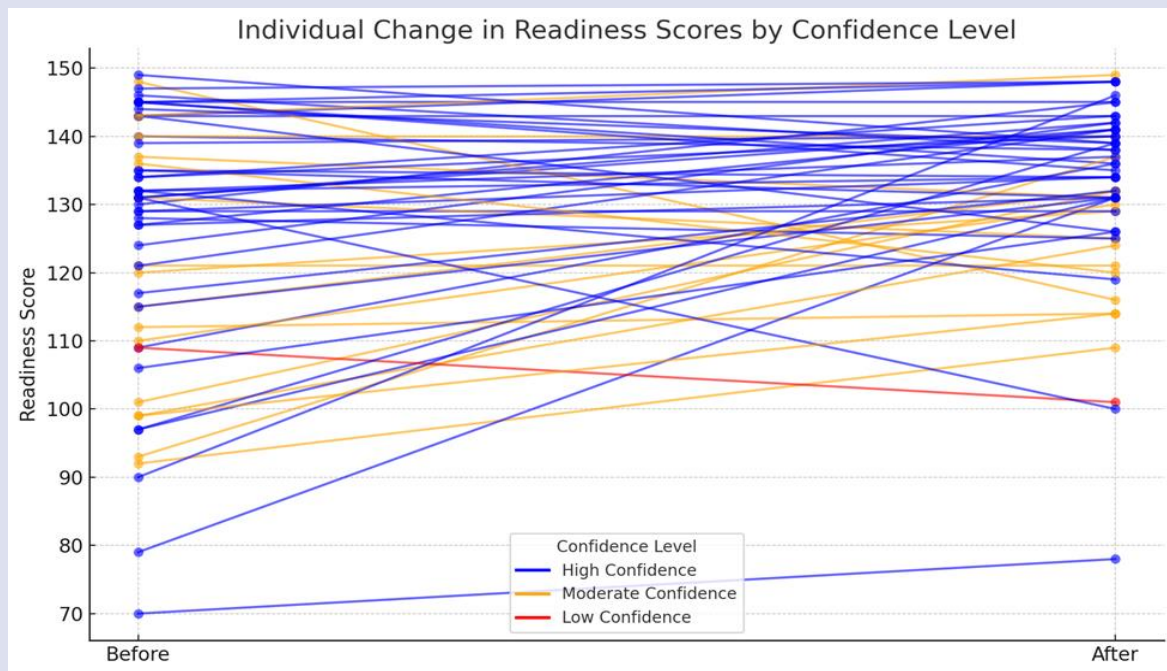


Figure 1. The individual changes in readiness scores of final-year dental students before and after the integrated clinical internship, stratified by self-confidence levels

Discussion

Scales developed based on universal measurement principles, sampling methods, and conceptual frameworks of those cultures. Therefore, it is essential to conduct validity and reliability studies before using a scale in different cultural and linguistic contexts.¹⁶ We

conducted a cultural adaptation, validation, and reliability analysis of the DU-PAS. In the next phase, we compared the impact of an integrated clinical education model on final-year dental students' knowledge and experience using the validated DU-PAS, and assessed their self-confidence using the Akin Self-Confidence Scale.

In our country, dental education consists of a series of courses and practical applications that provide the theoretical foundations and clinical skills necessary for professional practice. This education spans five years and begins after high school. The first three years focus on pre-clinical education, where students engage in theoretical coursework and laboratory practice, along with introductory courses in medical sciences and clinical dentistry. During this time, students develop a foundational understanding of medicine and enhance their manual skills. The final two years are dedicated to clinical education, which includes advanced theoretical courses in clinical medical sciences and clinical dentistry. These courses are essential for dentists throughout their professional careers.^{17,18}

The DU-PAS scale is structured into five main categories: (1) clinical skills competence, (2) theoretical knowledge, (3) professional attitudes and behaviors, (4) communication skills, and (5) ethical and legal issues. Each category contains a range of questions designed to assess the students' levels of preparedness. The students' responses are evaluated using a specific scoring system. The total scores indicate each student's overall level of preparedness. Our study's findings also suggest that the scale includes more dimensions.

In validated Turkish DU-PAS, 'I am able to interpret standard findings on dental radiographs.', 'I am able to perform patients' treatment sessions in an appropriate sequence.', 'I am able to restore teeth appropriately with tooth-colored fillings.', 'I am able to restore teeth appropriately with amalgam fillings.', 'I feel I can motivate my patients to promote self-care for their dental needs.', 'I am able to refer patients with complex treatment needs appropriately.', 'I reflect on my clinical practice to meet my learning needs.', 'I take responsibility for my ongoing professional development.', 'I take appropriate measures to protect patient confidentiality.', 'I am able to assess the treatment needs of patients requiring orthodontics.', 'I am able to perform non-surgical periodontal treatment with appropriate methods.', 'I am aware of my personal limitations in my treatments.', 'I feel comfortable asking for help from academic advisors and colleagues when necessary.' They were determined as items that could not be categorized in the DU-PAS scale.

In a study assessing the preparedness of final-year dental students in Turkey, it was found that the scores of Turkish students (75.68%) were higher than those of students from the United Kingdom (74%) and Pakistan (61.1%), but lower than those from Malaysia (79.5%).¹⁹ In our study, when we measured the self-confidence of participating students using the Akin Self-Confidence Scale, we discovered that the majority exhibited moderate and high self-confidence. Furthermore, the DU-PAS scores, which assess preparedness, indicated that several factors could influence these scores. These include the need to access, prepare, and negotiate multiple canals in posterior teeth, challenges posed by complex anatomy, and inadequate access. Such difficulties can lead to complications in applying rubber dams, taking

radiographs, and performing endodontic procedures on multi-rooted teeth. Consequently, these challenges may negatively impact students' self-confidence and suggest a need for appropriate measures to help students strengthen their endodontic skills.¹⁹

The final version of the Turkish DU-PAS Scale consists of 35 items and was applied to Necmettin Erbakan University Faculty of Dentistry students before and after the integrated clinic. There was a positive change before and after the integrated clinic internship in the preparedness scale applied to NEU final dental students. It was observed that after the integrated clinic, students' knowledge about diagnosis and treatment on their own and their ability to practice increased. The primary and secondary objectives of this study are to help dental students more effectively connect basic scientific concepts from their curriculum to clinical practice through an integrated clinical model. Additionally, this model enables students to manage patient care holistically, enhancing their problem-solving skills.

The strength of the study is that DU-PAS was validated in Turkish to improve the dental curriculum. This will help to identify students' weaknesses in dental practice. The study's limitations are that more final students or dentistry faculty have integrated internships. There is a need for studies in which students are evaluated not only by self-assessment scales but also by supervisors or educators.

Conclusions

DU-PAS has been validated in Turkish through item extraction. The 35-item version of the scale, derived from the original 50 items, has been shown to be valid and reliable for use within the Turkish population. This study represents the first validation of the DU-PAS scale to Turkish and introduces it to the literature. It was observed that the self-confidence of final dental students before the integrated internship was lower compared to their confidence after completing the internship. Important finding of this study is that the integrated internship positively affects dental students' preparedness after integrated intership.

Conflict of Interest Statement

The authors declare no conflict of interest.

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Comparative Impact of Chocolate and Chocolate- Raw Almond Intake on Salivary pH Dynamics and Stephan Curve

Zeynep Ceren Çelik^{1,a,*}, Sümeyye Şükran Özkeleş^{2,b}, Esra Özgöçmen Tula^{3,c}

¹Department of Restorative Dentistry, Faculty of Dentistry, Bursa Uludağ University, Bursa, Türkiye

²Fizyoloji Health Center, Bursa, Türkiye

³Department of Pedodontics, Faculty of Dentistry, Bursa Uludağ University, Bursa, Türkiye

*Corresponding author

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ABSTRACT

Objective: This study aimed to evaluate the effect of consuming chocolate alone versus in combination with raw almonds on salivary pH kinetics, focusing on their ability to prevent critical pH drops and their buffering efficiency over time.

Materials and Methods: This study assessed the Stephan Curve response to the consumption of chocolate alone and in combination with raw almonds in 34 healthy young adults, measuring salivary pH kinetics and buffering capacity. Saliva samples were collected at multiple time points using a standardized protocol, and pH was analyzed with a calibrated digital pH meter to evaluate the impact of each condition on oral clearance and acid neutralization.

Results: Both groups exhibited an immediate decrease in salivary pH post-consumption. The lowest pH values were observed at 1 minute for chocolate (pH = 5.1) and at 5 minutes for the chocolate-almond combination (pH = 5.6). The chocolate-alone group returned toward baseline within 30 minutes, whereas the chocolate-almond combination required approximately 45 minutes. Notably, the pH for the chocolate-almond combination remained above the critical pH threshold of 5.5 for hydroxyapatite, indicating a lower risk of enamel demineralization.

Conclusion: Adding raw almonds to chocolate slowed pH decline, keeping it above the critical threshold, indicating a potential cariostatic effect. Raw almonds may help reduce the cariogenic risk of high-carb foods.

Keywords: Saliva, chocolate, almond, dental caries

Çikolata ve Çikolata-Badem Kombinasyonunun Tükürük pH Dinamiği ve Stephan Eğrisi Üzerindeki Karşılaştırmalı Etkisi

Araştırma Makalesi

Süreç

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ÖZET

Amaç: Bu çalışmanın amacı, çikolatanın tek başına tüketilmesi ile çiğ bademle birlikte tüketilmesinin tükürük pH kinetiği üzerindeki etkisini değerlendirmek ve kritik pH düşüşlerini önleme yetenekleri ile zaman içindeki tamponlama verimliliklerini karşılaştırmaktır.

Materyal ve Metot: Bu çalışmada, 34 sağlıklı genç yetişkinde çikolatanın tek başına ve çiğ bademle birlikte tüketilmesine bağlı Stephan Eğrisi yanıtı değerlendirilmiş, tükürük pH kinetiği ve tamponlama kapasitesi ölçülmüştür. Standart bir protokol kullanılarak çoklu zaman noktalarında tükürük örnekleri toplanmış ve pH, kalibre edilmiş bir dijital pH metre ile analiz edilerek her bir koşulun oral klirens ve asit nötralizasyonu üzerindeki etkisi incelenmiştir.

Bulgular: Her iki grupta da tüketim sonrası tükürük pH'ında ani bir düşüş gözlemlenmiştir. En düşük pH değerleri, çikolata grubunda 1. dakikada (pH = 5,1), çikolata-badem kombinasyonunda ise 5. dakikada (pH = 5,6) kaydedilmiştir. Çikolata tek başına tüketildiğinde pH 30 dakika içinde başlangıç değerine yaklaşırken, çikolata-badem kombinasyonunda bu süre yaklaşık 45 dakika sürmüştür. Önemli bir şekilde, çikolata-badem kombinasyonunda pH, hidroksiapatit için kritik pH eşiği olan 5,5'in üzerinde kalmıştır, bu da mine demineralizasyonu riskinin daha düşük olduğunu göstermektedir.

Sonuç: Çikolataya çiğ badem eklenmesi, pH düşüşünü yavaşlatarak kritik eşiğin üzerinde kalmasını sağlamış ve potansiyel bir kariyostatik etkiye işaret etmiştir. Çiğ badem, yüksek karbonhidratlı gıdaların kariyojenik riskini azaltmada yardımcı olabilir.

Anahtar Kelimeler: Tükürük, çikolata, badem, diş çürüğü

^a zeynepceren@uludag.edu.tr

^b 0000-0002-6900-2632

^c esraozgocmentula@uludag.edu.tr

0000-0002-8136-082X

^b sumeyyesukran@gmail.com

0000-0002-2084-330X

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Introduction

Saliva is a biological secretion with various functions, including chewing, swallowing, taste perception, speech, and the initial digestion of carbohydrate-containing foods. Under healthy conditions, the pH of saliva generally ranges between 6.7 and 7.4. In addition to its static protective effects, saliva also exhibits dynamic effects that are activated during a stimulus or challenge. The oral clearance effect and buffering capacity of saliva are among the key dynamic mechanisms that help prevent the demineralization of dental tissues.^{1,2}

Oral clearance refers to the rate at which substances (e.g., drugs, foods, microorganisms) are removed from the oral cavity through mechanisms such as salivary flow, tongue movements, and swallowing.³ This mechanism plays a critical role in maintaining oral health. Oral clearance is influenced by various factors, including the quantity and quality of saliva, tongue mobility, swallowing function, and the structure of teeth.

When sugary foods are consumed, bacteria in the oral microbiota (particularly cariogenic species like *Streptococcus mutans*) metabolize these sugars to produce acids.⁴ These acids lower the oral pH to levels that can cause demineralization of tooth enamel. Once the pH drops, minerals in the enamel begin to dissolve, increasing the risk of caries formation. This pH fluctuation is effectively illustrated by the Stephan Curve.⁵

Dairy products contain substances with natural buffering effects that play a crucial role in maintaining oral health. Milk proteins (casein), calcium, and phosphates can prevent pH drops and neutralize the acidic environment caused by sugary foods more rapidly.⁶ However, like cheese and yogurt have the potential to reduce caries risk, they are not always practical to carry and consume during daily activities due to refrigeration requirements.

Nuts, such as walnuts and almonds, are portable and practical healthy snacks,⁷ but their effects on oral pH changes and Stephan Curve kinetics in conjunction with cariogenic foods have not been thoroughly investigated.

Foods with high fiber content and alkaline properties, such as raw almonds, may buffer the acidic effects of cariogenic foods and influence oral pH kinetics. Cariogenic foods like chocolate are widely consumed, pairing them with healthy snacks such as raw almonds may alter their impact on oral pH.⁸ Raw almonds, rich in fiber and alkaline properties, have been suggested to buffer pH changes, thereby reducing cariogenic risk.

While the Stephan Curve provides a framework for understanding pH dynamics following sugar consumption, the impact of co-consumption with healthy snacks on oral clearance and pH buffering remains underexplored. This study aims to investigate the effect of consuming fermentable sugar-containing cariogenic foods alone and in combination with practical, portable healthy snacks on oral clearance and Stephan Curve kinetics, focusing on their potential to mitigate cariogenic risks. The null hypothesis is that there is no significant difference in oral pH dynamics between the consumption of chocolate alone and the consumption of chocolate combined with raw almonds.

Materials and Methods

The study was approved by the Bursa Uludağ University Health Research Ethics Committee (Ethics Committee No: 2024-16/21). After providing an explanation in the local language, informed consent was obtained from the participants. A power analysis was conducted prior to the study to determine the minimum sample size required to detect a significant difference in salivary pH changes between groups, with a power of 80% and an alpha level of 0.05. Based on a previous related data⁶ and an expected medium effect size (Cohen's $d = 0.5$), the required sample size was calculated to be 32 participants. The study included young adults ($n=34$) aged 18-35 who were non-allergic to chocolate, chocolate derivatives, raw almonds, or any type of nuts; non-smokers; free of systemic diseases, and had not received antibiotic treatment in the past month.

A series of in vivo experiments were conducted to assess the Stephan Curve response to the consumption of 4.25 g of milk chocolate (Milk chocolate, 33 g, Napoliten™, ÜLKER, Türkiye) alone and in combination with ~1.5 g of raw almonds (Raw almond, Peyman, USA)

Participants were instructed to refrain from oral hygiene practices for a set duration prior to each trial.

The primary outcome measures were the minimum pH reached, the time taken to reach the minimum pH, and the overall area under the Stephan Curve. Secondary outcomes included the time required for pH to return to baseline levels and the buffering capacity of the different test conditions.

Saliva samples were collected between 9:00 am and 11:00 am to avoid the effects of circadian rhythm. Participants were instructed to refrain from eating, drinking, or chewing gum for at least two hours prior to sample collection. The sampling procedure included the following steps:

1. 5 minutes of rest.
2. Baseline: Collection of unstimulated saliva for 5 minutes.
3. Consumption of a 4.25 g of chocolate.
4. T0: 1 minute after consumption, collection of unstimulated saliva for 5 minutes.
5. T1: Collection of unstimulated saliva 10 minutes post-consumption for 5 minutes.
6. T2: Collection of unstimulated saliva 20 minutes post-consumption for 5 minutes.
7. T3: Collection of unstimulated saliva 30 minutes post-consumption for 5 minutes.

On a separate testing day, participants underwent the same procedure with an additional step: consuming a 4.25 g of chocolate, followed by the ingestion of one raw almond.

Salivary pH was directly estimated using a digital pH meter calibrated with pH 4 and 6.86 buffers at 25°C. The accuracy of the pH meter was regularly checked to ensure precise measurements. A pH-sensitive electrode was immersed in 1 ml of saliva, and the digital reading were recorded once it stabilizes. Between measurements, the electrode was cleaned with a drop of distilled water and placed in a pH 6.86 standard solution to maintain stability and monitor for potential drift.

Salivary pH was measured as soon as possible, but no later than 30 minutes after sample collection. Oral clearance time were estimated based on the time taken for salivary pH to return to baseline levels.

Results

The consumption of chocolate alone resulted in a significant and prolonged drop in salivary pH, with a minimum of 5.2 reached within 10 minutes. In contrast, the combination of chocolate and raw almonds led to a less pronounced pH decline, with a minimum of 5.59 observed at 15 minutes, which remained above the critical pH of 5.5 for hydroxyapatite crystals.

The area under the Stephan Curve was also considerably smaller for subjects consuming the chocolate-almond, indicating a more favorable pH profile and reduced cariogenic potential.

The baseline pH was not reached within 30 minutes in either condition. The time required for pH to return to baseline levels was approximately ~35 minutes for chocolate alone, compared to ~45 minutes for the chocolate-almond combination.

The Stephan Curve graph represents these phases, showing a rapid decline in pH after the intake of cariogenic foods, followed by a recovery period. Tooth demineralization occurs during the critical phase when pH falls below 5.5. Prolonged or frequent exposure to this phase increases the risk of caries as enamel minerals are continuously dissolved without adequate recovery time. By visualizing this process, the Stephan Curve highlights the dynamic relationship between diet, oral pH, and caries risk.

There was no significant difference in baseline salivary pH between the two groups. However, immediately after consumption (T0), the chocolate group exhibited a significantly greater drop in pH compared to the chocolate + raw almond group ($p < 0.001$). This difference remained significant at 5 minutes (T1), favoring the combination group ($p = 0.006$). At 20 minutes (T2), the pH levels in both groups showed recovery and were not statistically different ($p = 0.191$). By 30 minutes (T3), the chocolate group had a significantly higher pH than the combination group ($p = 0.0021$).

In terms of percentage change, the pH drop from baseline to T0 was significantly more pronounced in the chocolate group ($p = 0.0003$). Between T0 and T1, the chocolate group showed a slight increase in pH, while the combination group experienced a further decrease ($p = 0.0026$). From T1 to T2, pH recovery was significantly greater in the chocolate group ($p = 0.0012$). However, the additional increase between T2 and T3 was comparable between groups ($p = 0.161$). (Table 1)

Figure 1 presents the salivary pH changes over a 30-minute period following the consumption of chocolate alone and chocolate combined with raw almonds. The data illustrate the initial drop in pH and the subsequent recovery, highlighting the potential buffering effect of raw almonds. The critical pH threshold (5.5), below which enamel demineralization may occur, is also considered.

Table 1. Changes in measured parameter values (mean values) at different time points for Chocolate and Chocolate + Raw Almond groups.

	Chocolate	Chocolate +Raw Almond	P
Baseline	6.32 ± 0.70	6.71 ± 0.32	0.523
T0	5.16 ± 0.59	6.02 ± 0.49	< 0.001
T1	5.29 ± 0.62	5.65 ± 0.51	0.006
T2	5.99± 0.55	5.79± 0.36	0.191
T3	6.35 ± 0.47	5.97 ± 0.44	0.0021
Δ(T0-Baseline)	-%18.31	-%10.19	0.0003
Δ(T1-T0)	+%2.51 ^b	-%7.24	0.0026
Δ(T2-T1)	+%13.11	+3.77	0.0012
Δ(T3-T2)	+%6.01	+%3.11	0.161

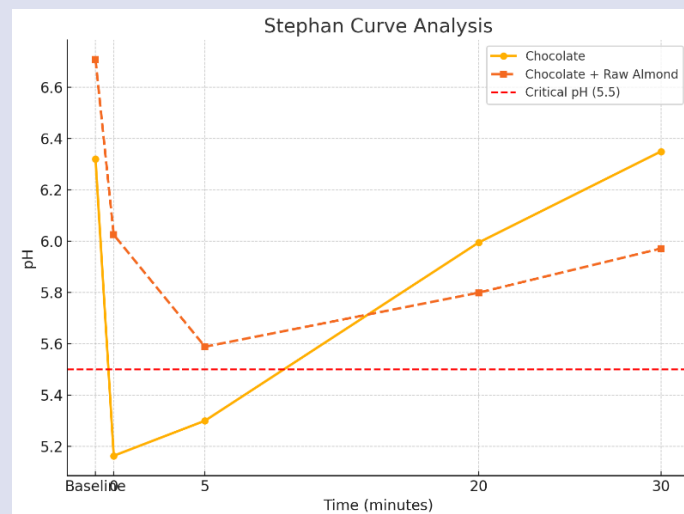


Figure 1. Effect of chocolate and chocolate with raw almond on salivary pH over time

Discussion

This study aimed to evaluate the effect of consuming chocolate alone versus with raw almonds on pH kinetics, focusing on their ability to prevent critical pH drops and their buffering efficiency over time.

The increase in salivary pH may enhance the competitive potential of less harmful oral bacteria, thereby inhibiting the growth of acidophilic bacterial species such as streptococci and lactobacilli.⁹ It can be anticipated that, with a higher pH, less cariogenic bacteria metabolize the available substrates to produce weaker acids, which may contribute to maintaining an elevated pH level.

When cariogenic products are consumed, the initial response of dental plaque is a rapid decrease in pH, often dropping below the critical threshold of 5.5, which is conducive to the demineralization of tooth enamel. For instance, studies have shown that after the consumption of candies, there is a sharp decline in salivary pH within minutes due to the production of organic acids by plaque bacteria metabolizing these sugars.^{10,11} This phenomenon aligns with studies shown a direct correlation between the consumption of fermentable carbohydrates and the acidogenic response of dental plaque.^{12,13}

Chocolate consuming dropped pH 5.2 but pH increased to 5.3 in five minutes and reached above critical pH level in 10 minutes. Moreover this was faster in 30 minutes even to higher pH 6.3 than chocolate and raw almond. Because of either cacao or theobromine which both of them have cariostatic properties, chocolate consumption here, reached to neutral pH even in ten minutes according to Figure 1. Similarly to our study observed a more pronounced decrease in pH in the group consuming chocolate, with post-consumption pH values being lower for chocolate (5.54) compared to milk (5.98).¹¹ Furthermore, König et al. emphasized in their study that the decrease in salivary pH following food consumption is subsequently followed by a pH increase.¹⁴ These results suggest that the chocolate-almond combination creates a more prolonged buffering effect in the oral environment, delaying the return of pH to baseline. The chocolate-almond combination required a longer buffering period (45 minutes vs. 30 minutes for chocolate alone), suggesting that the fat and protein content of almonds may influence the solubility of chocolate, slowing down the salivary neutralization process. The fat content of almonds might also contribute to prolonged food retention on tooth surfaces, further delaying pH recovery.

Moreover, the extent of the pH drop and the duration of the acidic environment can vary based on individual factors such as metabolic conditions. For example, research indicates that diabetic children exhibit a more pronounced acidogenic response compared to their non-diabetic counterparts, suggesting that underlying health conditions can exacerbate the cariogenic potential of dietary sugars.¹⁵ This highlights the importance of considering individual health status when evaluating the effects of cariogenic products on the Stephan curve. The area under the curve (AUC) of the Stephan curve is also a critical metric for

assessing caries risk. A higher AUC indicates a greater cumulative exposure to acidic conditions, which correlates with an increased risk of dental caries.¹⁵ Interventions aimed at reducing the cariogenic potential of diets, such as the inclusion of probiotics, have shown promise in mitigating the acidogenic response, as evidenced by a significant reduction in AUC following probiotic intake.¹⁶ This suggests that dietary modifications can influence the dynamics of the Stephan curve and potentially lower caries risk. In our study, the addition of raw almonds to the diet slowed the decrease in salivary pH and prevented it from dropping below the critical threshold, supporting this perspective.

However, since the minimum pH for the chocolate-almond combination remained at 5.59, staying above the critical pH threshold of 5.5 for hydroxyapatite, this combination may result in less demineralization compared to more acidic conditions. While the pH drop was less pronounced, the prolonged buffering requirement suggests that oral hygiene considerations are still necessary. Therefore, chocolate alone is neutralized more quickly, while the chocolate-almond combination has a longer-lasting effect in the oral cavity. This finding highlights the need for further research to understand the long-term impact of this combination on caries risk.

Studies on the oral clearance of sugary foods and beverages are well-documented.^{17,18} Additionally, research has shown that consuming dairy products accelerates oral clearance.⁶ Dairy products contain substances with natural buffering effects that play a crucial role in maintaining oral health. Milk proteins (casein), calcium, and phosphates can prevent pH drops and neutralize the acidic environment caused by sugary foods more rapidly. While dairy products like cheese and yogurt have the potential to reduce caries risk, they are not always practical to carry and consume during daily activities due to refrigeration requirements. Nuts, such as walnuts and almonds, are portable and practical snacks, but their effects on oral pH changes and Stephan Curve kinetics in conjunction with cariogenic foods have not been thoroughly investigated. While the buffering effects of dairy products are well-known, clinical studies exploring the potential buffering effects of nuts like walnuts and almonds are limited.

The findings of this study support the hypothesis that the inclusion of raw almonds with chocolate can mitigate the adverse effects of the cariogenic food on oral pH dynamics. The alkaline properties and high fiber content of raw almonds appear to counteract the acidogenic response triggered by the fermentable carbohydrates in chocolate, leading to a less severe pH drop that is also resolved more quickly.⁷ The fiber in almonds may help stimulate saliva flow, which can further aid in buffering the pH changes and clearing the oral cavity of residual food particles and acids. Additionally, the alkaline minerals present in almonds, such as calcium and magnesium, can directly neutralize the acidic byproducts of carbohydrate fermentation, helping to maintain a more favorable pH balance.

These results are consistent with previous research on the pH-modulating effects of non-cariogenic foods^{19,20} and the specific buffering potential of nuts.^{21,22} The combination of chocolate and raw almonds may thus represent a practical and readily available approach to reducing the cariogenic risk associated with popular snack choices. By pairing these items, consumers can enjoy cariogenic treats like chocolate while potentially mitigating their adverse impacts on oral health through the buffering and pH-modulating effects provided by the alkaline and fibrous raw almonds.

In a recent study, roasted almonds contained the highest carbohydrate levels, whereas raw almonds had the lowest. Notably, raw almonds have been reported to possess an anti-cariogenic effect, which may be attributed to their low carbohydrate content and the presence of polyphenols that inhibit bacterial adhesion and acid production²³ by cariogenic microorganisms such as *Streptococcus mutans*. The lower carbohydrate content of raw almonds compared to their roasted counterparts may further contribute to their potential role in caries prevention. These findings suggest that roasting may alter the carbohydrate composition of nuts, potentially due to moisture loss and structural changes in macronutrient composition.⁷

Conclusions

The consumption of chocolate with raw almonds resulted in a reduced rate of salivary pH decline, prevented the pH from dropping below the critical threshold, and led to a subsequent increase in pH. However, the basal pH level was not restored within the 30-minute period. These findings support the notion that raw almonds are non-cariogenic and to some extent cariostatic, suggesting that their inclusion in the diet following the consumption of high-carbohydrate sweets and snacks may help reduce the risk of dental caries. Additionally, raw almonds are a convenient dietary option as they require no refrigeration and may serve as a suitable alternative for individuals with intolerance or allergies to dairy products, as well as for vegan individuals.

Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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Authors' Contributions

Design of study: Z.C.C.; Data collection: E.O.T & Z.C.C.; Interpretation of data: Z.C.C. & S.S.O. & E.O.T.; Literature

search: Z.C.C. & E.O.T.; Writing-original draft preparation: Z.C.C.; All authors read and approved the final manuscript.

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Diagnosis of Medication-Related Osteonecrosis of the Jaw and Alternative Treatment Methods

Arzum Yılmaz^{1,a,*}, İlgin Arı^{2,b}, Erçin Samunahmetoğlu^{1,c}, Somayeh Hürmüzlü^{3,d}, Sedat Çetiner^{4,d}

¹Kent Clinic, Cankaya, Ankara, Türkiye.

²Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Hacettepe University, Ankara, Türkiye

³Disvest Polyclinic, Çankaya, Ankara, Türkiye.

⁴Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Gazi University, Ankara, Türkiye

*Corresponding author

Review Article

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ABSTRACT

There is currently no specific evidence regarding the pathogenesis of MRONJ and no definitively accepted treatment. Inhibition of bone remodeling is thought to lead to reduced mechanical damage and the resulting accumulation of areas of bone necrosis. When used in therapeutic doses, bisphosphonates inhibit the resorptive activity of osteoclasts, while stimulating the differentiation and bone deposition of osteoblasts. As a result, the bone regeneration mechanism is impaired and the risk of avascular necrosis increases as a result of decreased bone remodeling. Bone resorption markers type I Collagen (Ctx) C-Terminal Telopeptide, Type I Collagen (NTX) N-Telopeptide, Tetracycline Resistance Acid Phosphatase Isoform 5b (TRACP 5b), Nuclear Receptor Activator (RANKL) / Osteoprotegerin (OPG), Total Alkaline Phosphatase It has been reported that BRONJ is diagnosed by examining (Talp), Bone Specific Alkaline Phosphatase, Bone Sialoprotein, Pyridinoline, Deoxypyridinoline, Hydroxyproline values. CT is considered a standard method in the evaluation of MRONJ. Treatment of medication-induced osteonecrosis of the jaw basically aims to relieve pain, control secondary infection in soft and hard tissues, and minimize the progression of bone necrosis. Alternative treatment methods for MRONJ such as parathormone, platelet-rich plasma, laser applications, ozone treatment, use of bone morphogenic proteins, pentoxifylline, and surgical debridement guided by fluorescent staining method are also mentioned. The drugs that may be alternative to bisphosphonates are Denosumab, Strontium Ranelate (Sr), Teriparatide, Edta, Stromal Vascular Fraction Cells (Svf) but further studies are needed to be accepted as a definitive protocol. Despite the complications of bisphosphonate group drugs, their use is widespread and increasing due to their numerous indications. Informing dentists about the mechanism of bisphosphonate-derived drugs, denosumab and anti-angiogenic drugs the treatment of MRONJ and alternative drugs to these group drugs are important for the management of complications that develop due to these drugs.

Keywords: Bronj, Alternative, Treatment, Current, Necrosis.

Çenelerde İlaçlara Bağlı Gelişen Osteonekroz Teşhisi ve Alternatif Tedavi Yöntemleri

Derleme

Süreç

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ÖZET

MRONJ'nin patogeneziine dair kesin kanıtlar bulunmamaktadır ve genel kabul görmüş bir tedavi yöntemi mevcut değildir. Kemik remodellasyonunun baskılanması, mekanik hasarın azalmasına ve nekrotik kemik alanlarının birikmesine neden olur. Terapötik dozlarda kullanılan bifosfonat türevi ilaçlar, osteoklastların rezorptif aktivitesini inhibe ederken osteoblastların farklılaşmasını ve kemik yapımını da etkiler. Bu durum, kemik yenilenmesini bozar ve azalan kemik remodellasyonu nedeniyle avasküler nekroz riskini artırır. MRONJ tanısında; Tip I Kollajen C-terminal Telopeptid (CTX), N-terminal Telopeptid (NTX), TRACP 5b, RANKL/OPG oranı, Total Alkalen Fosfataz (TALP), Kemik Spesifik Alkalen Fosfataz, Kemik Sialoproteini, Piridinolini, Deoksipiridinolini ve Hidroksiprolin gibi kemik yıkım belirteçleri değerlendirilmektedir. Bilgisayarlı tomografi (BT), MRONJ'nin değerlendirilmesinde standart yöntemlerden biridir. Tedavi ise ağrının giderilmesi, yumuşak ve sert dokulardaki sekonder enfeksiyonun kontrolü ve nekrozun ilerlemesinin önlenmesini hedeflemektedir. Parathormon, PRP, lazer, ozon tedavisi, kemik morfogenetik proteinler, pentoksifilin ve floresan boyama rehberliğinde cerrahi debridman gibi alternatif tedavi yöntemleri araştırılmaktadır. Bifosfonatlara alternatif olabilecek ilaçlar arasında denosumab, stronsiyum ranelat, teriparatid, EDTA ve stromal vasküler fraksiyon hücreleri (SVF) yer almaktadır. Ancak bunların kesin protokol haline gelmesi için daha fazla çalışmaya ihtiyaç vardır. Diş hekimlerinin bu ilaçların etkileri ve olası komplikasyonları konusunda bilgilendirilmesi önemlidir.

Anahtar Kelimeler: Bronj; Alternatif, Tedavi, Güncel, Nekroz.

^a arzymilmaz@gmail.com

^c ercinsa@hotmail.com

^d scetiner@gazi.edu.tr

^b ariilgin@gmail.com

^d somaye.faraji88@gmail.com

^d somaye.faraji88@gmail.com

^b ariilgin@gmail.com

^d somaye.faraji88@gmail.com

^d somaye.faraji88@gmail.com

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Introduction

MRONJ (Medication-Related Osteonecrosis of the Jaw) is a condition that typically arises as a side effect of medications affecting bone metabolism. The drugs that cause MRONJ can be grouped into three main categories:^{1,2}

Bisphosphonates

Bisphosphonates are drugs commonly used for prophylactic or therapeutic purposes during the postmenopausal period. It is known that they increase bone mineral density, reducing bone fractures related to osteoporosis, and prevent mass deformation in the bone due to aging, glucocorticoid use, and the decrease in estrogen.¹

Bisphosphonates are not only preferred for menopause treatment but also for the treatment of fibrous dysplasia, heterotopic ossifications, Paget's disease, ankylosing spondylitis, hypercalcemia due to malignancies, and multiple myeloma.²

Bisphosphonates (BPs) are stable analogs of inorganic pyrophosphate, a by-product of cellular metabolism. Pyrophosphates are easily hydrolyzed and eliminated, but bisphosphonates are resistant to hydrolytic degradation due to the substitution of oxygen with carbon in the bisphosphonate molecule, which explains their accumulation in the bone matrix and their half-life of more than 11 years.³

Currently, there is no specific evidence related to the pathogenesis of MRONJ, and there is no universally accepted treatment. The most widely accepted hypothesis is the effect of bisphosphonates on angiogenesis and the inhibition of normal bone remodeling. It is thought that preventing bone remodeling leads to a decrease in mechanical damage and consequently to the accumulation of bone necrosis areas.^{1,3,4}

Human Monoclonal Antibody (Denosumab):

Denosumabs were started to be used as an alternative to bisphosphonates, but it is reported that in latest studies like bisphosphonates, it can increase the risk of MRONJ, although its effects subside more quickly after discontinuation. Denosumab suppresses osteoclast activity, thereby reducing bone resorption. Denosumab is used to prevent bone loss in conditions such as osteoporosis (Prolia) and metastatic bone diseases (Xgeva).⁵⁻⁷

- Examples: Denosumab (Prolia, Xgeva).

Anti-Angiogenic Drugs:

These drugs are used in cancer treatment to reduce tumor vascularization. They also impair the healing mechanisms of jawbone tissue, thereby increasing the risk of MRONJ.⁸

Examples: Bevacizumab, sunitinib, aflibercept.

Underlying Mechanism

Adequate bone metabolism is ensured by the proper functioning of the osteoblast-osteoclast mechanisms. This mechanism operates through a complex formed by kappa-B ligand (RANKL), osteoprotegerin (OPG), and transforming growth factor β 1 (TGF- β 1).^{3,9} This mechanism can be altered by the application of bisphosphonate derivative drugs. The effects of bisphosphonates on bone metabolism are achieved by inhibiting the osteoclastic activity responsible for bone resorption, but bisphosphonates do not only affect osteoclast cells; they also inhibit osteoblastic activity. They also have antitumor effects, such as preventing tumor invasion and/or inducing apoptosis of tumor cells in the extracellular matrix. Bisphosphonates induce apoptosis in tumoral cells, prevent the passage of tumor cells in the bone to the intercellular matrix, and thus prevent tumor invasion. Their antiangiogenic effects prevent metastasis.^{3,9,10}

When used in therapeutic doses, bisphosphonates inhibit the resorptive activity of osteoclasts, while stimulating the differentiation and bone deposition of osteoblasts.¹¹

However, the use of bisphosphonates in high doses has a cytotoxic effect on both osteoblasts and osteoclasts. As a result, the bone renewal mechanism is disrupted, and the risk of avascular necrosis increases due to reduced bone remodeling. It has been shown in vitro that bisphosphonates disrupt endothelial cell proliferation, adhesion, and migration. When bisphosphonates reach sufficient concentration in the bone, they create a toxic effect in the soft tissue covering the bone surface adjacent to the bone.^{3,10,11}

Bisphosphonates especially bind very easily to hydroxyapatite crystals in areas of active remodeling. They are released from these areas bound on the bone surface and are absorbed by osteoclasts. As a result, the surface properties necessary for osteoclasts to create bone resorption cannot be formed, and osteoclastic activity is suppressed. The most commonly accepted cellular target for bisphosphonates is osteoclasts, and it has been shown that nitrogen-containing bisphosphonates act by inhibiting enzymes of the mevalonate pathway (MVP), a significant regulatory mechanism.^{11,12} The inhibition of specific enzymes of the MVP leads to alterations in protein processing. The inhibition of the farnesyl diphosphate synthase enzyme in the mevalonate pathway by bisphosphonates results in inhibited cell proliferation without causing apoptosis in oral keratinocytes in the epithelium. Consequently, the integrity of the oral mucosa is disrupted, and healing is delayed.¹¹⁻¹³

The effect of Anti-Angiogenic Drugs on bone metabolism is as follows:

Anti-angiogenic drugs work by inhibiting angiogenesis (the formation of new blood vessels) that supply blood to tumors. These drugs typically target VEGF (Vascular Endothelial Growth Factor) or its receptors.^{8,14}

VEGF supports blood vessel formation and circulation, and it plays a critical role in bone healing by regulating the function of osteoblasts (bone-forming cells) and osteoclasts. By suppressing VEGF, these drugs reduce blood flow and nutrient delivery to bone tissue, impairing bone healing. This can lead to reduced microvascularization in the jawbone and an increased risk of necrosis.^{7,8,14}

Anti-angiogenic drugs are used in cancer treatment (e.g., solid tumors) to inhibit tumor growth and metastasis.

- Examples: Bevacizumab, Sunitinib, Pazopanib.

Classification of Bisphosphonates

Bisphosphonates are classified based on whether they contain nitrogen and their route of oral or intravenous administration: Non-nitrogenous bisphosphonates, also known as first-generation bisphosphonates, are the oldest bisphosphonates. They have short R2 chains. When they reach the bone tissue, they are captured by osteoclasts and exhibit their effects in this way. They are metabolized very quickly in the body.^{15,16} Nitrogen-containing bisphosphonates (aminobisphosphonates) have long R2 chains that contain nitrogen. They exhibit a much stronger anti-resorptive effect than non-nitrogenous bisphosphonates. They exhibit their anti-resorptive effects through the mevalonate pathway.¹⁵⁻¹⁷

Non-nitrogenous bisphosphonates and their trade names include: Etidronate (Didronel®, Osteum®), Tiludronate (Skelid®), Clodronate, etc.

Those administered intravenous bisphosphonates have a stronger and more prolonged effect compared to those taken orally and are used to stabilize bone remnants in metastatic cancers, treat bone resorption defects in multiple myeloma, and treat severe hypercalcemia.¹⁵⁻¹⁷

Nitrogen-containing bisphosphonates and their trade names include: Alendronate (Fosamax®), Zoledronate (Zometa®), Ibandronate (Boniva®, Roche), Risedronate (Actonel®, Acrel®), Pamidronate (Aredia®), etc.

Didronel (Etidronate): the first bisphosphonate marketed, does not contain nitrogen, is taken orally, and is the least effective in its group, considered an anti-mineralization bisphosphonate. It is used to treat hypertrophic calcification following bone injury and to limit excessive bone formation in Paget's disease.

Fosamax (Alendronate): taken orally, contains nitrogen, and is the most frequently used drug in the treatment of osteopenia and osteoporosis.

Actonel (Risedronate): taken orally, contains nitrogen, and is the second drug prescribed in the treatment of osteopenia and osteoporosis. Both of these drugs have a half-life in the bone of more than 11 years.

Boniva (Ibandronate): a nitrogen-containing bisphosphonate.

Zometa (Zoledronate): a more potent IV bisphosphonate.¹⁵⁻¹⁷

Bisphosphonates accumulate at a high rate in bones with a high capacity for renewal, such as alveolar bone, and in soft tissues adjacent to bones. The inability to

create an aseptic environment due to the oral cavity's wide microflora and its susceptibility to trauma increases the risk of osteonecrosis in the jawbones. Previously, BRONJ was only associated with the jaws, but recent studies have reported cases of femur fractures due to long-term use of bisphosphonate derivative drugs. For a patient to be diagnosed with bisphosphonate-related osteonecrosis, the following criteria must be met.^{13,16-18}

1. Past or current treatment with oral or IV bisphosphonates;
2. Presence of exposed, necrotic bone in the maxillofacial region for more than 8 weeks;
3. No radiation therapy applied to the jawbones.

Clinical Findings

Regarding the clinical findings, osteonecrosis of the jaws starts in the alveolar bone and progresses to the basal bone. It can present early subclinical signs such as sclerosis of the lamina dura, loss of lamina dura, and expansion of the periodontal gap. Sclerosis of the lamina dura is the first harbinger of metabolic bone changes. In the clinical examination of patients who develop osteonecrosis due to bisphosphonate use, significant findings include necrosis of the alveolar bone, which can be observed along with foul-smelling discharge.^{13,17}

Patients generally complain of severe local pain, discharge, and tooth loss, accompanied by soft tissue swelling. Differential diagnosis includes chronic sclerosing osteomyelitis, metastatic tumors, multiple myeloma, traumatic lesions, Paget's disease, and osteoradionecrosis.^{13,15,17}

The most common local predisposing factor for osteonecrosis is tooth extraction, with 52-61% of patients reporting tooth extraction due to periodontal or periapical infection. It has been observed that tooth extraction is a predisposing local factor in 69% of cases, followed by denture use (9.3%), implant placement (4.9%), and spontaneous development or unknown reasons (3.8%). It is known that osteonecrosis occurs more frequently in the mandible (74.3%) than in the maxilla (16.4%). However, a few reported cases have involved both jaws.^{4,13,17}

Diagnosis

One of the possible etiologies of MRONJ is destructive bone remodeling triggered by an imbalance between bone resorption and bone formation. Therefore, the diagnosis of MRONJ has been reported through the examination of bone destruction markers such as Type I Collagen (Ctx) C-Terminal Telopeptide, Type I Collagen (NTX) N-Telopeptide, Tartrate-Resistant Acid Phosphatase Isoform 5b (TRACP 5b), Nuclear Receptor Activator (RANKL) / Osteoprotegerin (OPG), Total Alkaline Phosphatase (Talp), Bone-Specific Alkaline Phosphatase, Bone Sialoprotein, Pyridinoline, Deoxypyridinoline, Hydroxyproline values. Valuable markers for diagnosis include^{13,18} :

- CTX
- NTX

- TRACP 5b
- RANKL/OPG
- ALP
- Bone sialoprotein
- Pyridinoline
- Deoxypyridinoline
- Hydroxyproline
- Serum Osteocalcin (s-OC)

s-OC (serum osteocalcin) is a biochemical marker of bone formation, and s-CTX is a marker of bone resorption. The assessment of s-CTX is a tool to evaluate the status of anti-resorptive treatment. s-OC measures the function of bone remodeling, thus contributing to the risk assessment

for MRONJ.¹⁸ For s-CTX value, having it above 150 is considered safe for us.

The importance of CTX in determining risk factors:

Serum CTX value can identify changes in bone remodeling and renewal from a few days to 2 weeks. CTX measures the serum level of the C-terminal telopeptide fragment of the type 1 collagen counterchain. The CTX test is not valid in cancer patients because the cancer itself leads to collagen degradation, resulting in higher than normal results.^{4,18} Additionally, in rheumatologic diseases like Rheumatoid Arthritis, Systemic Lupus Erythematosus, Dermatomyositis, the use of steroids results in inhibited collagen synthesis, leading to falsely low results.¹⁸ Similarly, in patients using methotrexate, it negatively affects bone marrow cells, showing a low CTX level.^{4,18} (Table 2)

Table 2: C-terminal cross-linked telopeptide (ctx) values.⁴

C-TERMINAL CROSS-LINKED TELOPEPTIDE (CTX) VALUE	RISK OF OSTEONECROSIS
≥ 150 pg/mL	NONE
126-149 pg/mL	MINIMAL
100-125 pg/mL	MODERATE
<100 pg/mL	HIGH

The Role of Mi-RNA in Diagnosis:

Recently, a new approach has been proposed to diagnose diseases using circulating microRNAs in body fluids, which have specificity and stability. The diagnostic performances of circulating microRNAs have been validated in many diseases, including cancers, heart diseases, and osteoporosis.^{18,19} In a study, Yang and colleagues investigated whether microRNA could be a biomarker for the detection of MRONJ. They obtained total RNAs of circulating lymphocytes for microRNA analysis from healthy individuals and patients with BRONJ. It has been revealed that most subtypes of microRNAs regulate bone metabolism and affect bone remodeling, suggesting that microRNA could influence specific regulations related to osteoblastogenesis and osteoclastogenesis in MRONJ. In the current study, they evaluated 7 types of circulating microRNA and found significant differences in three of them (miR-21, miR-23a, and miR-145) between the control and MRONJ groups. These three microRNAs have been identified to play a role in the onset and development of MRONJ.¹⁹ The study observed an increase in serum miR-21, miR-23a, and a decrease in serum miR-145 in MRONJ cases. A varying microRNA expression profile in numerous patients with MRONJ was identified, and post-transcriptional regulation could be important for the development of MRONJ, but circulating microRNAs have not yet been accepted as a direct method for MRONJ diagnosis.¹⁹

Radiological Findings

Common imaging methods to assess MRONJ include panoramic radiography (PR), Computed Tomography (CT), MRI, and Bone Scintigraphy. Compared to panoramic films, computed tomography has a significant advantage in morphological assessment and determining the extent of jaw osteonecrosis.^{8,20}

CT is considered the standard method for evaluating MRONJ. However, the CT imaging findings of MRONJ are not specific and may resemble those of ordinary osteomyelitis of the jaw.^{8,12}

In both osteomyelitis and MRONJ, findings often include sequestrum, periosteal reaction, cortical perforation, or soft tissue swelling, sometimes appearing as lytic or sclerotic lesions. Other conditions that are difficult to distinguish from MRONJ include osteoradionecrosis, cancer metastasis, and Paget's disease. Although MRI can provide supportive information for diagnosis, this method is not universally available. Conventional dental radiographs help in detecting osteosclerotic, osteolytic, reactive periosteal mixed lesions, and pathological fractures. Bone scintigraphies are among the best screening methods for MRONJ.^{8,20}

Treatment Methods

The treatment of medication-related osteonecrosis of the jaw (MRONJ) primarily aims to alleviate pain, control secondary infection in soft and hard tissues, and minimize the progression of bone necrosis. MRONJ treatments are classified into surgical and non-surgical options.²¹ Non-surgical treatments include the use of systemic antibiotics and oral antiseptics, variable hyperbaric oxygen therapy, low-level laser therapy, and medical ozone applications.^{21,22} Surgical treatments suggested in the literature are more aggressive treatments such as bone debridement, sequestrectomy, or resections of affected bone and jawbone.²² The treatment of jaw osteonecrosis related to bisphosphonates fundamentally aims to:

- alleviate pain,
- control secondary infection in soft and hard tissues,
- minimize the progression of bone necrosis.^{4,21,22}

In the guidelines published by the American Association of Oral and Maxillofacial Surgeons (AAOMS) in 2022 for cases related to osteonecrosis of jaws, cases are classified according to risk categories, and treatment approaches suitable for these classifications are determined.¹⁴ (Table 1) In the treatment of MRONJ, a combination of penicillin-

based antibiotics and β -lactamase inhibitor is considered the most ideal treatment.²³

Typically, areas of necrosis are colonized by anaerobic and facultative anaerobic gram-positive and gram-negative bacteria. The most common group of bacteria found in MRONJ-affected areas is Actinomyces, and many types of bacteria and fungi found in oral flora, such as Fusobacterium, Bacillus, Staphylococcus, Streptococcus, Selenomonas, Spirochetes, and Candida, also colonize the area.²⁴

Patients with medication-related osteonecrosis of the jaw use generally present to the clinic at Stage 2. Medical treatment should be initiated primarily. To prevent pain, osteomyelitis, and the development of secondary infections, (Penicillin V, Amoxicillin, Quinolones+Metronidazole combination, Erythromycin+Metronidazole combinations) and oral antiseptic solutions (0.12% Chlorhexidine Gluconate) should be used.

Penicillin or second-generation cephalosporins, chlorhexidine mouth rinses, periodic minor debridement, and regular lavage of the wound site form the basis of the

treatment. Clindamycin alone is not effective due to its insufficient effect on Actinomyces and Eikenella and similar microorganisms found in the exposed bone.^{23,24}

Sensitivities to antibiotics in the MRONJ-affected area are listed as 98% for moxifloxacin, 96% for amoxicillin-clavulanic acid, 85% for levofloxacin, 67% for penicillin, and 60% for clindamycin. Antibiotic treatment for MRONJ serves two purposes²³:

- Infection Control
- Perioperative Application

Current guidelines related to antibiotic prophylaxis in surgery recommend stopping prophylaxis 24 hours after wound closure. In a study conducted by Akashi and colleagues in 2018, the benefit of preoperative antibiotic use in MRONJ treatment was investigated, and the study found no difference in the risk of wound infection when comparing 1 day to 5 days of systemic antibiotic prophylaxis.²³

Table 1: The clinical features and treatment options of medication related osteonecrosis of jaws.¹⁴

STAGE	CLINICAL	TREATMENT
Patients at Risk	Cases using bisphosphonates orally or IV without necrotic exposed bone	No treatment required. Patient information.
Stage 0	Cases without clinical evidence of necrotic bone, showing non-specific clinical symptoms and findings	Systemic treatment with analgesics and antibiotics.
Stage 1	Cases with asymptomatic necrotic bone exposure without signs of infection	Antibacterial mouth rinse, clinical monitoring, patient education.
Stage 2	Cases with exposed bone area showing signs of infection such as pain and erythema, with or without purulent drainage	Systemic treatment with oral antibiotics, antibacterial mouth rinse, pain control, superficial debridement to prevent soft tissue irritation.
Stage 3	Cases with pain and infections, with exposed necrotic bone tissue progressing from alveolar bone to the lower border or ramus in the mandible, or to the maxillary sinus or zygomatic bone in the maxilla, resulting in pathological fractures, presence of extraoral fistula, osteolysis reaching to the lower border of the mandible or base of the maxillary sinus due to the formation of oro-antral or oro-nasal connections	Systemic treatment with oral antibiotics, antibacterial mouth rinse, pain control, surgical debridement to alleviate infection and pain.

Alternative Treatment Methods

Alternative treatment methods for MRONJ include the use of parathyroid hormone, platelet-rich plasma, laser applications, ozone therapy, the use of bone morphogenetic proteins, pentoxifylline, and surgical debridement guided by fluorescent staining method.^{8,25,26}

Prp and Growth Factors

Autologous platelet concentrates such as platelet-rich plasma (PRP) are increasingly applied in oral surgery as a new approach to tissue regeneration because they release high amounts of growth factors such as platelet-derived growth factor (PDGF), vascular endothelial growth factors (VEGF), and transforming growth factor-beta (TGF- β). They play a role in the healing of hard and soft tissues by stimulating mitogenesis, chemotaxis, and the production of fibronectin. High levels of Vascular Endothelial Growth Factor in wound sockets improve the formation of bone matrix and stimulate neoangiogenesis. Transforming Growth Factor-beta

stimulates fibroblast chemotaxis, stimulates the proliferation of gingival fibroblast cells, and produces fibronectin and collagen to repair connective tissues and regenerate bones. PRP accelerates epithelial wound healing, reduces tissue inflammation, speeds up the healing of bone and soft tissues, and promotes tissue vascularization. Considering these benefits, PRP will be effective in releasing growth factors in MRONJ patients and stimulating bone healing and neoangiogenesis, usually suppressed by BPs. Additionally, being an autologous product, PRP is biocompatible and safe, easy to use, and rich in growth factors.²⁷

Laser

Several clinical studies have shown promising results for the treatment of MRONJ with ER: Yag laser therapy. The use of ER, Cr: YSGG laser eliminates thermal effects on and around the incision areas during surgery, provides antibacterial and biostimulative effects, reduces postoperative pain, and promotes tissue healing. The

contactless cutting by the laser prevents mechanical trauma caused by friction, thus preventing the prolongation of the healing process. The Er:Yag laser creates microcracks and microplosions, allowing the removal of necrotic tissue without exposing surrounding healthy tissues to any contamination, thus ensuring complete healing for both soft and hard tissues.^{28,29} The use of the Er, Cr: YSGG laser has great potential in hard tissue surgery, allowing for effective resection of the maxilla without conventional rotary tools because the laser produces clear and precise cuts with minimal injury to hard and soft tissues. A study found that the combination of Er, Cr: YSGG laser and PRP application enhanced both bone and mucosal healing, with an 80% success rate in MRONJ patients undergoing conservative surgical treatment. The combination of low-level laser therapy (LLLT) with traditional surgical approaches is recommended to biologically stimulate tissue healing.^{28,29}

Hyperbaric Oxygen

The angiogenic effect of HBO (Hyperbaric Oxygen) therapy is known. It has been suggested that reducing the anaerobic environment could induce neovascularization. Preliminary studies examining the effectiveness of hyperbaric oxygen therapy in addition to surgical treatment have initially shown that hyperbaric oxygen therapy improves wound healing and long-term pain scores. Recent studies have confirmed the definitive role of HBO therapy in the treatment and prevention of osteoradionecrosis in jawbones, though its utility in BON cases has not been proven. The pathophysiological mechanisms of osteoradionecrosis and bisphosphonate-related jaw osteonecrosis are entirely different. In osteoradionecrosis, the radiation-affected area is hypoxic. In ORN, capillaries die in the radiation-affected area due to a hypocellular effect, while in bisphosphonate-related jaw osteonecrosis, capillaries die secondarily to bone death, and it has been reported that there is no lack of oxygenation in the necrosis area and the simple treatment mechanism of HBO does not work. Additionally, HBO treatment indications may not always be given in oncology patients.³⁰

Ozone

In pathologies related to avascular necrosis, it demonstrates its effect through the following mechanisms:

- By stimulating the endogenous antioxidant system,
- By activating blood flow, red blood cells (erythrocytes), and hemoglobin concentration; it increases diapedesis and phagocytosis.
- It acts as a bactericidal agent and stimulates all biological reactions, especially the tissue oxygenation process, as well as calcium, phosphorus, and iron metabolism.³¹
- To enhance the effectiveness of ozone therapy, antimicrobial therapy, namely beta-lactam group antibiotics and antifungal drugs, is required alongside non-invasive surgical interventions.³¹

Alternatives to Bisphosphonates

Denosumab

Denosumab is a human monoclonal antibody (IgG2) that acts by inhibiting the "Receptor activator of nuclear factor kappa-B ligand (RANKL)." Osteoclast-like giant cells contain RANK. Denosumab inhibits the RANK-RANKL interaction, the main driver of osteoclast activity, thereby preventing osteoclast maturation and reducing osteoclast-induced bone destruction.^{29,30} It decreases the risk of fractures by reducing the differentiation of bone matrix cells into mature osteoclasts, osteoclast function, and the lifespan of osteoclasts. It is a stronger osteoclast inhibitor than bisphosphonates, has a shorter half-life, and is eliminated from the body a little over 6 months. Due to its relatively short effect duration, it has been used in the treatment of giant cell tumors in growing children, especially in long bones. No effects on epiphyseal or metaphyseal bone growth have been reported yet. In recent studies it is reported that denosumab suppresses osteoclast activity, reducing bone resorption and increasing bone density. However, in areas with high bone turnover, such as the jawbone, this inhibition can impair bone healing, increasing the risk of MRONJ. However, its long-term effects are still unknown.^{31,32}

In postmenopausal osteoporosis, the combination of denosumab and teriparatide results in a greater increase in bone mineral density in the hip and spine compared to monotherapy.³³

Strontium ranelate (sr)

It is suggested as an anti-osteoporosis medication due to its dual effect on bone metabolism. In vitro studies have shown that SR acts by increasing the level of osteoprotegerin and decreasing the level of kappa-b ligand receptor. It is claimed to have effects on promoting bone formation and inhibiting bone resorption. Additionally, SR has been shown to have beneficial effects on both cortical and trabecular bone. A case report published by Pan and colleagues in 2017 demonstrated that Strontium Ranelate supports bone formation by stimulating the differentiation of osteoblasts and blocks bone resorption by inhibiting osteoclast differentiation. However, there is insufficient research to definitively consider it as an alternative to BP.³⁴

Teriparatide

Teriparatide is a synthetic polypeptide hormone containing the amino acid fragment 1-34 of the recombinant human parathyroid hormone, i.e., a parathyroid hormone analog. Teriparatide (parathyroid hormone analog) is the only medication shown to stimulate bone formation and potentially reverse osteoporosis to some degree. Teriparatide is recommended only for patients at high risk of fractures who cannot tolerate other medications. Although PTH is considered catabolic because it releases calcium from bone, low doses of teriparatide directly stimulate bone formation by osteoblasts.³⁵

Recently, teriparatide has been approved for the management of osteoporosis and has accelerated the healing of vertebral and long bone fractures. Unlike

bisphosphonates, which prevent bone mineral loss from bone tissue, intermittent treatment with teriparatide is well known to activate bone remodeling. It is claimed that teriparatide's enhanced remodeling and bone formation capability facilitate the healing and removal of necrotic or exposed bone. A study investigated whether short-term teriparatide and recombinant bone morphogenetic protein could enhance suppressed bone formation capacity. Recombinant human BMPs are an activation factor for bone repair, now more readily available in larger quantities due to the advent of recombinant DNA technology. The study's results showed significant increases in S-CTX and s-OC levels after treatment with rhBMP-2 and teriparatide, suggesting it could maximize bone regeneration in BRONJ patients and be considered an additional treatment method, potentially shifting treatment from resective to regenerative.³⁵

However, teriparatide is contraindicated for patients with hypercalcemic disorders, osteosarcoma, metastatic bone disease, Paget's disease, pregnancy, and those receiving radiation therapy to the skeleton or soft tissue, and those with severe kidney or liver failure.^{35,36}

When discussing alternatives to bisphosphonate derivative drugs, it is also necessary to mention EDTA and SVF from studies conducted on animals but not yet approved for use in humans.

Ethylenediaminetetraacetic acid (EDTA)

Ethylenediaminetetraacetic acid (EDTA) is widely used in medical applications as well as in dentistry. It is FDA-approved and regularly used worldwide to treat heavy metal poisonings in patients. In dentistry, it is routinely used to improve the smear layer, root canal treatment, and root surface during periodontal treatments; 17% EDTA is the most commonly used concentration in clinical dentistry and dental research. A study investigated whether ex-vivo EDTA decalcification would significantly reduce the bisphosphonate content in bone. Since EDTA's affinity for Ca ions is greater than that of the bisphosphonate group drug, it has been shown that EDTA binds to Ca in bone, inhibiting the formation of indigestible BP-Ca complexes. Additionally, adding EDTA to oral bisphosphonates has been shown to increase their bioavailability in the gastrointestinal (GI) system due to competitive EDTA-Ca chelation, thus reporting that it could reduce the binding of bisphosphonates to osteoclasts, preserving the normal function of osteoclasts.³⁷

Stromal Vascular Fraction Cells (Svf)

Stromal Vascular Fraction (SVF) cells are mesenchymal stem cells derived from adipose tissue. A study conducted in Japan in 2017 investigated the transplantation effects of stromal vascular fraction cells on bone and soft tissue wound healing in tooth extraction sockets in mice treated with chemotherapeutic bisphosphonate combination therapy.³⁸ Although bone marrow stem cell therapy has been shown to reduce MRONJ-like lesions in mice, the approval of stem cell therapy for MRONJ is strictly limited

due to various issues. The study showed that treatment with stromal vascular fraction (SVF) cells significantly increased blood vessel and vascular surface area, accelerating bone and soft tissue wound healing in tooth extraction sockets. Systemic transplantation of uncultured Stromal Vascular Fraction cells has been shown to reduce MRONJ-like lesions induced by tooth extraction in mice treated with bisphosphonates. Therefore, SVF therapy has been reported as a potentially more suitable treatment strategy for MRONJ.³⁸

Conclusions

Despite the complications associated with bisphosphonate group drugs, their use is widespread and increasing due to their numerous indications. Although there are many studies investigating the changes these drugs create in hard and soft tissues aimed at preventing osteonecrosis, which is of great interest to dentistry and difficult to treat, the pathogenesis has not yet been fully explained. The development of alternative drugs is promising for the management of MRONJ, but further studies are needed for regular use indications. Informing physicians about the mechanism of bisphosphonate derivative drugs, anti-angiogenic drugs and denosumab the treatment of MRONJ and alternative drugs to these groups are important for managing the complications associated with these drugs.

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Conflicts of Interest Statement

There is no conflict of interest between the authors.

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Mapping The Scientific Landscape Of Bruxism: A Comprehensive Bibliometric Analysis

Mansur Doğan^{1,a,*}

¹Department of Otorhinolaryngology, Faculty of Medicine, Sivas Cumhuriyet University, Sivas, Türkiye.

*Corresponding author

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ABSTRACT

Objectives: Bruxism is a jaw muscle activity defined as teeth clenching or grinding that can be seen both while awake and asleep. The central nervous system, autonomic nervous system, genetic factors and comorbidities play a role in its etiology. In recent years, a great deal of research has been conducted on bruxism.

Materials and Methods: In this study, 1,278 articles searched with the keyword "bruxism" in the Web of Science (WoS) database were subjected to bibliometric analysis. Publication trends, citation analyses and keyword clusters were examined using VOSviewer software.

Results: Bruxism research has increased since the 2000s and accelerated after 2013. By 2024, the annual number of publications reached 125. The Most Cited Study Lobbezoo et al. (2013, 2018) – International consensus reports on the definition and classification of bruxism. Thematic Clusters; Blue Cluster: Neurophysiological mechanisms and sleep bruxism, Yellow Cluster: Terminology and classification (Lobbezoo's consensus studies), Red Cluster: Pediatric bruxism and upper airway obstruction (snoring, mouth breathing), Green Cluster: Studies addressing ethical and legal dimensions.

Conclusions: Bruxism is a disorder that requires a multidisciplinary approach (neurology, dentistry, sleep medicine, pediatrics). Both the causes and effects of bruxism impact many individuals. A detailed analysis of the top ten most cited publications reveals a primary focus on three main themes: (1) diagnostic and classification systems, (2) neurophysiological foundations and diagnostic methods, and (3) epidemiological risk factors and prevalence studies. Future studies should focus on interdisciplinary collaboration and digital diagnostic methods. The identification of dominant themes in the literature and the identification of subfields that are not yet sufficiently represented make our study original. This study provides a quantitative map of the bruxism literature and provides a guiding resource for future research.

Keywords: Bruxism, Bibliometric Analysis, VOSviewer, Scientific Literature Mapping, Thematic Clustering.

Bruksizmin Bilimsel Görünümünün Haritalanması: Kapsamlı Bibliyometrik Analiz

Araştırma Makalesi

Süreç

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ÖZET

Amaç: Bruksizm, diş sıkma veya gıcırdatma olarak tanımlanan hem uyanıkken hem de uykuda görülebilen bir çene kası aktivitesidir. Etiyolojisinde merkezi sinir sistemi, otonom sinir sistemi, genetik faktörler ve komorbiditeler rol oynar. Son yıllarda bruksizm hakkında oldukça fazla araştırma yapılmaktadır.

Gereç ve Yöntemler: Bu çalışmada, Web of Science (WoS) veri tabanında "bruxism" anahtar kelimesiyle taranan 1.278 makale bibliyometrik analize tabi tutulmuştur. VOSviewer yazılımı kullanılarak yayın eğilimleri, atıf analizleri ve anahtar kelime kümelenmeleri incelenmiştir.

Bulgular: Bruksizm araştırmaları 2000'lerden itibaren artış göstermiş, 2013 sonrasında hızlanmıştır. 2024'e kadar yıllık yayın sayısı 125'e ulaşmıştır. En Çok Atıf Alan Çalışma Lobbezoo ve ark. (2013, 2018) – Bruksizmin tanımı ve sınıflandırılmasına dair uluslararası uzlaşma raporları olmuştur. Bruksizm ile ilgili yazılar her yıl düzenli bir şekilde artış göstermiş ve 2024 yılında 125 makale ile zirve yapmıştır. Tematik Kümelenmeler de Mavi Küme: Nörofizyolojik mekanizmalar ve uyku bruksizmi, Sarı Küme: Terminoloji ve sınıflandırma (Lobbezoo'nun uzlaşma çalışmaları), Kırmızı Küme: Pediatrik bruksizm ve üst solunum yolu tıkanıklığı (horlama, ağız solunumu), Yeşil Küme: Etik ve hukuki boyutları ele alan çalışmalardan oluşmaktadır.

Sonuçlar: Bruksizm multidisipliner bir yaklaşım gerektiren (nöroloji, diş hekimliği, uyku tıbbı, pediatri) bir rahatsızlıktır. Sebepleri gibi sonuçları da birçok insanı etkilemektedir. En çok atıf alan ilk on yayın detaylı analizi edildiğinde; (1) tanı ve sınıflandırma sistemleri, (2) nörofizyolojik temeller ve tanı yöntemleri, (3) epidemiyolojik risk faktörleri ve prevalans çalışmaları gibi temel olarak üç ana temaya yoğunlaşmaktadır. Gelecek çalışmalar, disiplinler arası iş birliği ve dijital tanı yöntemleri üzerine odaklanmalıdır. Literatürde hâkim olan temaların belirlenmesi ve henüz yeterince temsil edilmeyen alt alanların tespit edilmesi, bizim çalışmamızı özgün kılmaktadır. Bu çalışma, bruksizm literatürünün niceliksel bir haritasını sunarak gelecek araştırmalara yol gösterici bir kaynak sağlamaktadır.

Anahtar Kelimeler: Bruksizm, Bibliyometrik Analiz, VOSviewer, Bilimsel Literatür Haritalama, Tematik Kümeleme.



mansurdogan@hotmail.com



0000-0002-3964-9363

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Introduction

Bruxism is a jaw muscle activity that can be seen both in wakefulness and sleep, characterized by involuntary clenching or grinding of the teeth. There are many factors that trigger bruxism. In recent years, significant research has been conducted on the neurophysiological basis of sleep bruxism, its etiological factors in childhood and related to the upper respiratory tract, its conceptual framework and ethical-legal dimensions. Bruxism is defined as the clenching, grinding or pushing/stretching of the lower jaw with repetitive jaw muscle activity. Sleep and wake bruxism are considered as two separate conditions with different pathophysiologies; however, they may overlap in some individuals. The definition and causes of sleep bruxism have changed over time, and rather than peripheral factors (e.g. dental occlusion), the central nervous system and autonomic nervous system, genetics and comorbidities have come to the fore. There is strong evidence that dental occlusion is not the main cause of bruxism.¹⁻³

Sleep bruxism is closely related to the central nervous system and the autonomic nervous system. In particular, structures such as the mesencephalic trigeminal nucleus (MTN) and ARAS (ascending reticular activating system) in the brainstem play a role. Bruxism during sleep is accompanied by activation in brain, heart and respiratory functions. It is suggested that bruxism is not a parafunction but a function that activates the ARAS nuclei.^{1,4,5}

The prevalence of bruxism in children varies between 5% and 50%. Sleep disorders have been associated with snoring, headache, jaw muscle fatigue, and tooth wear. Sleep-related breathing disorders (e.g., obstructive sleep apnea, mouth breathing, allergies) are important risk factors. A significant relationship has been shown between bruxism and sleep-disordered breathing in children, but causality is not clear.⁶⁻¹⁰

Ethical and legal responsibilities are important in the diagnosis and treatment of bruxism. Especially in children, correct diagnosis, parental information, determination of possible comorbidities, and selection of appropriate treatment approaches are necessary. It is recommended that clinical guidelines be developed and ethical principles be observed in treatment processes.⁷

Bruxism is a multifactorial and complex condition and is associated with the central nervous system and autonomic mechanisms. Dental problems are one of the most important causes of bruxism. Upper respiratory tract disorders are important risk factors in children. Ethical and legal responsibilities should be taken into consideration in diagnosis, treatment and management. Research on the conceptual framework and mechanisms of bruxism is ongoing. In this publication, we have created a bibliometric map of publications on bruxism. We believe that past publications can guide future publications.

Materials and Methods

Bibliometric analysis is a quantitative research method that enables the systematic examination of the structural characteristics, developmental trends, and knowledge flow within scientific literature.¹¹⁻¹³ In this study, a comprehensive bibliometric analysis was conducted to map the current landscape of scholarly publications on bruxism, identify leading contributors in the field, and reveal the thematic structure of the related literature.

The analysis followed a structured process in accordance with standard procedures typically employed in bibliometric research. In the initial stage, the primary research question guiding this study was formulated as follows: *“What is the current state of academic research on bruxism, and how are the thematic trends distributed across the literature?”* To address this question, a systematic review of the relevant scientific literature was performed.

The Web of Science (WoS) database was selected as the primary source for data collection due to its comprehensive coverage and high-quality indexing, particularly in fields such as health sciences and dentistry.¹⁴ A focused search strategy was then developed: the keyword “bruxism” was used exclusively within the title field, and filters were applied to include only articles, exclude publications from the year 2025, and limit results to those written in English. As a result, a total of 1,278 articles were included in the final dataset.

During the data extraction phase, bibliographic records obtained from WoS were imported into the EndNote reference management software, and duplicate entries were removed to ensure data consistency. Subsequently, key bibliometric variables such as author name(s), year of publication, journal title, number of citations, document type, and author keywords were extracted and organized for analysis.

For data visualization, the software VOSviewer—a widely used tool in bibliometric research—was employed. VOSviewer facilitates the creation of visual maps that depict relationships among authors, publications, and keywords, thereby offering valuable insights into the structural dynamics and thematic clustering within the field.¹⁵

In the final stage, the findings were systematically interpreted to identify not only the prevailing research trends but also gaps in the literature and promising directions for future inquiry. Accordingly, the bibliometric analysis presented in this study not only provides a quantitative overview of the bruxism literature but also contributes foundational knowledge to guide subsequent research strategies and agenda-setting in the field.

Results

This section presents the findings of the bibliometric analysis conducted in the field of bruxism. The primary aim of the analysis is to quantitatively assess the current state of scientific output within this domain, identify the most influential publications and authors, uncover

thematic clusters, and map the structural characteristics of the literature. The findings are organized under several key subheadings, including annual publication trends, most-cited articles, keyword co-occurrence analysis, and thematic clustering.

During the data collection phase, a focused search was conducted in the Web of Science (WoS) database using the keyword “bruxism” within the title field. The search was refined to include only article-type publications, exclude those published in the year 2025, and limit the results to those written in English. Following this filtering process, a total of 1,278 articles published between 1971 and 2024 were included in the analysis.

The bibliometric evaluation of this dataset yielded insights into the historical trajectory of research in the field, the degree of interdisciplinary collaboration, and the evolving priorities within bruxism scholarship. Examining the annual distribution of academic output is particularly critical for understanding the developmental dynamics of the field.

Accordingly, the number of publications on bruxism was analyzed by year, offering a quantitative overview of the field’s scientific evolution. The corresponding results are presented in Figure 1.

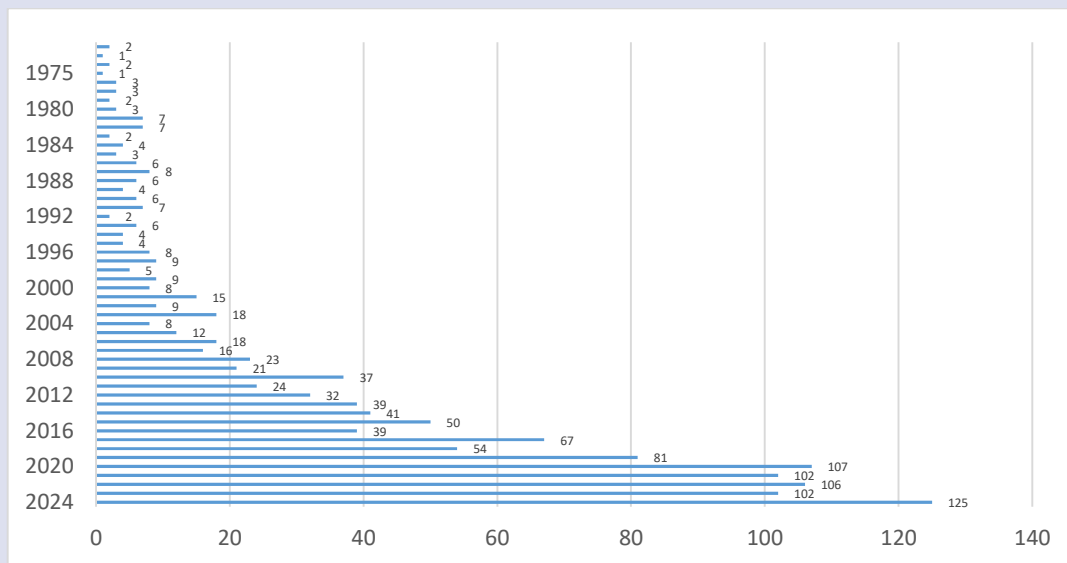


Figure 1. Annual distribution of publications on bruxism (1971–2024)

As part of the study, a total of 1,278 articles retrieved from the Web of Science (WoS) database—filtered to include only those containing the keyword “bruxism” in the title field and classified strictly as article-type publications—were analyzed in terms of their annual distribution. This time series analysis, covering the period from 1971 to 2024, illustrates the historical progression of scholarly interest in the topic of bruxism.

The earliest identified publication dates back to 1971, with a notably low volume of research output throughout the 1970s and 1980s. During this early period, the number of annual publications generally ranged between 1 and 8, suggesting that bruxism had not yet emerged as a prominent topic of academic inquiry. Until the late 1990s, the field experienced little growth in research activity. However, beginning in the early 2000s, there was a gradual increase in scholarly attention. By 2001, the number of publications reached 15 and continued to rise at a steady pace in the subsequent years.

A more pronounced upward trend became evident starting around 2010, with a particularly significant turning point observed in 2013—coinciding with the publication of an influential international consensus report on the definition and classification of bruxism led

by Lobbezoo^{16,17} and colleagues. Following this milestone, the number of publications increased consistently, reaching 81 in 2019 and 107 in 2020.

In the post-pandemic period (2021–2024), publication output remained elevated, culminating in an all-time high of 125 articles in 2024. This trend indicates that research interest in bruxism has expanded beyond clinical aspects to encompass psychosocial dimensions and lifestyle-related factors. In particular, the growing attention to bruxism’s associations with sleep disorders, stress-induced behavioral responses, and digital lifestyle patterns may account for the increased volume of scholarly output.

The data derived from the time series analysis clearly demonstrate that, although bruxism research was historically limited in scope, the past decade has witnessed a significant surge in interdisciplinary engagement. The findings suggest that the field is still in an upward trajectory of scholarly development, with substantial potential for future research.

In the next stage of analysis, the top ten most cited publications within the WoS dataset were identified, as shown in Table 1.

Table 1. Top ten most cited publications in the bruxism literature

Rank	Author(s)	Publication title	Journal	Citations
1	Lobbezoo, F., Ahlberg, J., & Winocur, E. (2013) ¹⁶	Bruxism defined and graded: An international consensus	Journal of Oral Rehabilitation	796
2	Lobbezoo, F., Ahlberg, J., & Manfredini, D. (2018) ¹⁷	International consensus on the assessment of bruxism: Report of a work in progress	Journal of Oral Rehabilitation	773
3	Lavigne, G. J., Rompre, P. H., & Montplaisir, J. Y. (1996) ¹⁸	Sleep bruxism: Validity of clinical research diagnostic criteria in a controlled polysomnographic study	Journal of Dental Research	532
4	Lavigne, G. J., & Montplaisir, J. Y. (1994) ¹⁹	Restless legs syndrome and sleep bruxism: Prevalence and association among Canadians	Sleep	515
5	Ohayon, M. M., Li, K. K., & Guilleminault, C. (2001) ²⁰	Risk factors for sleep bruxism in the general population	Chest	342
6	Nishigawa, K., Bando, E., & Nakano, M. (2001) ²¹	Quantitative study of bite force during sleep-associated bruxism	Journal of Oral Rehabilitation	238
7	Macaluso, G. M., Guerra, P., & Terzano, M. G. (1998) ²²	Sleep bruxism is a disorder related to periodic arousals during sleep	Journal of Dental Research	231
8	Rompré, P. H., Daigle-Landry, D., & Lavigne, G. J. (2007) ²³	Identification of a sleep bruxism subgroup with a higher risk of pain	Journal of Dental Research	224
9	Kato, T., Rompré, P., & Lavigne, G. J. (2001) ²⁴	Sleep bruxism: An oromotor activity secondary to micro-arousal	Journal of Dental Research	198
10	Maluly, M., Andersen, M. L., & Tufik, S. (2013) ²⁵	Polysomnographic study of the prevalence of sleep bruxism in a population sample	Journal of Dental Research	164

The bibliometric analysis identified the top ten most cited publications within the field of bruxism, as presented in Table 1. Collectively, these studies offer foundational insights into both the diagnostic criteria and the pathophysiological mechanisms associated with bruxism. Leading this list is the highly influential consensus paper by Lobbezoo, Ahlberg, and Winocur¹⁶, which proposed a widely accepted definition and grading system for bruxism. With 796 citations, this publication stands as a landmark reference in the literature.

Ranked second is another consensus report authored by the same research group in 2018, which outlines a methodological framework for the assessment of bruxism. This publication has received 773 citations, further underscoring the central role of standardized definitions and diagnostic approaches in the scholarly discourse on bruxism. Together, these two studies highlight the field's strong emphasis on classification and the need for uniform diagnostic guidelines.

The third most cited study, conducted by Lavigne, Rompré, and Montplaisir¹⁸, is a controlled polysomnographic investigation assessing the validity of clinical diagnostic criteria for sleep bruxism. With 532 citations, it reflects the scholarly focus on objective measurement techniques. Similarly, the fourth-ranked study by Lavigne and Montplaisir¹⁸ evaluated the prevalence and association between restless legs syndrome and sleep bruxism within a Canadian sample. This interdisciplinary work has garnered 515 citations, emphasizing the interconnected nature of bruxism with broader sleep disorders.

Fifth on the list is the study by Ohayon, Li, and Guilleminault²⁰, which explores risk factors associated with sleep bruxism in the general population. With 342 citations, it brings attention to the epidemiological dimensions of the disorder and contributes to filling significant gaps in prevalence data.

The sixth and seventh most cited studies, by Nishigawa et al.²¹ and Macaluso et al.²² respectively, delve into the quantitative measurement of bite force and the physiological

mechanisms underlying bruxism. These studies, with 238 and 231 citations respectively, underscore sustained academic interest in the biomechanical and neurophysiological foundations of the condition.

The eighth and ninth studies—Rompré et al.²³ and Kato et al.²⁴—focus on the identification of high-risk subgroups and the analysis of oromotor activities secondary to micro-arousals, receiving 224 and 198 citations respectively. These findings advance the nuanced understanding of bruxism's clinical subtypes and underlying triggers.

Finally, the tenth publication by Maluly et al.²⁵ represents one of the earliest large-scale polysomnographic prevalence studies, offering valuable epidemiological evidence and contributing 164 citations. This study has been instrumental in validating diagnostic accuracy in population-based research.

A consistent pattern across the top ten publications is the recurrent presence of authors such as Lobbezoo and Lavigne¹⁷⁻¹⁹, whose contributions have significantly shaped the field. Furthermore, the fact that most of these highly cited studies were published in prominent journals such as the *Journal of Dental Research* and the *Journal of Oral Rehabilitation* confirms the centrality of bruxism within the dental and orofacial sciences.

Taken together, these findings demonstrate that the most impactful research on bruxism has predominantly focused on diagnostic criteria, pathophysiology, and epidemiology. The high citation rates associated with methodologically rigorous studies further reflect the field's prioritization of empirical validation and clinical relevance.

Another important finding of the present study is the bibliometric analysis of author keywords used in the bruxism literature. This analysis aimed to uncover dominant thematic trends, primary research foci, and interdisciplinary connections. The most frequently used keywords across the dataset were identified and clustered based on their co-occurrence patterns. The resulting co-occurrence map is presented in Figure 1, providing a visual representation of the thematic organization of the literature.

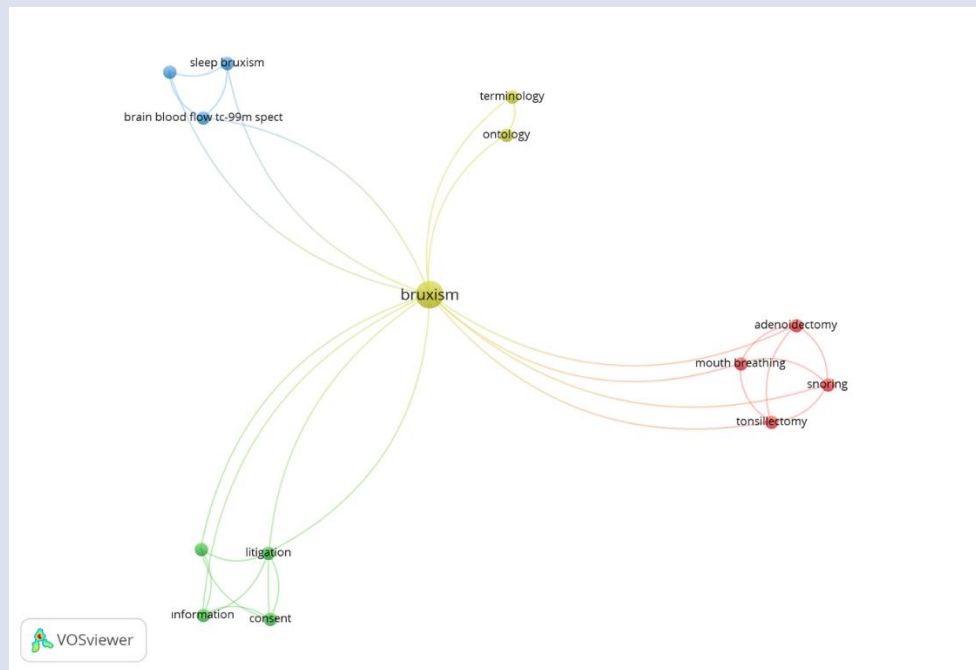


Figure 2. Co-occurrence map of the most frequently used keywords in bruxism research

The keyword co-occurrence network analysis revealed four distinct thematic clusters organized around the core concept of *bruxism*. Each of these clusters represents a different subdomain within the bruxism literature, encompassing clinical, diagnostic, ethical, and pediatric dimensions (see Figure 1).

The first cluster (blue) is composed of keywords related to *sleep bruxism* and neurophysiological mechanisms. Terms such as “*sleep bruxism*” and “*brain blood flow Tc-99m SPECT*” characterize this cluster, indicating the presence of studies that utilize nuclear medicine techniques (e.g., Tc-99m single-photon emission computed tomography) to objectively diagnose bruxism. This thematic area frames bruxism not merely as a behavioral condition but as a physiological phenomenon rooted in neurobiological processes. The convergence of neuroscience and nuclear imaging in these studies highlights the field’s growing multidisciplinary.

The second cluster (yellow) represents publications focused on the conceptual and terminological framework of bruxism. The presence of keywords such as “*terminology*” and “*ontology*” points to scholarly efforts aimed at defining, classifying, and categorizing subtypes of bruxism. This cluster is closely linked with the international consensus reports published in 2013 and 2018, which underscore the necessity of establishing a shared scientific vocabulary and diagnostic framework for advancing standardized research and clinical practice.

The third cluster (red) encompasses etiological factors related to pediatric bruxism and upper airway obstruction. Keywords such as “*adenoidectomy*”, “*mouth breathing*”, “*snoring*”, and “*tonsillectomy*” signify the relevance of sleep-disordered breathing and anatomical impairments in the development of bruxism during childhood. This cluster illustrates that bruxism is not

confined to the stomatognathic system alone but intersects significantly with pediatric otolaryngology. The increasing evidence supporting correlations between bruxism and systemic health conditions further emphasizes the need for cross-disciplinary research approaches.

The fourth cluster (green) addresses the ethical and legal dimensions of bruxism diagnosis and treatment. Terms such as “*litigation*”, “*consent*”, and “*information*” indicate a research focus on informed consent, patient rights, and potential medico-legal implications. This cluster highlights the growing importance of ethical awareness and legal responsibility in dental practice. Furthermore, it reflects emerging scholarly interest in the ethical management of patient data and communication within the context of bruxism-related interventions.

Taken together, the resulting keyword co-occurrence map clearly demonstrates that bruxism is a multidimensional phenomenon, extending beyond its dental origins to incorporate neurological, pediatric, conceptual, and ethical dimensions. The diversity of these clusters reinforces the continued interdisciplinary expansion of the field and suggests that future research will benefit from the integration of varied disciplinary perspectives.

The insights derived from the co-occurrence analysis not only reflect frequently used terms within the literature but also reveal how these terms aggregate into distinct thematic structures. These thematic orientations showcase the breadth of scholarly inquiry and underline the diversity of conceptual frameworks used to investigate bruxism. The table below presents a detailed thematic classification of these clusters, along with representative keywords and illustrative publications drawn from the literature.

Table 2. Thematic clusters derived from the keyword co-occurrence analysis in the bruxism literature, including key concepts and representative publications

Cluster Color	Thematic Area	Keywords	Representative Publications
Blue Cluster 1	Neurophysiological Mechanisms and Sleep Bruxism	['sleep bruxism', 'brain blood flow tc-99m spect']	Lavigne et al. (1996) ¹⁸ ; Huynh et al. (2006) ²⁶ ; Kato et al. (2001) ²⁴
Yellow Cluster 2	Conceptualization and Diagnostic Terminology	['terminology', 'ontology']	Lobbezoo et al. (2013) ¹⁶ ; Lobbezoo et al. (2018) ¹⁷
Red Cluster 3	Pediatric Bruxism and Upper Airway Association	['adenoidectomy', 'mouth breathing', 'snoring', 'tonsillectomy']	Ohayon et al. (2001) ²⁰ ; Raphael et al. (2012) ²⁷
Green Cluster 4	Ethical, Legal, and Informational Processes	['litigation', 'consent', 'information']	Winocur et al. (2011) ²⁸ ; Manfredini et al. (2014) ²⁹

In accordance with the aforementioned thematic classification, each cluster is examined below in detail with respect to its key concepts, representative studies, and prevailing research orientations within the bruxism literature.

The Neurophysiological Mechanisms and Sleep Bruxism Cluster (Blue Cluster) is characterized by the keywords “*sleep bruxism*” and “*brain blood flow Tc-99m SPECT*”, suggesting that bruxism is increasingly conceptualized as a physiological dysfunction occurring primarily during sleep. Studies within this cluster employ objective diagnostic tools such as polysomnography, electroencephalography (EEG), and nuclear imaging techniques to explore the neurological underpinnings of bruxism. Notably, Lavigne et al.¹⁸ experimentally validated diagnostic criteria for sleep bruxism, while Huynh et al.²⁶ and Kato et al.²⁴ provided in-depth analyses of jaw muscle activity triggered by micro-arousals and autonomic cardiac fluctuations. This cluster reflects the growing interest in the neurobiological dimension of bruxism and its relevance to multidisciplinary research across neurology, sleep medicine, and oral health.

The Conceptualization and Diagnostic Terminology Cluster (Yellow Cluster) centers on the development of a standardized framework for defining and classifying bruxism. Keywords such as “*terminology*” and “*ontology*” dominate this cluster, reflecting a focus on methodological and theoretical contributions. A key study by Lobbezoo et al.¹⁶ proposed an international consensus for grading bruxism across clinical, research, and public health contexts. This was followed by further refinement of assessment standards in a subsequent consensus report by Lobbezoo et al.¹⁷ This cluster makes a significant contribution to resolving terminological inconsistencies and promoting a shared scientific language across disciplines.

The Pediatric Bruxism and Upper Airway Association Cluster (Red Cluster) includes terms such as “*snoring*”, “*mouth breathing*”, “*adenoidectomy*”, and “*tonsillectomy*”, highlighting the link between childhood bruxism and upper airway disorders. Physiological stressors such as mouth breathing and snoring during sleep are considered potential triggers for bruxism in children. Supporting this, Ohayon et al.²⁰ explored environmental and physiological risk factors, while Raphael et al.²⁷ examined upper airway obstructions in pediatric samples with temporomandibular disorders. This cluster resides at the intersection of pediatrics, otolaryngology, and dentistry, underscoring the importance of interdisciplinary perspectives in understanding the multifactorial etiology of bruxism.

The Ethical, Legal, and Informational Processes Cluster (Green Cluster) is defined by the presence of keywords such as “*litigation*”, “*consent*”, and “*information*”. It points to the ethical and legal implications of diagnosing and treating bruxism, particularly in dental practice. Key concerns in this cluster include obtaining informed consent, transparently communicating treatment risks, and managing complications with professional accountability. Winocur et al.²⁸ discussed the associations between bruxism, stress, anxiety, and patient behavior, while Manfredini et al.²⁹ addressed the ethical and legal considerations surrounding dental implant failures potentially linked to bruxism. As such, this cluster represents a unique and growing research domain focused on safeguarding ethical responsibility and legal compliance in clinical care.

Collectively, these thematic insights reinforce the view that bruxism is not merely a localized dental issue but a complex, multidimensional phenomenon. The clusters reflect a broadening of the academic scope, with interdisciplinary collaboration proving essential to advancing the understanding and management of bruxism in both clinical and research settings.

Discussion and Conclusions

This study provides a comprehensive bibliometric analysis of the bruxism literature, aiming to systematically uncover the structural characteristics, historical development, thematic orientations, and prominent scientific contributions within the field. The findings offer valuable insights into both the quantitative progression of research output and the thematic evolution of content.

An analysis of publication trends over time indicates that scholarly output on bruxism began to accelerate in the early 2000s, with a marked increase in momentum observed after 2010. This trend reflects a shift in scholarly interest, positioning bruxism not only as a dental health concern but also as a multidisciplinary phenomenon involving sleep disorders, neurophysiological mechanisms, stress-related behavioral responses, and lifestyle-related factors. Particularly noteworthy is the publication of the international consensus report by Lobbezoo et al.¹⁶, which marked a turning point by establishing standardized definitions and classifications for bruxism, thereby catalyzing sustained growth in the volume of literature in subsequent years.

A closer examination of the ten most highly cited publications reveals three dominant thematic areas in the literature: (1) diagnostic and classification frameworks, (2)

neurophysiological foundations and diagnostic methodologies, and (3) epidemiological risk factors and prevalence studies. Researchers such as Lobbezoo^{16,17} and Lavigne^{18,19} clearly emerge as leaders in the field. The prevalence of these publications in high-impact journals such as *Journal of Oral Rehabilitation* and *Journal of Dental Research* further demonstrates that bruxism is primarily situated within the dental research domain. However, growing linkages with sleep science, neurology, psychology, and pediatrics reflect the field's expansion into broader academic territories.

The keyword co-occurrence analysis revealed four primary thematic clusters, further highlighting the interdisciplinary nature and methodological diversity of bruxism research. The first cluster—*Neurophysiological Mechanisms and Sleep Bruxism* (Blue Cluster)—is characterized by studies treating bruxism as a neurological motor disorder that manifests during sleep. Research in this cluster often utilizes objective diagnostic tools such as polysomnography, electroencephalography (EEG), and Tc-99m SPECT imaging. Seminal works by Lavigne et al.¹⁸ and Kato et al.²⁴ have laid the scientific foundation in this domain, reinforcing the notion that bruxism should be understood not merely as a behavioral condition but as a neurologically driven dysfunction.

The second cluster—*Conceptualization and Diagnostic Terminology* (Yellow Cluster)—encompasses efforts to define and standardize bruxism-related terminology. The consensus reports published by Lobbezoo et al.^{16,17} advocate for separate diagnostic criteria for sleep and awake bruxism, emphasizing the importance of standardization across studies and disciplines. This cluster plays a pivotal role in reducing terminological inconsistencies and promoting a shared scientific lexicon.

The third cluster—*Pediatric Bruxism and Upper Airway Associations* (Red Cluster)—focuses on the relationship between pediatric bruxism and physiological stressors such as upper airway obstructions. Research suggests that factors like adenoid hypertrophy, enlarged tonsils, and mouth breathing may contribute to the development of bruxism in children. Ohayon et al.²⁰ and Raphael et al.²⁷ have drawn attention to this association, highlighting the significance of anatomical and physiological variables in understanding pediatric cases. This cluster resides at the intersection of pediatrics, otolaryngology, and dentistry, emphasizing the need for interdisciplinary collaboration.

The fourth and final cluster—*Ethical, Legal, and Informational Processes* (Green Cluster)—addresses the ethical and legal dimensions of bruxism diagnosis and treatment. Key themes include informed consent, patient communication, and professional accountability in clinical practice. Winocur et al.²⁸ examined the relationship between bruxism, psychological factors, and patient behavior, while Manfredini et al.²⁹ explored the legal implications of treatment failures, particularly in the context of dental implants. This cluster underscores the growing importance of ethical sensitivity and legal compliance in patient-centered care.

While this bibliometric analysis identifies well-established areas of research within the bruxism literature, it also reveals notable gaps that warrant further investigation. Specifically, the relationship between psychosocial variables—such as stress, anxiety, and personality traits—and bruxism remains insufficiently explored in a causal framework. Although these

factors have been examined in previous studies, few have employed experimental or longitudinal designs capable of establishing robust causal links. Future research would benefit from methodologically rigorous studies that address these limitations.

Additionally, as digitalization increasingly shapes modern lifestyles, the potential link between bruxism and digital behaviors is emerging as a timely research avenue. Factors such as screen time, late-night use of electronic devices, and poor sleep hygiene have been hypothesized to contribute to bruxism yet remain underrepresented in the literature. This gap suggests a need for multi-center studies, particularly among adolescents and young adults, to assess the impact of digital habits on bruxism prevalence and severity.

Furthermore, the integration of emerging technologies in diagnostic practices remains at an early stage. Wearable sensor technologies, mobile health (mHealth) applications, and AI-assisted assessment tools offer promising innovations for improving diagnostic accuracy and clinical decision-making. However, empirical studies validating these technologies in bruxism diagnosis are limited. High-quality experimental research is urgently needed to evaluate their reliability, clinical applicability, and user acceptability.

Another key finding is the limited prevalence of interdisciplinary methodological frameworks in the existing literature. Collaborative research designs that combine neuroscience, sleep medicine, artificial intelligence, behavioral sciences, and dentistry hold great potential to advance both theoretical and practical understanding of bruxism. Such integrative approaches can offer a more comprehensive perspective on the biopsychosocial dimensions of the disorder and contribute to the development of innovative interventions.

In conclusion, this study offers a systematic overview of the bruxism literature through a bibliometric lens, mapping the field's historical development, publication density, and evolving research orientations. The analysis covered annual publication trends, the most cited studies, and thematic clustering based on keyword co-occurrence, thereby elucidating the structural and content dynamics of the domain. Beyond merely cataloging the current academic landscape, the findings provide a strategic foundation for shaping future research directions.

Identifying dominant research themes alongside underexplored subdomains is among the study's most valuable contributions. The in-depth analysis of core themes—diagnostic criteria, sleep-related pathophysiology, pediatric factors, and ethical-legal contexts—underscores the multidimensional nature of bruxism and the necessity for interdisciplinary engagement. Supporting cross-disciplinary collaborations across neuroscience, behavioral science, sleep medicine, dentistry, ethics, and digital health technologies will foster a more holistic and applied research agenda.

Moreover, the integration of digital health innovations and AI-based diagnostic systems promises to enhance diagnostic sensitivity and facilitate personalized care approaches. Coupled with ethically grounded, evidence-based, patient-centered research, such advances will contribute not only to academic knowledge production but also to the improvement of healthcare quality.

Taken together, this bibliometric analysis offers a comprehensive snapshot of the current state of bruxism

research and outlines a forward-looking framework for its future evolution. The findings are expected to serve as a valuable reference for researchers and practitioners aiming to design new studies and address critical gaps in the literature.

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Conflicts of Interest statement

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

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Mapping the Scientific Landscape of Bruxism: A Comprehensive Bibliometric Analysis

Mansur Doğan^{1,a,*}

¹Department of Otorhinolaryngology, Faculty of Medicine, Sivas Cumhuriyet University, Sivas, Türkiye.

*Corresponding author

Review Article

History

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ABSTRACT

Objectives: Bruxism is a jaw muscle activity defined as teeth clenching or grinding that can be seen both while awake and asleep. The central nervous system, autonomic nervous system, genetic factors and comorbidities play a role in its etiology. In recent years, a great deal of research has been conducted on bruxism.

Materials and Methods: In this study, 1,278 articles searched with the keyword "bruxism" in the Web of Science (WoS) database were subjected to bibliometric analysis. Publication trends, citation analyses and keyword clusters were examined using VOSviewer software.

Results: Bruxism research has increased since the 2000s and accelerated after 2013. By 2024, the annual number of publications reached 125. The Most Cited Study Lobbezoo et al. (2013, 2018) – International consensus reports on the definition and classification of bruxism. Thematic Clusters; Blue Cluster: Neurophysiological mechanisms and sleep bruxism, Yellow Cluster: Terminology and classification (Lobbezoo's consensus studies), Red Cluster: Pediatric bruxism and upper airway obstruction (snoring, mouth breathing), Green Cluster: Studies addressing ethical and legal dimensions.

Conclusions: Bruxism is a disorder that requires a multidisciplinary approach (neurology, dentistry, sleep medicine, pediatrics). Both the causes and effects of bruxism impact many individuals. A detailed analysis of the top ten most cited publications reveals a primary focus on three main themes: (1) diagnostic and classification systems, (2) neurophysiological foundations and diagnostic methods, and (3) epidemiological risk factors and prevalence studies. Future studies should focus on interdisciplinary collaboration and digital diagnostic methods. The identification of dominant themes in the literature and the identification of subfields that are not yet sufficiently represented make our study original. This study provides a quantitative map of the bruxism literature and provides a guiding resource for future research.

Keywords: Bruxism, Bibliometric Analysis, VOSviewer, Scientific Literature Mapping, Thematic Clustering.

Bruksizmin Bilimsel Görünümünün Haritalanması: Kapsamlı Bibliyometrik Analiz

Araştırma Makalesi

Süreç

Geliş: 01/05/2025

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ÖZET

Amaç: Bruksizm, diş sıkma veya gıcırdatma olarak tanımlanan hem uyanıkken hem de uykuda görülebilen bir çene kası aktivitesidir. Etiyolojisinde merkezi sinir sistemi, otonom sinir sistemi, genetik faktörler ve komorbiditeler rol oynar. Son yıllarda bruksizm hakkında oldukça fazla araştırma yapılmaktadır.

Gereç ve Yöntemler: Bu çalışmada, Web of Science (WoS) veri tabanında "bruxism" anahtar kelimesiyle taranan 1.278 makale bibliyometrik analize tabi tutulmuştur. VOSviewer yazılımı kullanılarak yayın eğilimleri, atıf analizleri ve anahtar kelime kümelenmeleri incelenmiştir.

Bulgular: Bruksizm araştırmaları 2000'lerden itibaren artış göstermiş, 2013 sonrasında hızlanmıştır. 2024'e kadar yıllık yayın sayısı 125'e ulaşmıştır. En Çok Atıf Alan Çalışma Lobbezoo ve ark. (2013, 2018) – Bruksizmin tanımı ve sınıflandırılmasına dair uluslararası uzlaşma raporları olmuştur. Bruksizm ile ilgili yazılar her yıl düzenli bir şekilde artış göstermiş ve 2024 yılında 125 makale ile zirve yapmıştır. Tematik Kümelenmeler de Mavi Küme: Nörofizyolojik mekanizmalar ve uyku bruksizmi, Sarı Küme: Terminoloji ve sınıflandırma (Lobbezoo'nun uzlaşma çalışmaları), Kırmızı Küme: Pediatrik bruksizm ve üst solunum yolu tıkanıklığı (horlama, ağız solunumu), Yeşil Küme: Etik ve hukuki boyutları ele alan çalışmalardan oluşmaktadır.

Sonuçlar: Bruksizm multidisipliner bir yaklaşım gerektiren (nöroloji, diş hekimliği, uyku tıbbı, pediatri) bir rahatsızlıktır. Sebepleri gibi sonuçları da birçok insanı etkilemektedir. En çok atıf alan ilk on yayın detaylı analizi edildiğinde; (1) tanı ve sınıflandırma sistemleri, (2) nörofizyolojik temeller ve tanı yöntemleri, (3) epidemiyolojik risk faktörleri ve prevalans çalışmaları gibi temel olarak üç ana temaya yoğunlaşmaktadır. Gelecek çalışmalar, disiplinler arası iş birliği ve dijital tanı yöntemleri üzerine odaklanmalıdır. Literatürde hâkim olan temaların belirlenmesi ve henüz yeterince temsil edilmeyen alt alanların tespit edilmesi, bizim çalışmamızı özgün kılmaktadır. Bu çalışma, bruksizm literatürünün niceliksel bir haritasını sunarak gelecek araştırmalara yol gösterici bir kaynak sağlamaktadır.

Anahtar Kelimeler: Bruksizm, Bibliyometrik Analiz, VOSviewer, Bilimsel Literatür Haritalama, Tematik Kümeleme.



mansurdogan@hotmail.com



0000-0002-3964-9363

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Introduction

Bruxism is a jaw muscle activity that can be seen both in wakefulness and sleep, characterized by involuntary clenching or grinding of the teeth. There are many factors that trigger bruxism. In recent years, significant research has been conducted on the neurophysiological basis of sleep bruxism, its etiological factors in childhood and related to the upper respiratory tract, its conceptual framework and ethical-legal dimensions. Bruxism is defined as the clenching, grinding or pushing/stretching of the lower jaw with repetitive jaw muscle activity. Sleep and wake bruxism are considered as two separate conditions with different pathophysiologies; however, they may overlap in some individuals. The definition and causes of sleep bruxism have changed over time, and rather than peripheral factors (e.g. dental occlusion), the central nervous system and autonomic nervous system, genetics and comorbidities have come to the fore. There is strong evidence that dental occlusion is not the main cause of bruxism.¹⁻³

Sleep bruxism is closely related to the central nervous system and the autonomic nervous system. In particular, structures such as the mesencephalic trigeminal nucleus (MTN) and ARAS (ascending reticular activating system) in the brainstem play a role. Bruxism during sleep is accompanied by activation in brain, heart and respiratory functions. It is suggested that bruxism is not a parafunction but a function that activates the ARAS nuclei.^{1,4,5}

The prevalence of bruxism in children varies between 5% and 50%. Sleep disorders have been associated with snoring, headache, jaw muscle fatigue, and tooth wear. Sleep-related breathing disorders (e.g., obstructive sleep apnea, mouth breathing, allergies) are important risk factors. A significant relationship has been shown between bruxism and sleep-disordered breathing in children, but causality is not clear.⁶⁻¹⁰

Ethical and legal responsibilities are important in the diagnosis and treatment of bruxism. Especially in children, correct diagnosis, parental information, determination of possible comorbidities, and selection of appropriate treatment approaches are necessary. It is recommended that clinical guidelines be developed and ethical principles be observed in treatment processes.⁷

Bruxism is a multifactorial and complex condition and is associated with the central nervous system and autonomic mechanisms. Dental problems are one of the most important causes of bruxism. Upper respiratory tract disorders are important risk factors in children. Ethical and legal responsibilities should be taken into consideration in diagnosis, treatment and management. Research on the conceptual framework and mechanisms of bruxism is ongoing. In this publication, we have created a bibliometric map of publications on bruxism. We believe that past publications can guide future publications.

Materials and Methods

Bibliometric analysis is a quantitative research method that enables the systematic examination of the structural characteristics, developmental trends, and knowledge flow within scientific literature.¹¹⁻¹³ In this study, a comprehensive bibliometric analysis was conducted to map the current landscape of scholarly publications on bruxism, identify leading contributors in the field, and reveal the thematic structure of the related literature.

The analysis followed a structured process in accordance with standard procedures typically employed in bibliometric research. In the initial stage, the primary research question guiding this study was formulated as follows: *"What is the current state of academic research on bruxism, and how are the thematic trends distributed across the literature?"* To address this question, a systematic review of the relevant scientific literature was performed.

The Web of Science (WoS) database was selected as the primary source for data collection due to its comprehensive coverage and high-quality indexing, particularly in fields such as health sciences and dentistry.¹⁴ A focused search strategy was then developed: the keyword "bruxism" was used exclusively within the title field, and filters were applied to include only articles, exclude publications from the year 2025, and limit results to those written in English. As a result, a total of 1,278 articles were included in the final dataset.

During the data extraction phase, bibliographic records obtained from WoS were imported into the EndNote reference management software, and duplicate entries were removed to ensure data consistency. Subsequently, key bibliometric variables such as author name(s), year of publication, journal title, number of citations, document type, and author keywords were extracted and organized for analysis.

For data visualization, the software VOSviewer—a widely used tool in bibliometric research—was employed. VOSviewer facilitates the creation of visual maps that depict relationships among authors, publications, and keywords, thereby offering valuable insights into the structural dynamics and thematic clustering within the field.¹⁵

In the final stage, the findings were systematically interpreted to identify not only the prevailing research trends but also gaps in the literature and promising directions for future inquiry. Accordingly, the bibliometric analysis presented in this study not only provides a quantitative overview of the bruxism literature but also contributes foundational knowledge to guide subsequent research strategies and agenda-setting in the field.

Results

This section presents the findings of the bibliometric analysis conducted in the field of bruxism. The primary aim of the analysis is to quantitatively assess the current state of scientific output within this domain, identify the most influential publications and authors, uncover

thematic clusters, and map the structural characteristics of the literature. The findings are organized under several key subheadings, including annual publication trends, most-cited articles, keyword co-occurrence analysis, and thematic clustering.

During the data collection phase, a focused search was conducted in the Web of Science (WoS) database using the keyword “bruxism” within the title field. The search was refined to include only article-type publications, exclude those published in the year 2025, and limit the results to those written in English. Following this filtering process, a total of 1,278 articles published between 1971 and 2024 were included in the analysis.

The bibliometric evaluation of this dataset yielded insights into the historical trajectory of research in the field, the degree of interdisciplinary collaboration, and the evolving priorities within bruxism scholarship. Examining the annual distribution of academic output is particularly critical for understanding the developmental dynamics of the field.

Accordingly, the number of publications on bruxism was analyzed by year, offering a quantitative overview of the field’s scientific evolution. The corresponding results are presented in Figure 1.

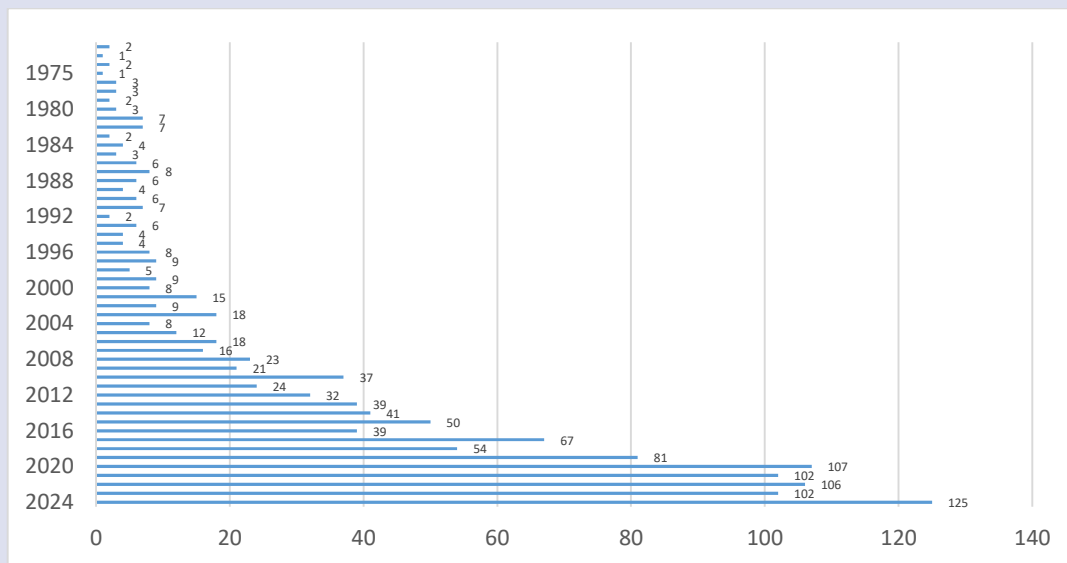


Figure 1. Annual distribution of publications on bruxism (1971–2024)

As part of the study, a total of 1,278 articles retrieved from the Web of Science (WoS) database—filtered to include only those containing the keyword “bruxism” in the title field and classified strictly as article-type publications—were analyzed in terms of their annual distribution. This time series analysis, covering the period from 1971 to 2024, illustrates the historical progression of scholarly interest in the topic of bruxism.

The earliest identified publication dates back to 1971, with a notably low volume of research output throughout the 1970s and 1980s. During this early period, the number of annual publications generally ranged between 1 and 8, suggesting that bruxism had not yet emerged as a prominent topic of academic inquiry. Until the late 1990s, the field experienced little growth in research activity. However, beginning in the early 2000s, there was a gradual increase in scholarly attention. By 2001, the number of publications reached 15 and continued to rise at a steady pace in the subsequent years.

A more pronounced upward trend became evident starting around 2010, with a particularly significant turning point observed in 2013—coinciding with the publication of an influential international consensus report on the definition and classification of bruxism led

by Lobbezoo^{16,17} and colleagues. Following this milestone, the number of publications increased consistently, reaching 81 in 2019 and 107 in 2020.

In the post-pandemic period (2021–2024), publication output remained elevated, culminating in an all-time high of 125 articles in 2024. This trend indicates that research interest in bruxism has expanded beyond clinical aspects to encompass psychosocial dimensions and lifestyle-related factors. In particular, the growing attention to bruxism’s associations with sleep disorders, stress-induced behavioral responses, and digital lifestyle patterns may account for the increased volume of scholarly output.

The data derived from the time series analysis clearly demonstrate that, although bruxism research was historically limited in scope, the past decade has witnessed a significant surge in interdisciplinary engagement. The findings suggest that the field is still in an upward trajectory of scholarly development, with substantial potential for future research.

In the next stage of analysis, the top ten most cited publications within the WoS dataset were identified, as shown in Table 1.

Table 1. Top ten most cited publications in the bruxism literature

Rank	Author(s)	Publication title	Journal	Citations
1	Lobbezoo, F., Ahlberg, J., & Winocur, E. (2013) ¹⁶	Bruxism defined and graded: An international consensus	Journal of Oral Rehabilitation	796
2	Lobbezoo, F., Ahlberg, J., & Manfredini, D. (2018) ¹⁷	International consensus on the assessment of bruxism: Report of a work in progress	Journal of Oral Rehabilitation	773
3	Lavigne, G. J., Rompre, P. H., & Montplaisir, J. Y. (1996) ¹⁸	Sleep bruxism: Validity of clinical research diagnostic criteria in a controlled polysomnographic study	Journal of Dental Research	532
4	Lavigne, G. J., & Montplaisir, J. Y. (1994) ¹⁹	Restless legs syndrome and sleep bruxism: Prevalence and association among Canadians	Sleep	515
5	Ohayon, M. M., Li, K. K., & Guilleminault, C. (2001) ²⁰	Risk factors for sleep bruxism in the general population	Chest	342
6	Nishigawa, K., Bando, E., & Nakano, M. (2001) ²¹	Quantitative study of bite force during sleep-associated bruxism	Journal of Oral Rehabilitation	238
7	Macaluso, G. M., Guerra, P., & Terzano, M. G. (1998) ²²	Sleep bruxism is a disorder related to periodic arousals during sleep	Journal of Dental Research	231
8	Rompré, P. H., Daigle-Landry, D., & Lavigne, G. J. (2007) ²³	Identification of a sleep bruxism subgroup with a higher risk of pain	Journal of Dental Research	224
9	Kato, T., Rompré, P., & Lavigne, G. J. (2001) ²⁴	Sleep bruxism: An oromotor activity secondary to micro-arousal	Journal of Dental Research	198
10	Maluly, M., Andersen, M. L., & Tufik, S. (2013) ²⁵	Polysomnographic study of the prevalence of sleep bruxism in a population sample	Journal of Dental Research	164

The bibliometric analysis identified the top ten most cited publications within the field of bruxism, as presented in Table 1. Collectively, these studies offer foundational insights into both the diagnostic criteria and the pathophysiological mechanisms associated with bruxism. Leading this list is the highly influential consensus paper by Lobbezoo, Ahlberg, and Winocur¹⁶, which proposed a widely accepted definition and grading system for bruxism. With 796 citations, this publication stands as a landmark reference in the literature.

Ranked second is another consensus report authored by the same research group in 2018, which outlines a methodological framework for the assessment of bruxism. This publication has received 773 citations, further underscoring the central role of standardized definitions and diagnostic approaches in the scholarly discourse on bruxism. Together, these two studies highlight the field's strong emphasis on classification and the need for uniform diagnostic guidelines.

The third most cited study, conducted by Lavigne, Rompré, and Montplaisir¹⁸, is a controlled polysomnographic investigation assessing the validity of clinical diagnostic criteria for sleep bruxism. With 532 citations, it reflects the scholarly focus on objective measurement techniques. Similarly, the fourth-ranked study by Lavigne and Montplaisir¹⁸ evaluated the prevalence and association between restless legs syndrome and sleep bruxism within a Canadian sample. This interdisciplinary work has garnered 515 citations, emphasizing the interconnected nature of bruxism with broader sleep disorders.

Fifth on the list is the study by Ohayon, Li, and Guilleminault²⁰, which explores risk factors associated with sleep bruxism in the general population. With 342 citations, it brings attention to the epidemiological dimensions of the disorder and contributes to filling significant gaps in prevalence data.

The sixth and seventh most cited studies, by Nishigawa et al.²¹ and Macaluso et al.²² respectively, delve into the quantitative measurement of bite force and the physiological

mechanisms underlying bruxism. These studies, with 238 and 231 citations respectively, underscore sustained academic interest in the biomechanical and neurophysiological foundations of the condition.

The eighth and ninth studies—Rompré et al.²³ and Kato et al.²⁴—focus on the identification of high-risk subgroups and the analysis of oromotor activities secondary to micro-arousals, receiving 224 and 198 citations respectively. These findings advance the nuanced understanding of bruxism's clinical subtypes and underlying triggers.

Finally, the tenth publication by Maluly et al.²⁵ represents one of the earliest large-scale polysomnographic prevalence studies, offering valuable epidemiological evidence and contributing 164 citations. This study has been instrumental in validating diagnostic accuracy in population-based research.

A consistent pattern across the top ten publications is the recurrent presence of authors such as Lobbezoo and Lavigne¹⁷⁻¹⁹, whose contributions have significantly shaped the field. Furthermore, the fact that most of these highly cited studies were published in prominent journals such as the *Journal of Dental Research* and the *Journal of Oral Rehabilitation* confirms the centrality of bruxism within the dental and orofacial sciences.

Taken together, these findings demonstrate that the most impactful research on bruxism has predominantly focused on diagnostic criteria, pathophysiology, and epidemiology. The high citation rates associated with methodologically rigorous studies further reflect the field's prioritization of empirical validation and clinical relevance.

Another important finding of the present study is the bibliometric analysis of author keywords used in the bruxism literature. This analysis aimed to uncover dominant thematic trends, primary research foci, and interdisciplinary connections. The most frequently used keywords across the dataset were identified and clustered based on their co-occurrence patterns. The resulting co-occurrence map is presented in Figure 1, providing a visual representation of the thematic organization of the literature.

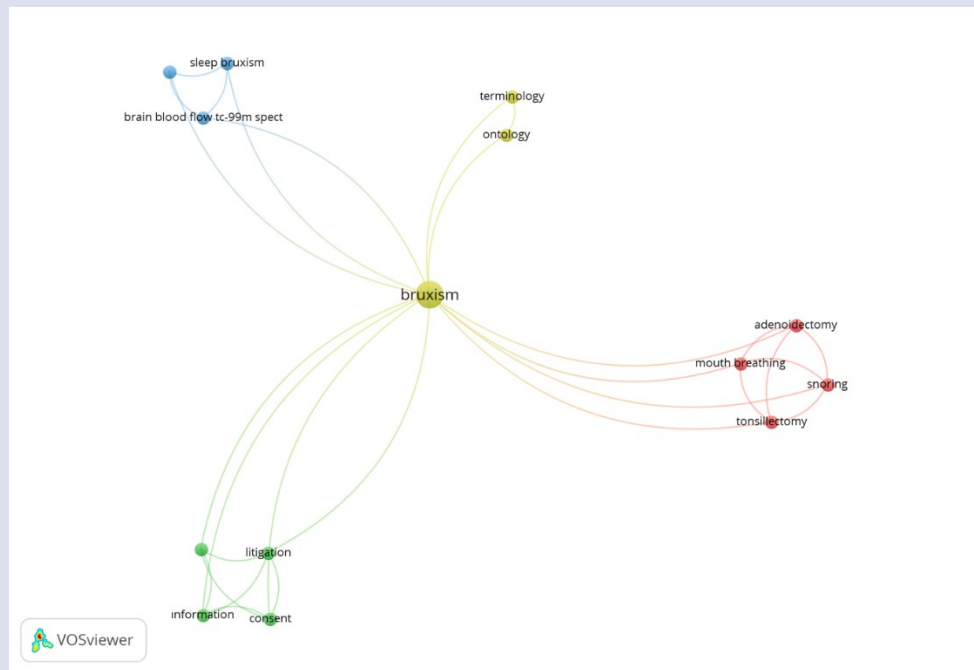


Figure 2. Co-occurrence map of the most frequently used keywords in bruxism research

The keyword co-occurrence network analysis revealed four distinct thematic clusters organized around the core concept of *bruxism*. Each of these clusters represents a different subdomain within the bruxism literature, encompassing clinical, diagnostic, ethical, and pediatric dimensions (see Figure 1).

The first cluster (blue) is composed of keywords related to *sleep bruxism* and neurophysiological mechanisms. Terms such as “*sleep bruxism*” and “*brain blood flow Tc-99m SPECT*” characterize this cluster, indicating the presence of studies that utilize nuclear medicine techniques (e.g., Tc-99m single-photon emission computed tomography) to objectively diagnose bruxism. This thematic area frames bruxism not merely as a behavioral condition but as a physiological phenomenon rooted in neurobiological processes. The convergence of neuroscience and nuclear imaging in these studies highlights the field’s growing multidisciplinary.

The second cluster (yellow) represents publications focused on the conceptual and terminological framework of bruxism. The presence of keywords such as “*terminology*” and “*ontology*” points to scholarly efforts aimed at defining, classifying, and categorizing subtypes of bruxism. This cluster is closely linked with the international consensus reports published in 2013 and 2018, which underscore the necessity of establishing a shared scientific vocabulary and diagnostic framework for advancing standardized research and clinical practice.

The third cluster (red) encompasses etiological factors related to pediatric bruxism and upper airway obstruction. Keywords such as “*adenoidectomy*”, “*mouth breathing*”, “*snoring*”, and “*tonsillectomy*” signify the relevance of sleep-disordered breathing and anatomical impairments in the development of bruxism during childhood. This cluster illustrates that bruxism is not

confined to the stomatognathic system alone but intersects significantly with pediatric otolaryngology. The increasing evidence supporting correlations between bruxism and systemic health conditions further emphasizes the need for cross-disciplinary research approaches.

The fourth cluster (green) addresses the ethical and legal dimensions of bruxism diagnosis and treatment. Terms such as “*litigation*”, “*consent*”, and “*information*” indicate a research focus on informed consent, patient rights, and potential medico-legal implications. This cluster highlights the growing importance of ethical awareness and legal responsibility in dental practice. Furthermore, it reflects emerging scholarly interest in the ethical management of patient data and communication within the context of bruxism-related interventions.

Taken together, the resulting keyword co-occurrence map clearly demonstrates that bruxism is a multidimensional phenomenon, extending beyond its dental origins to incorporate neurological, pediatric, conceptual, and ethical dimensions. The diversity of these clusters reinforces the continued interdisciplinary expansion of the field and suggests that future research will benefit from the integration of varied disciplinary perspectives.

The insights derived from the co-occurrence analysis not only reflect frequently used terms within the literature but also reveal how these terms aggregate into distinct thematic structures. These thematic orientations showcase the breadth of scholarly inquiry and underline the diversity of conceptual frameworks used to investigate bruxism. The table below presents a detailed thematic classification of these clusters, along with representative keywords and illustrative publications drawn from the literature.

Table 2. Thematic clusters derived from the keyword co-occurrence analysis in the bruxism literature, including key concepts and representative publications

Cluster Color	Thematic Area	Keywords	Representative Publications
Blue Cluster 1	Neurophysiological Mechanisms and Sleep Bruxism	['sleep bruxism', 'brain blood flow tc-99m spect']	Lavigne et al. (1996) ¹⁸ ; Huynh et al. (2006) ²⁶ ; Kato et al. (2001) ²⁴
Yellow Cluster 2	Conceptualization and Diagnostic Terminology	['terminology', 'ontology']	Lobbezoo et al. (2013) ¹⁶ ; Lobbezoo et al. (2018) ¹⁷
Red Cluster 3	Pediatric Bruxism and Upper Airway Association	['adenoidectomy', 'mouth breathing', 'snoring', 'tonsillectomy']	Ohayon et al. (2001) ²⁰ ; Raphael et al. (2012) ²⁷
Green Cluster 4	Ethical, Legal, and Informational Processes	['litigation', 'consent', 'information']	Winocur et al. (2011) ²⁸ ; Manfredini et al. (2014) ²⁹

In accordance with the aforementioned thematic classification, each cluster is examined below in detail with respect to its key concepts, representative studies, and prevailing research orientations within the bruxism literature.

The Neurophysiological Mechanisms and Sleep Bruxism Cluster (Blue Cluster) is characterized by the keywords “*sleep bruxism*” and “*brain blood flow Tc-99m SPECT*”, suggesting that bruxism is increasingly conceptualized as a physiological dysfunction occurring primarily during sleep. Studies within this cluster employ objective diagnostic tools such as polysomnography, electroencephalography (EEG), and nuclear imaging techniques to explore the neurological underpinnings of bruxism. Notably, Lavigne et al.¹⁸ experimentally validated diagnostic criteria for sleep bruxism, while Huynh et al.²⁶ and Kato et al.²⁴ provided in-depth analyses of jaw muscle activity triggered by micro-arousals and autonomic cardiac fluctuations. This cluster reflects the growing interest in the neurobiological dimension of bruxism and its relevance to multidisciplinary research across neurology, sleep medicine, and oral health.

The Conceptualization and Diagnostic Terminology Cluster (Yellow Cluster) centers on the development of a standardized framework for defining and classifying bruxism. Keywords such as “*terminology*” and “*ontology*” dominate this cluster, reflecting a focus on methodological and theoretical contributions. A key study by Lobbezoo et al.¹⁶ proposed an international consensus for grading bruxism across clinical, research, and public health contexts. This was followed by further refinement of assessment standards in a subsequent consensus report by Lobbezoo et al.¹⁷ This cluster makes a significant contribution to resolving terminological inconsistencies and promoting a shared scientific language across disciplines.

The Pediatric Bruxism and Upper Airway Association Cluster (Red Cluster) includes terms such as “*snoring*”, “*mouth breathing*”, “*adenoidectomy*”, and “*tonsillectomy*”, highlighting the link between childhood bruxism and upper airway disorders. Physiological stressors such as mouth breathing and snoring during sleep are considered potential triggers for bruxism in children. Supporting this, Ohayon et al.²⁰ explored environmental and physiological risk factors, while Raphael et al.²⁷ examined upper airway obstructions in pediatric samples with temporomandibular disorders. This cluster resides at the intersection of pediatrics, otolaryngology, and dentistry, underscoring the importance of interdisciplinary

perspectives in understanding the multifactorial etiology of bruxism.

The Ethical, Legal, and Informational Processes Cluster (Green Cluster) is defined by the presence of keywords such as “*litigation*”, “*consent*”, and “*information*”. It points to the ethical and legal implications of diagnosing and treating bruxism, particularly in dental practice. Key concerns in this cluster include obtaining informed consent, transparently communicating treatment risks, and managing complications with professional accountability. Winocur et al.²⁸ discussed the associations between bruxism, stress, anxiety, and patient behavior, while Manfredini et al.²⁹ addressed the ethical and legal considerations surrounding dental implant failures potentially linked to bruxism. As such, this cluster represents a unique and growing research domain focused on safeguarding ethical responsibility and legal compliance in clinical care.

Collectively, these thematic insights reinforce the view that bruxism is not merely a localized dental issue but a complex, multidimensional phenomenon. The clusters reflect a broadening of the academic scope, with interdisciplinary collaboration proving essential to advancing the understanding and management of bruxism in both clinical and research settings.

Discussion and Conclusions

This study provides a comprehensive bibliometric analysis of the bruxism literature, aiming to systematically uncover the structural characteristics, historical development, thematic orientations, and prominent scientific contributions within the field. The findings offer valuable insights into both the quantitative progression of research output and the thematic evolution of content.

An analysis of publication trends over time indicates that scholarly output on bruxism began to accelerate in the early 2000s, with a marked increase in momentum observed after 2010. This trend reflects a shift in scholarly interest, positioning bruxism not only as a dental health concern but also as a multidisciplinary phenomenon involving sleep disorders, neurophysiological mechanisms, stress-related behavioral responses, and lifestyle-related factors. Particularly noteworthy is the publication of the international consensus report by Lobbezoo et al.¹⁶, which marked a turning point by establishing standardized definitions and classifications for bruxism, thereby catalyzing sustained growth in the volume of literature in subsequent years.

A closer examination of the ten most highly cited publications reveals three dominant thematic areas in the literature: (1) diagnostic and classification frameworks, (2) neurophysiological foundations and diagnostic methodologies, and (3) epidemiological risk factors and prevalence studies. Researchers such as Lobbezoo^{16,17} and Lavigne^{18,19} clearly emerge as leaders in the field. The prevalence of these publications in high-impact journals such as *Journal of Oral Rehabilitation* and *Journal of Dental Research* further demonstrates that bruxism is primarily situated within the dental research domain. However, growing linkages with sleep science, neurology, psychology, and pediatrics reflect the field's expansion into broader academic territories.

The keyword co-occurrence analysis revealed four primary thematic clusters, further highlighting the interdisciplinary nature and methodological diversity of bruxism research. The first cluster—*Neurophysiological Mechanisms and Sleep Bruxism* (Blue Cluster)—is characterized by studies treating bruxism as a neurological motor disorder that manifests during sleep. Research in this cluster often utilizes objective diagnostic tools such as polysomnography, electroencephalography (EEG), and Tc-99m SPECT imaging. Seminal works by Lavigne et al.¹⁸ and Kato et al.²⁴ have laid the scientific foundation in this domain, reinforcing the notion that bruxism should be understood not merely as a behavioral condition but as a neurologically driven dysfunction.

The second cluster—*Conceptualization and Diagnostic Terminology* (Yellow Cluster)—encompasses efforts to define and standardize bruxism-related terminology. The consensus reports published by Lobbezoo et al.^{16,17} advocate for separate diagnostic criteria for sleep and awake bruxism, emphasizing the importance of standardization across studies and disciplines. This cluster plays a pivotal role in reducing terminological inconsistencies and promoting a shared scientific lexicon.

The third cluster—*Pediatric Bruxism and Upper Airway Associations* (Red Cluster)—focuses on the relationship between pediatric bruxism and physiological stressors such as upper airway obstructions. Research suggests that factors like adenoid hypertrophy, enlarged tonsils, and mouth breathing may contribute to the development of bruxism in children. Ohayon et al.²⁰ and Raphael et al.²⁷ have drawn attention to this association, highlighting the significance of anatomical and physiological variables in understanding pediatric cases. This cluster resides at the intersection of pediatrics, otolaryngology, and dentistry, emphasizing the need for interdisciplinary collaboration.

The fourth and final cluster—*Ethical, Legal, and Informational Processes* (Green Cluster)—addresses the ethical and legal dimensions of bruxism diagnosis and treatment. Key themes include informed consent, patient communication, and professional accountability in clinical practice. Winocur et al.²⁸ examined the relationship between bruxism, psychological factors, and patient behavior, while Manfredini et al.²⁹ explored the legal implications of treatment failures, particularly in the context of dental implants. This cluster underscores the growing importance of ethical sensitivity and legal compliance in patient-centered care.

While this bibliometric analysis identifies well-established areas of research within the bruxism literature, it also reveals notable gaps that warrant further investigation. Specifically,

the relationship between psychosocial variables—such as stress, anxiety, and personality traits—and bruxism remains insufficiently explored in a causal framework. Although these factors have been examined in previous studies, few have employed experimental or longitudinal designs capable of establishing robust causal links. Future research would benefit from methodologically rigorous studies that address these limitations.

Additionally, as digitalization increasingly shapes modern lifestyles, the potential link between bruxism and digital behaviors is emerging as a timely research avenue. Factors such as screen time, late-night use of electronic devices, and poor sleep hygiene have been hypothesized to contribute to bruxism yet remain underrepresented in the literature. This gap suggests a need for multi-center studies, particularly among adolescents and young adults, to assess the impact of digital habits on bruxism prevalence and severity.

Furthermore, the integration of emerging technologies in diagnostic practices remains at an early stage. Wearable sensor technologies, mobile health (mHealth) applications, and AI-assisted assessment tools offer promising innovations for improving diagnostic accuracy and clinical decision-making. However, empirical studies validating these technologies in bruxism diagnosis are limited. High-quality experimental research is urgently needed to evaluate their reliability, clinical applicability, and user acceptability.

Another key finding is the limited prevalence of interdisciplinary methodological frameworks in the existing literature. Collaborative research designs that combine neuroscience, sleep medicine, artificial intelligence, behavioral sciences, and dentistry hold great potential to advance both theoretical and practical understanding of bruxism. Such integrative approaches can offer a more comprehensive perspective on the biopsychosocial dimensions of the disorder and contribute to the development of innovative interventions.

In conclusion, this study offers a systematic overview of the bruxism literature through a bibliometric lens, mapping the field's historical development, publication density, and evolving research orientations. The analysis covered annual publication trends, the most cited studies, and thematic clustering based on keyword co-occurrence, thereby elucidating the structural and content dynamics of the domain. Beyond merely cataloging the current academic landscape, the findings provide a strategic foundation for shaping future research directions.

Identifying dominant research themes alongside underexplored subdomains is among the study's most valuable contributions. The in-depth analysis of core themes—diagnostic criteria, sleep-related pathophysiology, pediatric factors, and ethical-legal contexts—underscores the multidimensional nature of bruxism and the necessity for interdisciplinary engagement. Supporting cross-disciplinary collaborations across neuroscience, behavioral science, sleep medicine, dentistry, ethics, and digital health technologies will foster a more holistic and applied research agenda.

Moreover, the integration of digital health innovations and AI-based diagnostic systems promises to enhance diagnostic sensitivity and facilitate personalized care approaches. Coupled with ethically grounded, evidence-based, patient-centered research, such advances will contribute not only to

academic knowledge production but also to the improvement of healthcare quality.

Taken together, this bibliometric analysis offers a comprehensive snapshot of the current state of bruxism research and outlines a forward-looking framework for its future evolution. The findings are expected to serve as a valuable reference for researchers and practitioners aiming to design new studies and address critical gaps in the literature.

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Conflicts of Interest statement

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

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Emergence Profile Aesthetics in Implant-Supported Lateral Tooth Rehabilitation; 2 Years Follow Up

Tuğba Hergüner^{1-a*}

¹Department of Prosthodontic Dentistry, Faculty of Dentistry, Institute of Health Sciences, Cumhuriyet University, Sivas, Türkiye.

*Corresponding author

Case Report

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ABSTRACT

Anterior aesthetic restorations are among the most challenging areas of prosthetic dentistry. The soft tissue emergence profile of implant-supported restorations plays a critical role in both aesthetics and long-term success. The permanent restoration and the peri-implant mucosa should mimic the natural tooth's relationship with adjacent teeth and soft tissues. However, after the removal of the healing abutment, a circular and narrow soft tissue geometry is often observed. An inadequate emergence profile can negatively affect the cleanability and aesthetics of the restoration. In order to achieve a long-lasting and aesthetic restoration, reshaping of the emergence profile is required. In delayed loading protocols of restorations, the emergence profile can be shaped using a provisional restoration. Although this approach may require more appointments and chair time, considering the clinical outcomes, it enables aesthetic, successful, and cost-effective treatments. In this case report, the process of achieving a successful and harmonious soft tissue emergence profile in an implant-supported lateral incisor restoration is presented.

Keywords: Soft tissue, gingiva, dental implantation, esthetics, dentistry

İmplant Destekli Lateral Diş Rehabilitasyonunda Çıkış Profili Estetiği; 2 Yıllık Takip

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ÖZET

Ön bölgede estetik restorasyonlar, protetik diş tedavisinin en zorlu alanlarından biridir. İmplant destekli restorasyonların yumuşak doku çıkış profili hem estetik hem de uzun vadeli başarı açısından kritik rol oynamaktadır. Kalıcı restorasyon ve implant çevresindeki mukoza, doğal dişin komşu dişlerle ve yumuşak dokularla ilişkisini taklit etmelidir ancak çoğu kez iyileşme başlığı çıkarıldıktan sonra dairesel ve küçük bir yumuşak doku geometrisi izlenmektedir. Uygun olmayan çıkış profili restorasyonun temizlenebilirliğini ve estetiğini etkilemektedir. Estetik ve uzun vadeli bir restorasyon sağlayabilmek için çıkış profilinin yeniden oluşturulması gerekmektedir. Restorasyonun gecikmeli yüklemelerinde çıkış profili şekillendirme geçici bir restorasyonla sağlanabilmektedir. Bu yaklaşımda randevu sayısı ve hasta başında geçen zaman fazla olsa da klinik sonuçlar göz önüne alındığında estetik, başarılı ve aynı zamanda düşük maliyetli tedaviler yapılabilmektedir. Bu olgu sunumunda, implant destekli lateral diş restorasyonunda başarılı ve uyumlu yumuşak doku çıkış profili oluşturma süreci anlatılmaktadır.

Anahtar Kelimeler: yumuşak doku, diş eti, diş implantasyonu, estetik, diş hekimliği

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^a tugbaherguner@cumhuriyet.edu.tr 0000-0001-6655-1145

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Introduction

Dental implants are a widely preferred option in the fixed prosthetic treatment of patients with tooth loss. A successful treatment involves not only the implant itself but also the aesthetics and function of the implant-supported prosthesis. Achieving a successful aesthetic restoration after implant placement is influenced by several factors, including the use of appropriate provisional restorations, shaping of the gingival contour, and the material selected for the final restoration.¹ In anterior regions where aesthetics are critical, the location of the crown margin, the zenith point, and the emergence profile of the gingiva are essential for soft tissue shaping. Implants differ from natural teeth in terms of dimensions and shape at both the crestal bone and mucosal levels. After the healing abutments are removed, the geometry of the gingival emergence profile is circular. This circular form is often incompatible with the anatomical emergence profile of the missing tooth and the contours of adjacent dental tissues.² An appropriate gingival emergence profile not only ensures the aesthetics of the implant-supported prosthesis but also facilitates hygiene, thereby affecting the health of the peri-implant tissues.³

The definitive restoration and the peri-implant mucosa should mimic the relationship between the natural tooth, adjacent teeth, and surrounding soft tissues. In order to achieve a successful and long-term aesthetic outcome, re-establishment of the emergence profile is essential. Various case-specific approaches exist for soft tissue contouring. In delayed loading protocols, peri-implant mucosa can be shaped through controlled and continuous pressure applied with a provisional restoration. This method is also referred to as the dynamic compression technique. In this approach, the provisional restoration supports the gingiva in the interdental area and the emergence profile with appropriate contours, thereby allowing the tissue to be shaped into the desired form.⁴⁻⁷

In soft tissue contouring achieved through provisional restorations, it is recommended to use screw-retained provisional abutments that eliminate the need for cement and to ensure that the surfaces of the provisional restoration are smooth in order to support soft tissue healing. Smoothly prepared restoration surfaces reduce the risk of contamination.⁸⁻¹⁰

When the provisional restoration is placed, the initial response of the peri-implant soft tissue to pressure is of an ischemic nature, typically observed as a temporary moderate blanching of the tissue. In order to manage this reaction, the restoration margins should be adjusted in a controlled manner during the shaping process, and the final emergence profile form should be achieved gradually in stages.¹⁰ During soft tissue shaping with the provisional restoration, the gingival form can be modified, supported, and preserved, allowing the soft tissue profile to be accurately transferred to the definitive restoration. Provisional restorations not only maintain the patient's esthetics and function, but also serve as a diagnostic tool for the final restoration.^{2,11}

Case Report

A 44-year-old female patient presented to the Department of Prosthodontics at Sivas Cumhuriyet University with a complaint of missing tooth number 12. Medical history revealed no systemic diseases and no current medication use. In the patient's dental history, it was learned that there was a mobile primary tooth in the area of tooth number 12, which she had previously lost, and that an implant (Ø3.3 / L13.0 Megagen, Korea) was placed in this area 4 months ago and the healing cap was placed 2 weeks ago (Figure 1A and 1B).

Intraoral examination following removal of the healing abutment revealed that the peri-implant soft tissue contour was insufficient and narrow to support the emergence profile of a lateral incisor (Figure 2). From a labial view, the gingival zenith was not in harmony with the contralateral lateral incisor. The patient declined any minor soft tissue surgical procedures. Given the patient's high esthetic expectations, it was decided to perform soft tissue conditioning prior to the definitive screw-retained zirconia-based ceramic crown restoration. Preparations for the restoration were initiated.

At the first appointment, the healing abutment was removed and a suitable temporary abutment was selected intraorally (Figure 3). To create the desired soft tissue emergence profile, a free-hand composite provisional restoration was fabricated by adding composite resin (3M Filtek Universal Restorative Composite, 3M, USA) both intraorally and extraorally onto the selected abutment. Considering the abutment-composite bonding strength, the restoration was prepared with reduced occlusion (Figure 4). All composite surfaces were carefully polished to promote optimal soft tissue healing.



Figure 1A and 1B: Intraoral view 2 weeks after placement of the healing abutment



Figure 2: Emergence profile after removal of the healing abutment



Figure 3: Selection of the temporary abutment intraorally



Figure 4: Screw-retained temporary composite restoration

After placement and fixation of the provisional restoration, the screw access channel was sealed with an isolation band, but not closed with composite to facilitate future access between appointments. The contours of the restoration were gradually shaped in a controlled manner by incremental additions of composite to avoid soft tissue ulceration or recession. Weekly appointments were scheduled until the desired emergence profile form and width were achieved (Figure 5). During clinical try-ins, the gingival margin was marked using a marker pen, and necessary adjustments were made. The emergence profile of the lateral incisor was fully developed over a 3-week period (Figure 6).

Impression procedures for the definitive restoration were then initiated. The provisional composite restoration was removed for the emergence profile impression. To accurately transfer the soft tissue form, light-body impression material was applied to the emergence surface of the provisional restoration, which was then repositioned intraorally. A-type monophase impression material (Zhermack Hydrorise Monophase, Italy) was used to take an impression over the provisional restoration. After removal, the provisional restoration was connected to an implant analog and transferred into the impression (Figure 7). Opposing arch impressions and the interocclusal relationship were also recorded. Immediately after the maxillary model was

obtained, the provisional restoration was reinserted to maintain soft tissue contours and prevent collapse.

A screw-retained zirconia-based ceramic definitive restoration was fabricated in a dental laboratory. At the clinical try-in, the fit, occlusion, and esthetics of the restoration were evaluated. Following the manufacturer's instructions, the

titanium base (T-base) abutment was torqued to 25 N/cm. The screw access hole was sealed with an isolation band and covered with composite resin to complete the permanent restoration (Figure 8). Intraoral and radiographic evaluations at the 3-month follow-up revealed clinically and patient perceived satisfactory outcomes (Figure 9).



Figure 5: Changes in the emergence profile over time



Figure 6: Emergence profile at the end of the third week

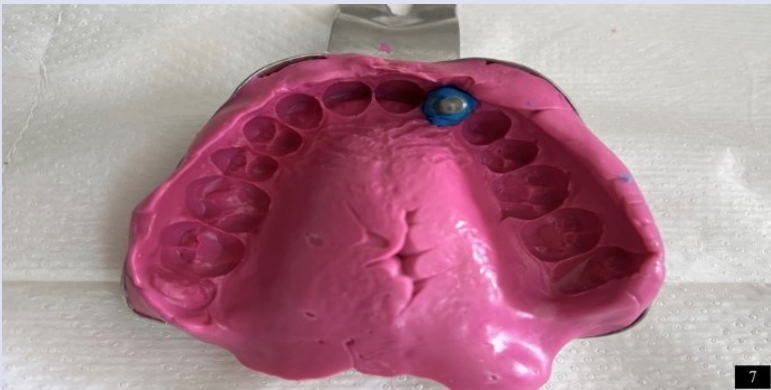


Figure 7: Transfer of the emergence profile to the impression



Figure 8: The final restoration

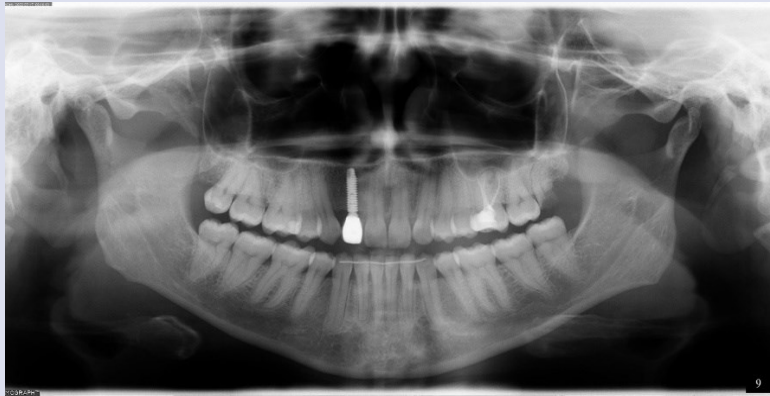


Figure 9: Radiograph of the final restoration at 3 months



Figure 10: Radiograph of the final restoration at 2 years

At the two-year follow-up, the absence of patient-reported complaints was corroborated by consistent intraoral and radiographic findings (Figure 10). The

restoration continued to demonstrate esthetic and functional success (Figure 11A and 11B)



Figure 11A and 11B: Clinical view of the final restoration at 2 years

Discussion

Creating an ideal emergence profile is a challenging procedure that involves various approaches, particularly in esthetically demanding anterior regions. Following implant placement, an additional healing period of up to three months may be required to allow for complete soft tissue healing and osseointegration. In order to accelerate the restorative process in the esthetic zone, immediate provisional restorations can be fabricated after implant placement. There are systematic reviews indicating that peri-implant tissue levels and soft tissue changes are comparable between immediate and conventional loading protocols.^{12,13} In immediate loading protocols, an ideal emergence profile can be achieved without the need for additional surgical intervention by using screw-retained provisional restorations with either temporary or definitive abutments. While some studies suggest that the use of definitive abutments is more beneficial for maintaining marginal peri-implant tissue health, there are also reports indicating that temporary abutments do not result in statistically significant soft tissue loss.^{14–16} However, these procedures are not suitable for all cases, as they are limited by factors such as initial implant stability, hard and soft tissue defects, and occlusal relationships.¹⁷ In this case, since the patient did not present to our clinic within the appropriate timeframe for immediate loading conditions, a treatment plan was developed based on the existing circumstances.

Minor surgical procedures, such as gingivoplasty, can help shape the emergence profile before the placement of provisional restorations; however, such operations can affect the stability of the tissues.^{18–20} In this case, no surgical intervention was performed to modify the emergence profile prior to prosthetic treatment.

Achieving an optimal emergence profile requires careful consideration of various factors from the early stages to the final phases of treatment. When there is sufficient soft tissue, reaching an ideal emergence profile depends on the selection of the implant, the healing abutment, and the appropriate provisional prosthetic restoration.²¹ Different approaches may be preferred in the use of implant-supported provisional restorations depending on the case and timing.²² Spyropoulou *et al.* recorded the soft tissue contours after intraoral soft tissue

conditioning using a provisional restoration made of autopolymerizing acrylic resin. The intraoral use of acrylic resin monomer may cause thermal and chemical irritation to the soft tissues.²³ In this case, composite resin was preferred as the provisional restoration material due to its ease of polishing and ability to accept additions.

Screw-retained provisional restorations can be utilized to achieve an optimal emergence profile. Temporary cements may cause irritation to the soft tissues in cases requiring frequent removal of the provisional restoration. Another advantage of using screw-retained restorations is the elimination of the rough surface created at the crown–abutment interface, providing a highly polished surface that facilitates soft tissue healing.²⁴

In this case report, a screw-retained abutment was preferred to eliminate the disadvantages that may arise from the use of temporary cement between appointments.

Accurate transfer of the emergence profile created by the provisional restoration to the impression is crucial. When the gingiva is left unsupported, it tends to shrink and collapse. Therefore, during the impression phase, the emergence profile should be accurately recorded and adequately supported. Various techniques have been described in the literature to achieve this.^{25,26} With the advancement of technology, many implant companies have developed various components to facilitate provisional restorations and the transfer of the emergence profile.^{27,28} In a study, an ideal emergence profile was achieved by fabricating a temporary restoration using a silicone index, which is indicated in cases where the existing soft tissues have completely healed and need to be shaped entirely through prosthetic procedures.²⁹ In cases where the implant manufacturing company does not offer access to these advantageous components—which reduce the number of appointments and chair time—or when the patient's financial resources are limited, alternative techniques may be considered. Each method presents its own case-specific advantages and disadvantages. Therefore, the most ideal technique is the one tailored to the clinical scenario. Within the limitations of this case report, a suitable approach was selected, resulting in successful long-term outcomes.

Conclusions

The use of provisional restorations to create the gingival emergence profile is currently an acceptable treatment option in clinical practice, providing a natural-looking implant-supported restoration. The emergence profile approach applied in this case successfully met the patient's functional and esthetic expectations. Since a failed prosthetic restoration can negatively impact both the patient's health and aesthetic outcomes despite successful osseointegration of the implant, long-term follow-up of the results is recommended.

Conflict of Interest Statement

No potential conflict of interest to report

Patient consent

Verbal and written signed consent was taken before the rehabilitation.

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