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Relationship Between Digital Literacy, Artificial Intelligence Readiness, and Professionalism Among Dental Students

Diş Hekimliği Öğrencilerinde Dijital Okuryazarlık, Yapay Zeka Hazır Bulunuşluğu ve Profesyonellik İlişkisi

Zeliha Muslu[1*], Ali Sungur[2]

ABSTRACT

Objectives: This study investigated the relationships between clinical dental students' medical AI readiness, digital literacy, and professionalism. Additionally, the potential mediating role of medical AI readiness in the association between digital literacy and professionalism was evaluated.

Materials and Methods: The sample for this cross-sectional analytical study comprised 210 clinical-stage students at the Sivas Cumhuriyet University Faculty of Dentistry. Data were collected using the Digital Literacy Scale (DLS), the Medical Artificial Intelligence Readiness Scale (MAIRS-MS), and the Professionalism Assessment Scale (PAS). Analyses were performed using Spearman's rho correlation and path analysis (p<0.05).

Results: Significant positive correlations were observed between digital literacy, professionalism, and medical AI readiness. Path analysis suggested that digital literacy is a significant correlate of both professionalism and MAIRS-MS. However, medical AI readiness did not significantly mediate the relationship between digital literacy and professionalism in this sample. Notably, the 'Ethics' sub-dimension of medical AI readiness showed significant associations with specific professionalism dimensions.

Conclusions: Digital literacy was observed to be significantly associated with dental students' professionalism and medical AI readiness. The lack of a direct correlation between professionalism and medical AI readiness suggests that AI is not yet fully integrated into professional identity. However, the finding that students who understand the ethical dimension of AI exhibit better professional behavior suggests the need to integrate AI ethics courses into professional training.

Keywords: *Artificial intelligence, Computer literacy, Dental students, Professionalism.*

ÖZET

Amaç: Bu çalışma; klinik dönemdeki diş hekimliği öğrencilerinin yapay zeka hazır bulunuşlukları, dijital okuryazarlık seviyeleri ve profesyonellik algıları arasındaki ilişkiyi incelemeyi amaçlamaktadır. Ayrıca, dijital okuryazarlığın profesyonellik ile ilişkisinde tıbbi yapay zekâ hazır bulunuşluğunun potansiyel aracı rolü analiz edilmiştir.

Gereç ve Yöntemler: Bu kesitsel analitik çalışmanın örneklemini Sivas Cumhuriyet Üniversitesi Diş Hekimliği Fakültesi'nde klinik aşamada olan 210 öğrenci oluşturmuştur. Veriler, Dijital Okuryazarlık Ölçeği (DLS), Tıbbi Yapay Zekâya Hazır Olma Ölçeği (MAIRS-MS) ve Profesyonellik Değerlendirme Ölçeği (PAS) kullanılarak toplanmıştır. Analizler Spearman'ın rho korelasyonu ve yol analizi kullanılarak yapılmıştır ($p < 0{,}05$).

Bulgular: Dijital okuryazarlık, profesyonellik ve tıbbi yapay zeka hazır bulunuşluğu arasında anlamlı pozitif korelasyonlar saptanmıştır. Yol analizi, dijital okuryazarlığın hem profesyonellik hem de tıbbi yapay zeka hazır bulunuşluğu ile anlamlı bir ilişkide olduğuna işaret etmiştir. Bununla birlikte, bu örneklemde tıbbi yapay zeka hazır bulunuşluğunun dijital okuryazarlık ile profesyonellik arasındaki ilişkide anlamlı bir aracı rolü saptanmamıştır. Özellikle, yapay zeka hazır bulunuşluğunun 'Etik' alt boyutu ile belirli profesyonellik boyutları arasında anlamlı ilişkiler bulunmuştur.

Sonuçlar: Dijital okuryazarlık, diş hekimliği öğrencilerinin profesyonelliği ve tıbbi yapay zekaya hazır bulunuşluğu ile anlamlı derecede ilişkili bulunmuştur. Bulgular, tıbbi yapay zeka hazır bulunuşluğunun bu örneklemde dijital okuryazarlık ve profesyonellik arasında anlamlı bir aracılık yapmadığını, ancak yapay zeka etiği ile mesleki davranış arasındaki korelasyonun diş hekimliği müfredatına etik yapay zeka eğitiminin entegre edilmesinin potansiyel faydalarına işaret ettiğini göstermektedir.

Anahtar Kelimeler: *Bilgisayar okuryazarlığı, Diş hekimliği öğrencileri, Profesyonellik, Yapay zeka.*

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Introduction

Artificial intelligence (AI) is a field of computer science that concentrates on creating intelligent systems that demonstrate traits linked to human intellect, including learning, reasoning, and problem-solving.[1] The rapid development and integration of AI applications are transforming healthcare and education models.[2] In dentistry, AI applications are rapidly gaining ground in diagnostic, clinical decision-making, and treatment planning processes, reducing workload, increasing accuracy and improving reliability.[3] Maintaining the high quality offered by AI, particularly in areas such as automated radiological image analysis and prosthesis design, has made it critical for dentists to possess the skills and basic knowledge to evaluate these applications.[4]

AI-powered diagnostic tools are reported to have higher sensitivity than human observers for early caries detection, further highlighting the importance of integrating technology into dental education.[5] To adapt to this technological transformation, individuals must possess certain competencies. Digital literacy, a primary competency, is a multifaceted concept encompassing not only technical skills but also the ability to access information on digital platforms, critically evaluate it, and use it effectively.[6] In dental education, this concept is defined as "future professionals critically interacting with digital health technologies to improve patient care".[7] Another important concept related to digital literacy is AI literacy, which represents the ability to correctly use, identify, and ethically evaluate AI products to adapt to AI-focused digital transformation.[8]

Today, AI applications are effectively used not only in clinical practice but also in dental education. The literature shows that AI-supported personalized feedback systems significantly improve radiographic diagnostic performance among dental students.[9,10] Keeping up with current technologies ensures that prospective dentists have access to accurate information and supports their clinical skills and self-confidence.[10] Today's dental students, as "digital natives" born into technology, have the potential to integrate AI and digital tools into their clinical practice rapidly; however, this technical familiarity does not always translate into correct use of these tools from academic and ethical standpoints.[6] On the other hand, a significant portion of educators in dental faculties remains relatively unfamiliar with these technologies.[11,12] This "digital divide" leads students to turn to unsupervised sources such as social media rather than structured academic guidance and to experience "hallucinations" (false information generated by AI).[13–15] Furthermore, ethical violations, such as breaches of patient data confidentiality and algorithmic bias, demonstrate that these technologies, despite their "life-saving" potential, pose serious risks when not used correctly.[13-16]

The effective use of artificial intelligence applications requires a strong foundation in digital literacy; therefore, these two concepts are closely related. It is argued that if technological advancements are not adequately integrated into educational processes, a mismatch may occur between clinical practices and professional responsibilities, directly jeopardizing patient safety.[17] In this context, digital literacy forms the basic cognitive foundation necessary to understand the technical and ethical dimensions of AI technologies.

Beyond technological capabilities, integrating these tools into clinical decision-making processes necessitates a reinterpretation of professional values. Professionalism, a fundamental pillar of healthcare, encompasses ethical values, responsibility, patient privacy, and lifelong learning.[18] The acceleration of digitalization and AI integration has posed unprecedented questions for professionalism, requiring a re-examination under "digital professionalism" (e-professionalism) to address data security, algorithmic biases, shared decision-making responsibilities, and maintaining a human-centered approach.[19,20]

The effective, safe, and ethical use of medical AI applications is directly related to healthcare professionals' knowledge, attitudes, and integration skills regarding the technology.[21,22] This is where the concept of "AI readiness" comes into play. This concept refers to individuals' capacity to understand, evaluate, and integrate AI technologies into their clinical practice. AI literacy encompasses the ability to understand the basic logic of algorithms, question data quality, and assess the compatibility of system outputs with the clinical context.[22] The literature reports that dental students generally have a positive attitude towards AI, but significant deficiencies exist in their knowledge and application.[10,23] Determining the readiness level of dental students in this area is crucial for curriculum development and the formulation of educational strategies.

The literature suggests a positive correlation between AI readiness and perceptions of professionalism and self-efficacy.[24] However, educators' relative unfamiliarity with these technologies in current dental education leads students to learn these skills from external sources rather than through a structured curriculum. There is still a gap in the literature regarding how digital literacy levels and AI readiness among clinical dental students shape their perceptions of professionalism.[11,25] To address this deficiency, this study aims to examine the relationship between medical AI readiness, digital literacy levels, and perceptions of professionalism among clinical dental students. Furthermore, the potential mediating role of medical AI readiness in the association between digital literacy and professionalism was evaluated. The findings of this investigation are anticipated to illuminate the reshaping of dental education curricula to align with the requirements of digital transformation and contribute to the development of future dentists' professional identity. Our hypothesis is that as students' digital literacy and medical AI readiness levels increase, their perceptions of professionalism and ethical responsibility will also increase proportionally.

Materials and Methods

A cross-sectional, descriptive study was approved by the Sivas Cumhuriyet University Health Sciences Research Ethics Committee under decision number 2025-07/70, dated 31.07.2025. All processes were conducted in accordance with the principles of the Helsinki Declaration. The study population consists of clinical-stage (4th- and 5th-year) students at the Sivas Cumhuriyet University Faculty of Dentistry during the 2025-2026 academic year. No sampling was performed; the aim was to reach the entire population. 210 students (105 fourth-year, 105 fifth-year) who voluntarily participated in the study and completed the questionnaire were included in the analyses. Data were collected between 25.08.2025 and 05.01.2026 through digital questionnaire forms. Informed consent was obtained from the participants before the questionnaire.

Equipment for data collection

Individual Data Form: Contains inquiries regarding participants' age and gender, grade level, and technology use habits.

Medical Artificial Intelligence Readiness Scale: Developed and validated by Karaca et al.[22]., this scale evaluates the readiness of medical and dental students to incorporate AI technologies into their professional practice across cognitive, visionary, and ethical dimensions.

Digital Literacy Scale: Measures individuals' competence in accessing information in the digital world, critically evaluating it, and using it in accordance with ethical guidelines.[6] This Likert-type scale, consisting of 17 items and 4 sub-items, was developed by Ng.[27] The validity and reliability study of the Turkish version was conducted by Hamutoğlu et al.[28]

Professionalism Assessment Scale (PAS): A self-assessment instrument of 22 items developed by Klemenc-Ketis Z and Vrecko H.[29] for medical students. Its adaptation and updating for dental students in Turkey were carried out by Kaşali, Özkal Eminoğlu, Demirer, and Çınar Tanrıverdi.[30] The scale has a structure consisting of three factors: "empathy and humanism," "responsibility," and "professional relationship and development." The higher the score on the scale, the more professionalism is interpreted.

Data Collection Process

Data were gathered from August 25, 2025, to January 05, 2026, using the Google Forms online survey platform. Participants were apprised of the study's objective and granted informed consent. Completing the surveys took approximately 10 minutes.

Statistical Analysis

Statistical analyses were performed using R (version 4.4.1) and IBM SPSS Amos (version 24.0; IBM Corp., Armonk, NY, ABD**)** software. Cronbach's Alpha coefficient was used to evaluate the internal consistency of the scales. The Shapiro-Wilk and Kolmogorov-Smirnov tests were used to assess normality. The Mann-Whitney U Test was used to compare scale scores that did not conform to normality assumptions between pairs of groups. The Kruskal-Wallis test was used to compare scale scores that did not conform to normality assumptions across groups of three or more. Spearman's Test was used to examine the relationship between scale scores that did not conform to normal distribution. The rho correlation coefficient was used. The suitability of the mediating effect model for normality was examined under the assumption of multiple normality. Since the data did not conform to a normal distribution, path analysis was tested using the Bootstrap Maximum Likelihood method. Analysis results were presented as mean ± standard deviation and median (minimum–maximum)/rank mean for quantitative variables. The significance level was set at $p < 0.05$.

Results

This cross-sectional, analytical investigation aimed to ascertain the correlations among digital literacy levels, medical AI readiness, and professional attitudes among dental students. The sample consisted of 210 clinical students (105 (50%) in their 4th year and 105 (50%) in their 5th year) at Sivas Cumhuriyet University Faculty of Dentistry who voluntarily participated in the study. Data were gathered via an online survey tool utilizing a sociodemographic information form, the "DLS," the "MAIRS-MS," and the "PAS".

As presented in Table 1, descriptive statistics on the sociodemographic characteristics and technology use habits of the dental faculty students participating in the study indicate that 69% (n=145) were female and 31% (n=65) were male. The average age of the students was calculated as 22.79 ± 1.53 (Median=23, Min =21, Max =35). Regarding daily internet usage, 42.4% used the internet for 3-5 hours, 33.8% for 1-3 hours, and 21% for 5 hours or more. Instagram was the most used social media platform among dental students, with 61%, while Google Scholar was the most preferred platform for academic research, with 61.3%, followed by PubMed with 23.5%. In terms of digital device use, almost all students (97.6%) used smartphones, and one-third (33.3%) used tablets.

Table 1. Sociodemographic data of participants.

	Frequency	Percentage
Gender		
Male	65	31
Female	145	69
Class		
4th Grade	105	50
5th Grade	105	50
Daily internet usage time		
0-1 hour	6	2.9
1-3 hours	71	33.8
3-5 hours	89	42.4
5 hours and above	44	21
The social media platform you use most often		
Instagram	128	61
X/Twitter	18	8.6
Facebook	1	0.5
TikTok	8	3.8
Other	55	26.2

Your most frequently used academic research site		
PubMed	48	23.5
Scopus	4	2
Google Scholar	125	61.3
ScienceDirect	4	2
Other	23	11.3
Your most frequently used digital devices~		
Smartphone	205	97.6
Tablet	70	33.3
Other	210	100
	Mean ± Standard Deviation	Median (min- max)
Age	22.79 ± 1.53	23 (21-35)

~Multiple Responses

Given the non-normal distribution of the data, the median (minimum–maximum) scores for the scales were as follows: DLS: [64 (17-85)], PAS: [90 (22-110)], and MAIRS-MS: [73 (22-110)]. The internal consistency coefficients (Cronbach's Alpha) for the scales were 0.968, 0.984, and 0.978, respectively. Furthermore, Cronbach's Alpha values for all sub-dimensions of the scales were also found. Alpha coefficients were found to be above 0.817, indicating that the data collection tools have a high level of reliability (Table 2).

Table 2. Descriptive statistics and Cronbach's Alpha values for scale scores.

	Mean ± Standard Deviation	Mean (min -max)	Cronbach's Alpha
Attitude	25.64 ± 6.08	27 (7-35)	0.929
Technical	21.27 ± 5.58	22.5 (6-30)	0.937
Cognitive	7.4 ± 1.85	8 (2-10)	0.855
Social	6.85 ± 1.95	7 (2-10)	0.817
Digital Literacy Scale	61.16 ± 14.45	64 (17- 85)	0.968
Empathy and humanism	41.18 ± 9.1	42 (10-50)	0.975
Professionalism, relationships and development.	32.36 ± 7.08	33 (8-40)	0.948
Responsibility	15.96 ± 3.52	16 (4-20)	0.900
Professionalism Assessment Scale	89.5 ± 19.36	90 (22-110)	0.984
Cognitive	24.9 ± 6.76	24 (8-40)	0.950
Skill	27 ± 7.1	28 (8-40)	0.961
Foresight	9.94 ± 2.77	10 (3-15)	0.939
Ethics	10.4 ± 2.72	11 (3-15)	0.934
Medical Artificial Intelligence Readiness Scale	72.25 ± 17.92	73 (22-110)	0.978

The relationships among the scale scores were analyzed using Spearman's rho, and the results are presented in Table 3. According to the analysis results, a statistically significant, positive, and moderate correlation was found between dental students' digital literacy levels and their professionalism assessments (r = 0.407; p < 0.001). Similarly, a statistically significant, positive, and moderate correlation was found between digital literacy and medical AI readiness levels (r = 0.435; p < 0.001). However, no statistically significant correlation was found between professionalism assessment and medical AI readiness levels (p > 0.05). At the sub-dimension level, significant positive correlations were observed, particularly between the "Tech-

Table 3. Examining the relationship between scale scores.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Attitude	*r*	1													
	p	.													
2. Technical	*r*	0.712	1												
	p	**<0.001**	.												
3. Cognitive	*r*	0.621	0.618	1											
	p	**<0.001**	**<0.001**	.											
4. Social	*r*	0.582	0.755	0.660	1										
	p	**<0.001**	**<0.001**	**<0.001**	.										
5. Digital Literacy Scale	*r*	0.866	0.934	0.737	0.810	1									
	p	**<0.001**	**<0.001**	**<0.001**	**<0.001**	.									
6. Empathy and humanism	*r*	0.392	0.313	0.416	0.283	0.380	1								
	p	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	.								
7. Professionalism, relationships and development	*r*	0.409	0.360	0.411	0.308	0.414	0.849	1							
	p	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	.							
8. Responsibility	*r*	0.392	0.264	0.359	0.300	0.356	0.819	0.791	1						
	p	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	.						
9. Professionalism Assessment Scale	*r*	0.407	0.337	0.428	0.311	0.407	0.952	0.947	0.884	1					
	p	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	.					
10. Cognitive	*r*	0.325	0.426	0.198	0.459	0.404	0.018	0.035	0.074	0.025	1				
	p	**<0.001**	**<0.001**	**0.004**	**<0.001**	**<0.001**	0.793	0.609	0.287	0.719	.				
11th Skill	*r*	0.350	0.438	0.283	0.440	0.416	0.176	0.149	0.136	0.151	0.785	1			
	p	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.011**	**0.031**	**0.049**	**0.029**	**<0.001**	.			
12. Foresight	*r*	0.347	0.405	0.317	0.419	0.417	0.236	0.216	0.209	0.227	0.661	0.799	1		
	p	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.001**	**0.002**	**0.002**	**0.001**	**<0.001**	**<0.001**	.		
13. Ethics	*r*	0.272	0.332	0.311	0.335	0.324	0.249	0.196	0.205	0.224	0.552	0.771	0.850	1	
	p	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.004**	**0.003**	**0.001**	**<0.001**	**<0.001**	**<0.001**	.	
14. Medical Artificial Intelligence Readiness Scale	*r*	0.356	0.454	0.277	0.465	0.435	0.132	0.128	0.117	0.119	0.892	0.956	0.851	0.793	1
	p	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	0.057	0.064	0.092	0.085	**<0.001**	**<0.001**	**<0.001**	**<0.001**	.

r: Spearman's rho Correlation Coefficient nical" sub-dimension of the Digital Literacy Assessment and the "Skills" sub-dimension of the Medical AI Readiness Assessment. On the other hand, a statistically significant but very weak correlation was determined between the 'Empathy and Humanism' dimension of professionalism and the 'Skills' dimension of MAIRS-MS ($r = 0.176$, $p = 0.011$).

The Mann-Whitney U test was used to compare scale scores by gender, and the results are presented in Table 4. As a result of the analysis, the DLS total score showed a statistically significant difference by gender ($p = 0.020$). The median DLS score of male dental students [66 (IQR: 60-72)] was significantly higher than that of female students [63 (IQR: 58-68)]. When the sub-dimensions were examined, significant differences were found in favor of men in the "Technical" (Male=24, Female=22; p=0.002) and "Social" (Male=8, Female=7; p = 0.001) sub-dimensions of the Digital Literacy Scale. In addition, male students (Median = 27) scored significantly higher than female students (Median = 24) on the "Cognitive" sub-dimension of the MAIRS-MS ($p = 0.024$). No significant differences were found between genders in the total score or sub-dimensions of the PAS ($p > 0.05$).

Table 4. Comparison of scale scores by gender.

	Male	Female	Test Statistics	p
Attitude	27 (7:35) / 107.08	27 (7-35) / 104.79	-0.253	0.800 x
Technical	24 (6:30) / 124.67	22 (6-30) / 96.91	-3,061	**0.002** x
Cognitive	8 (2:10) / 115.95	8 (2-10) / 100.82	-1,668	0.095 x
Social	8 (2: 10) / 126.02	7 (2-10) / 96.3	-3,276	**0.001** x
Digital Literacy Scale	66 (19: 85) / 120.07	63 (17-85) / 98.97	-2,326	**0.020** x
Empathy and humanism	41 (10:50) / 102.21	42 (10-50) / 106.98	-0.526	0.599 x
Professionalism, relationships and development.	32 (8:40) / 102.95	33 (8-40) / 106.64	-0.408	0.683 x
Responsibility	16 (4: 20) / 98.02	16 (4-20) / 108.85	-1,194	0.233 x
Professionalism Assessment Scale	91 (22: 110) / 102.12	90 (22-110) / 107.01	-0.539	0.590 x
Cognitive	27 (9:40) / 119.65	24 (8-40) / 99.16	-2,260	**0.024** x
Skill	29 (8:40) / 114.88	27 (8-40) / 101.3	-1,497	0.134 x
Foresight	10 (3:15) / 109.68	10 (3-15) / 103.62	-0.668	0.504 x
Ethics	11 (3:15) / 108.8	11 (3-15) / 104.02	-0.527	0.598 x
Medical Artificial Intelligence Readiness Scale	78 (25: 110) / 116.32	72 (22-110) / 100.65	-1,727	0.084 x

Mann-Whitney U Test; Median (minimum-maximum)/rank mean

The students' scale scores were compared across class levels using the Mann-Whitney U test, and the results are presented in Table 5. According to the analysis findings, a statistically significant difference in the total PAS score was observed across class levels ($p = 0.017$). The median PAS score of 4th-year students who have completed the pre-clinical period and moved on to clinical training (93) is significantly higher than that of 5th-year students (88). A statistically significant decrease was observed in the 'Empathy and Humanism' subscale scores between 4th and 5th-year students ($p = 0.004$). The median score of 4th-year students [43 (min: 10, max: 50)] was significantly higher than that of 5th-year students [40 (min: 10, max: 50)]. However, no statistically significant differences were found in the total scores and sub-dimensions of the DLS and the MAIRS-MS across class levels ($p > 0.05$).

Table 5. Comparison of scale scores by class.

	4th Grade	5th Grade	Test Statistics	p
Attitude	27 (7-35) / 107.33	27 (7-35) / 103.67	-0.437	0.662 x
Technical	23 (6-30) / 112.44	22 (6-30) / 98.56	-1.655	0.098 x
Cognitive	8 (2-10) / 108.74	8 (2-10) / 102.26	-0.773	0.439 x
Social	7 (2-10) / 111.57	7 (2-10) / 99.43	-1.448	0.148 x
Digital Literacy Scale	64 (17- 85) / 110.21	63 (17-85) / 100.79	-1.123	0.261 x
Empathy and humanism	43 (10-50) / 117.45	40 (10-50) / 93.55	-2.850	**0.004** x
Professionalism relationship and development	34 (8-40) / 113.57	32 (8-40) / 97.43	-1.924	0.054 x
Responsibility	16 (4-20) / 111.91	16 (4-20) / 99.09	-1.529	0.126 x
Professionalism Assessment Scale	93 (22-110) / 115.5	88 (22-110) / 95.5	-2.386	**0.017** x
Cognitive	24 (8-40) / 103.82	24 (8-40) / 107.18	-0.400	0.689 x
Skill	29 (8-40) / 107.17	27 (8-40) / 103.83	-0.398	0.691 x
Foresight	10 (3-15) / 108.78	9 (3-15) / 102.22	-0.781	0.435 x
Ethics	11 (3-15) / 107.27	11 (3-15) / 103.73	-0.421	0.674 x
Medical Artificial Intelligence Readiness Scale	73 (22-110) / 106.8	73 (22-110) / 104.2	-0.309	0.757 x

Mann-Whitney U Test; Median (minimum-maximum)/ rank mean

Potential variations in scale results were examined across different durations of daily internet involvement using the Kruskal-Wallis test. This analysis confirmed that the cumulative outcomes of the DLS, Professionalism Assessment Scale, and MAIRS-MS did not differ significantly, with both total and sub-dimension ratings remaining consistent regardless of daily internet usage levels.

One of the main hypotheses of the study, the mediating role of the Medical AI Readiness Scale in the relationship between the DLS and the Professionalism Assessment Scale, was tested using the Bootstrap Maximum Likelihood method (Table 6). An evaluation of the model fit parameters for the proposed structural framework revealed a discrepancy; while GFI=1, CFI=1, and SRMR=0.000 initially suggested a high level of fit, the RMSEA value of 0.522 was significantly above the acceptable threshold, indicating a poor model fit. Consequently, the model's overall fit to the data is considered questionable, and the results are interpreted as statistical associations rather than definitive causal links. According to the path analysis results, the unstandardized path coefficient (β) for the direct relationship of the DLS on the Medical AI Readiness Scale was statistically significant and positive (β = 0.631; 95% CI [0.375, 0.861]; $p < 0.001$). Similarly, the unstandardized path coefficient (β) for the direct association between the DLS and the PAS was also statistically significant and positive (β = 0.841; 95% CI [0.507, 1.148]; $p < 0.001$). However, the unstandardized path coefficient (β) for the link between the Medical AI Readiness Scale and the PAS was not found to be statistically significant (β = 0.029; 95% CI [-0.144, 0.240]; p = 0.769). The mediation analysis revealed that the indirect relationship via the Medical AI Readiness Scale was not statistically significant (β = 0.018; p = 0.765).

Table 6. Structural Model Results

Dependent variable		Independent variable	β^1 (95% CI)	β^2 (95% CI)	S. Error	p	R^2
Medical Artificial Intelligence Readiness Scale	<---	Digital Literacy Scale	0.631 (0.375: 0.861)	0.509 (0.306: 0.671)	0.127	**<0.001**	0.259
Professionalism Assessment Scale	<---	Medical Artificial Intelligence Readiness Scale	0.029 (-0.144: 0.24)	0.027 (-0.138: 0.225)	0.100	0.769	0.412
Professionalism Assessment Scale	<---	Digital Literacy Scale	0.841 (0.507: 1.148)	0.628 (0.415: 0.795)	0.167	**<0.001**	
Digital Literacy Scale --> Medical Artificial Intelligence Readiness Scale --> Professionalism Assessment Scale			0.018 (-0.079: 0.175)	0.014	---	0.765	---

[1]Unstandardized path coefficients, [2]Standardized path coefficients

The structural model used to examine the direct associations among the variables is presented in Figure 1. When the goodness-of-fit indices of the model were examined, GFI=1.00, CFI=1.00, and SRMR=0.000 were observed. However, the RMSEA value of 0.522 indicated a poor fit, suggesting that the model's overall fit to the data is questionable despite other indices. According to the path analysis results, digital literacy was found to have a direct, positive, and statistically significant association with professionalism (unstandardized β = 0.841, standardized β = 0.628, p < 0.001) and medical AI readiness (unstandardized β = 0.631, standardized β = 0.509, p < 0.001).

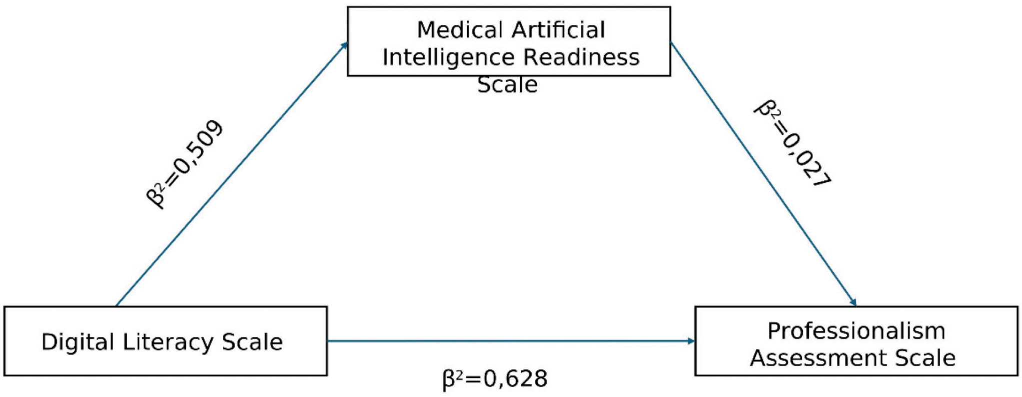

Figure 1. Path analysis model showing the relationships between variables (Standard coefficients)

Discussion

This study investigated the relationships between digital literacy, medical AI readiness, and professionalism levels among dental faculty students. It also examined how these variables were distributed according to various sociodemographic factors. Our findings revealed statistically significant, positive, and moderate correlations between students' digital literacy levels and their professionalism assessments and medical AI readiness. A notable finding from the structural analysis pertains to the evaluation of the mediation model. The analysis suggests that professionalism is significantly associated with digital literacy, while no evidence of a significant mediating role for medical AI readiness was detected in this relationship within this sample.

Our analysis of the data revealed a significant positive correlation between students' digital literacy levels and their professionalism assessments. This situation may suggest that healthcare professionals with higher digital literacy tend to exhibit professional values and ethical behaviors more consistently. The literature emphasizes the importance of digital literacy in areas such as effective communication, accurate information access, and patient safety.[26] The concept of "digital professionalism" proposed by Mather and Cummings[20] also supports this finding. The integration of digital technologies into healthcare settings necessitates the continuation of professional behaviors in digital environments. As students' digital literacy skills improve, they will be able to assume the professional responsibilities required by the digital age more easily. Our path analysis results reveal that digital literacy is significantly associated with both professionalism ($\beta = 0.841$, $p < 0.001$) and medical AI readiness ($\beta = 0.435$, $p < 0.001$) in this sample. The results indicate that digital capabilities affect professional growth processes and are important for future technological integrations. In the literature, digital literacy is defined as the ability to find, critically analyze, and reproduce information in digital environments within an ethical framework. Individuals lacking this fundamental competence are unlikely to safely integrate complex AI algorithms into their professional practice.[6,7] The associations identified in our research suggest that digital literacy is a foundational competency for dental students to integrate these tools with professional standards and ethical responsibilities.[16] This finding emphasizes that inherent technical familiarity, often attributed to 'digital natives,' does not automatically equate to the academic and ethical proficiency required in a clinical setting. Indeed, the positive correlation between perceived professionalism and medical AI readiness is based on the fact that individuals with high levels of digital literacy approach technology with a conscious attitude that prioritizes patient benefit and protects professional values.[15] Consequently, it is theoretically argued that without a solid foundation of digital literacy, students' cognitive and visionary preparation for AI technologies will be incomplete, making it difficult to exhibit professional attitudes in the digitalized healthcare ecosystem.[22,31]

Another noteworthy point of the study is the positive relationship between digital literacy and medical AI readiness. In particular, there is a strong correlation between the "Technical" sub-dimension of the DLS and the "Skills" sub-dimension of the MAIRS-MS. This indicates that students familiar with computers and digital systems are much more receptive to the idea of using artificial intelligence applications in the clinic and feel more competent in this area. Similar results were reported in the study conducted by Sim et al.[32] on dental hygienist students. Given that digital systems underpin artificial intelligence, it is perfectly natural that a student who understands the logic of these systems is better prepared for it.

Our study did not find a statistically significant relationship between professionalism assessment and medical AI readiness. However, studies in the literature report positive relationships between these two concepts. For example, Ta'an et al.[33] found a relationship between professional identity and medical AI readiness among healthcare workers and emphasized the importance of the ethical dimension in particular. Similarly, El-Bassal et al.[34] stated that professionalism moderates the relationship between medical AI readiness and nurses' self-efficacy. Although a weak, statistically insignificant correlation trend ($r = 0.119$, $p = 0.085$) was observed between students' interest in and readiness for AI and their professional attitudes, further analyses (Path Analysis) show that the main factor shaping professional attitudes is Digital Literacy rather than medical AI readiness. This finding leads to the hypothesis that AI may not yet be fully integrated into dental students' ethical and professional value systems, potentially being perceived more as a technical tool rather than an integral component of professional identity. Furthermore, when the relationships between the sub-dimensions of the scales are examined; a statistically significant, positive but weak correlation was found between the 'Ethics' sub-dimension of the Medical AI Readiness Scale and the ' Responsibility ' (r = 0.205, p = 0.003) and 'Professional Relationship and Development' (r = 0.196, p = 0.004) sub-dimensions of the PAS. This suggests a potential association between students' understanding of the ethical dimension of AI and more positive professional behavior attitudes. These findings point toward the possible benefits of integrating AI ethics courses with professionalism training in dental education in this context.

When examining sociodemographic data, it was found that the gender factor created some differences. Male students scored higher on the total score of the DLS and in the "Technical" and "Social" sub-dimensions. Furthermore, it was determined that male students scored higher than female students in the "Cognitive" sub-dimension of the MAIRS-MS. These findings are consistent with some studies in the literature. Aydınlar et al.[16], in their study on health students in Turkey, reported that male students had higher rates of exposure to coding and digital technologies than female students. In another study conducted by Gencer[35] among medical faculty students, it was found that cognitive readiness for AI was significantly higher in male students. Since our study did not directly measure sociocultural or background factors, further qualitative or longitudinal research is required to identify the underlying drivers of these observed gender-based variances in digital competencies.

In our class-level comparisons, we found an unexpected result: 4th-year students scored significantly higher than 5th-year students on the PAS, particularly in the "Empathy and Humanism" sub-dimension. This finding is quite remarkable, as while an increase in professionalism perception is expected in later years of education, the opposite was observed in our study. Studies in the literature report a decrease in empathy levels among students during the clinical years of medical education.[36] On the other hand, a recent study by Çakan and İpek[10] on dental students reported that artificial intelligence readiness peaked in the 2nd year and showed a significant decrease in the 5th year. The cross-sectional nature of our study is a significant limitation in interpreting these findings; tracking changes in students' perceptions of empathy and professionalism longitudinally would provide a deeper understanding of these dynamics.

A notable finding of this study involves the mediation analysis performed via the structural model. The results showed no evidence of a significant mediating role for medical AI readiness in the relationship between digital literacy and professionalism in this sample. Instead, digital literacy was found to be directly and significantly associated with the level of professionalism. This suggests that fundamental digital competencies (information security, digital ethics, critical information literacy) show a stronger association with professional attitudes and behaviors among today's dental students compared to AI-specific skills. AI is rapidly becoming widespread in fields such as radiographic analysis or treatment planning.[37] However, students' current awareness and usage levels regarding these technologies might not yet have reached a depth that is significantly linked to their professional identity development within this sample. In light of these findings, it has been concluded that professionalism among dental faculty students is primarily associated with digital literacy in this sample, and no evidence of a significant mediating role for medical AI readiness was found in this relationship.

While today's dental students belong to the digitally native generation, the relative lack of familiarity between some educators and these technologies may create certain challenges in education. In this process, it is argued that educators should assume the role of "digital mentors," rather than simply being technical experts, guiding students in blending technology with clinical reasoning and professional ethical values [25]. For more effective guidance, literature suggests it is important for educators to update their own digital literacy, incorporate the limitations of AI (such as algorithmic bias) into the curriculum, and position technology as a tool that supports, rather than replaces, clinical decisions.[32] In this way, the technological proficiency of students combined with the professional experience of educators could potentially create a safe and competent foundation for future dental practice.[7]

Our study has several methodological limitations. First, the cross-sectional and self- reported nature of the data collection may lead to common method bias, as all variables were measured at a single time point. Furthermore, given the cross-sectional design, the observed relationships should be interpreted as statistical associations rather than causal proof. Additionally, the exceptionally high Cronbach' s alpha values observed in our scales might suggest item redundancy rather than superior reliability, which should be addressed in future research with more concise tools. A major methodological limitation involves the discrepancy in the structural model fit indices; while the GFI and CFI reached 1.00, the RMSEA value of 0.522 indicates a poor model fit, requiring the path analysis results to be interpreted as preliminary statistical links rather than definitive mechanisms. Despite these limitations, the findings suggest that digital literacy is a significant correlate of both medical AI readiness and professionalism among clinical dental students.

Conclusions

Our results point toward the possibility that students' professional identity in the digital age is more closely associated with core digital competencies than AI-specific technical skills alone. While students demonstrate a general openness to AI, the lack of a significant mediating role for medical AI readiness could suggest that these tools are not yet fully integrated into their professional value systems. Future research encompassing longitudinal designs and larger sample groups would be beneficial for the generalizability and potential causal interpretation of the findings.

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The author declares that there are no financial conflicts of interest with any institution, organization, or individual

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Idea/Concept: Z.M, A.S Design: Z.M, A.S Control/Supervision: Z.M, A.S Materials: Z.M, A.S Data Collection and/or Processing: Z.M, A.S Analysis and/or Interpretation: Z.M, A.S Literature Review: Z.M, A.S Writing the Article: Z.M, A.S Critical Review: Z.M, A.S

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Turkish Orthodontists and Dental Loupes: A Cross-Sectional Survey of Knowledge and Experience

Türk Ortodontistlerin Dental Büyüteçler Hakkındaki Bilgi ve Deneyimi: Bir Anket Çalışması

Hatice Kübra Olkun[1*]

ABSTRACT

Objectives: As dental loupe use has increased within dentistry, little data have been reported for orthodontists. This study aims to determine among Turkish orthodontists the (1) prevalence of dental loupe use, (2) variables associated with dental loupe users and non-users, and (3) awareness of dental loupes.

Materials and Methods: A Turkish-language translation of a previously published 22-question English-language questionnaire on dental loupe use and experience was sent to 1,615 Turkish orthodontic trainees and orthodontists registered with the Turkish Orthodontic Society via e-mail or post, along with a description of the study.

Results: The response rate was 18.39%, and 12 incomplete questionnaires were excluded. Of those included, 8.42% reported using dental loupes. Among these users, significantly more were men (83.33%), aged over 46 years (79.17%), working in private practice (70.83%), had over 25 years of experience (45.83%), and wore corrective lenses (62.50%) ($p<0.01$). Of the 261 indicating they did not use dental loupes, significantly more ($p<0.01$) were women (63.98%), aged 26-30 years (34.87%), orthodontic trainees (45.59%), in a university setting (60.5%), had 5 years or less of experience (54.41%), and did not wear corrective lenses (60.54%). While significantly more non-users endorsed not being interested in buying dental loupes (92.34%), a significant number of non-users gave their reason for not buying dental loupes as not having the opportunity to try them or not having enough information (49.81%).

Conclusion: While methodologically limited, this study revealed that orthodontists in Turkey have low knowledge and use of dental loupes. Further studies should investigate these findings.

Keywords: *Lenses, Orthodontics, Visual aids.*

ÖZET

Amaç: Bu çalışma, Türk ortodontistleri arasında (1) dental büyüteç kullanım yaygınlığını, (2) dental büyüteç kullanan ve kullanmayanlarla ilişkili değişkenleri ve (3) dental büyüteçlere ilişkin farkındalık düzeylerini belirlemeyi amaçlamaktadır.

Gereç ve Yöntemler: Büyüteç kullanımı ve deneyimi ile ilgili daha önce yayınlanmış İngilizce 22 soru formunun Türkçe tercümesi, Türk Ortodonti Derneği'ne kayıtlı 1.615 ortodontist ve ortodonti öğrencisine çalışmanın açıklamasıyla birlikte e-posta veya posta yoluyla gönderildi.

Bulgular: Anketi eksik yanıtlayan 12 kişi hariç tutularak elde edilen yanıtlanma oranı %18,39'dur. Dahil edilenlerin % 8,42'si büyüteç kullanıyordu, önemli ölçüde ($p<0.01$) büyük bir kısmı erkekti (% 83,33), 46 yaşın üstündeydi (% 79,17), özel muayenehanesinde çalışıyordu (% 70,83), 25 yıldan fazla deneyimliydi (% 45,83) ve gözlük kullanıyordu (% 62,50). Büyüteç kullanmadığını belirten 261 kişiden önemli ölçüde ($p<0.01$) büyük bir kısmı kadındı (% 63,98), 26-30 yaş arasındaydı (% 34,87), ortodonti öğrencileriydi (% 45,59), üniversite ortamında çalışıyorlardı (% 60,5), 5 yıl veya daha az deneyime sahipti (% 54,41) ve gözlük kullanmıyordu (% 60,54). Kullanıcı olmayanların çoğu, büyüteç satın almayı düşünmezken (% 92,34), ayrıca önemli bir kısmı büyüteç satın almama gerekçeleri olarak, onları deneme fırsatına sahip olmama veya yeterli bilgiye sahip olmama olarak belirtmişlerdir (% 49,81).

Sonuç: Metodolojik olarak sınırlı olmakla birlikte, bu çalışma Türkiye'deki ortodontistlerin dental büyüteçleri hakkında bilgi ve kullanımının düşük olduğunu ortaya koymuştur. Gelecekte yapılacak çalışmaların bu bulguları doğrulaması ve genişletmesi gerekmektedir.

Anahtar Kelimeler: *Görsel yardımlar, Lensler, Ortodonti.*

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Introduction

Magnification optics, especially dental loupes, have proliferated in dentistry, as dentists seek better tools to see the oral structures and reduce their need to assume unnatural postures that potentially can cause musculoskeletal discomfort.[1,2] In dentistry, magnification optics were first used in endodontics, especially for removal of broken instruments, retrograde filling, opening calcified canals, finding pulp chamber canals, and using the microscope helps find the complex structure of the canals.[3] Other dental specialities use magnification optics as well, including: restorative dentistry, for dentin crack detection, incipient decay detection, and cavity preparation; prosthetic dental treatment; periodontology, for probe reading and periodontal surgery; and maxillofacial and craniofacial surgery.[4-7] Some have even used operative otoscopes in specialist pediatric dentistry.[8]

With the use of smaller braces and more aesthetically acceptable materials (such as ceramic and lingual bracket systems), the importance of bracket positioning, and the widespread awareness of tooth damage during debonding, dental loupes have become increasingly popular in orthodontics.[9] Previous limited research in general dentistry and orthodontics indicates that the integration of magnification significantly enhances visual acuity, thereby improving the precision of bracket placement and facilitating the safer removal of residual composite resin during debonding procedures without damaging the enamel.[9,10] Furthermore, this clinical advantage was validated by Al-Adawi et al., whose controlled micro-morphological analysis demonstrated that clinicians utilizing magnification achieved cleaner enamel margins and significantly fewer micro-scratches during adhesive remnants removal compared to naked-eye conditions.[11] Existing surveys in the literature have also focused on evaluating the ergonomic benefits of loupes, demonstrating a notable reduction in neck and back pain among practitioners who adopt magnification early in their careers.[12] However, data specifically addressing comprehensive survey-based investigations on the use of dental loupes in orthodontics is particularly sparse.[9-12] This study aims to determine among Turkish orthodontists the (1) prevalence of dental loupe use, (2) variables associated with dental loupe users and non-users, and (3) awareness level concerning dental loupes.

Materials And Methods

Ethics Approval And Subject Selection

Institutional review board approval was from Marmara University Non-Interventional Clinical Research Ethics Committee (decision no: 2018-206; date: 28 June 2018). Potential participants were orthodontic trainees and orthodontist members of the Turkish Orthodontic Society (N=1,615).

Instrument Development

The questionnaire consisted of three parts and 22 questions, including: (1) demographic and occupational characteristics of all participants (14 questions), (2) dental loupe feature preference and duration of use (5 questions), and (3) factors presumed to contribute to non-use.

Instrument Translation

The questionnaire was adapted from previous studies[9,13] and the author completed translation into Turkish, with some style editing required. Five orthodontists and 5 orthodontic trainees from the same department evaluated the Turkish translated questionnaire, and their feedback was incorporated into the final draft of the Turkish questionnaire. Finally, the questions were back-translated into English using Google Translate (Google LLC, Mountain View, California, USA) and edited for style by a native English speaker not involved in the study and checked by the author for accuracy.

Instrument Administration, Data Collection, Data Entry, and Exclusion Criteria

Participants were sent the study package by email or in person, which contained (1) a letter stating the purpose of the questionnaire and (2) the questionnaire. Two follow-up communications were transmitted to initial non-responders. Participants receiving an email completed the questionnaire online in Google Forms (Mountain View, California, USA), allowing automatic spreadsheet (Google Sheets, Mountain View, California, USA) data entry. Completed questionnaires received conveyed by hand were entered into the same spreadsheet manually by the author. Questionnaires were accepted for 2 months, beginning from the date of the first email distribution to potential participants. Incomplete questionnaires were excluded from the study.

Risk Of Bias (Quality) Assessment

Because of the limitations of survey studies, bias risk is expected to be high (self-selection bias), but being a small pilot study, this was not formally assessed. Studies involving use of translated materials carry an additional risk for introducing bias. Use of "field-testers" and back-translation of the instrument into English by an uninvolved native English speaker were implemented to reduce this risk. Finally, use automatic data collection was used to reduce the risk of errors and other quality concerns.

Strategy For Data Synthesis

Descriptive statistics (frequencies, mean, standard deviations, percents) were calculated for all variables. Statistical significance for all tests was calculated based on a two-tailed alpha level of 0.05. Chi squared analysis was used for nominal data, such as gender or institution type. For higher order data (i.e., ages), one-way analysis of variance was conducted. Pearson correlation, Tukey honestly significant difference, and linear regression analysis was also calculated, as appropriate, to evaluate possible variables associations with dental loupe use or non-use. No weighting of variables or models to account for heterogeneity were used. Subgroups (i.e., dental loupe users, dental loupe non-users) were each analyzed individually in different data files. Data were analyzed using PSPP, version 1.2.0-g0fb4db (The Free Software Foundation, Boston, MA). No special or additional commands were used. Finally, data will be made available to interested researchers upon reasonable request to the corresponding author.

Results

General

Of 1,615 potential participants, 297 returned questionnaire, and 12 of those returned were incomplete and excluded from the study. Of the 285 (114 male) included respondents, only 8.42% indicated they used dental loupes, significantly more (<0.01) of whom were men (83.33%), aged over 46 years (79.17%), in private orthodontic practice (70.83%), had more than 25 years of experience (45.83%), and wore corrective lenses (62.50%) (Table 1-2). Of the 261 indicating that they do not use dental loupes, significantly more (<0.01) were women (63.98%), aged 26-30 years (34.87%), orthodontic trainees (45.59%), in a university setting (60.5%), had 5 years or less of experience (54.41%), and did not wear corrective lenses (60.54%) (Table 1-2). For both dental loupe users and non-users, significantly more respondents felt the best reason to use dental loupes was to do their work better rather than posture ($p<0.05$) and felt use of dental loupe was an ergonomic benefit ($p<0.05$).

Among all participants, dental loupe use was positively correlated with gender ($p<0.001$), exposure to information about dental loupes ($p<0.01$), glasses use ($p<0.05$), and benefits for positioning brackets ($p<0.001$). Dental loupe use was negatively correlated with age group ($p<0.001$), institution ($p<0.01$), and years of experience ($p<0.001$).

Table 1. Characteristics of Turkish Orthodontists Using Dental Loupes (N=24)

Variable	Outcomes	Result	N
Gender	Men	x2=10.67, df 1, p<0.01	20
Age Group	Aged over 46 years	x2=37.67, df 3, p<0.001	19
Academic rank	Private practice	x2=27, df 3, p<0.001	17
Institution	Private sector	x2=8.17, df 1, p<0.01	19
Years of experience	>25 years of experience	x2=9, df 3, p<0.05	11
Reason for buying	To do my job better	x2=6, df 1, p<0.05	18
Ergonomic Benefits	Yes	x2=10.6, df 1, p<0.001	20
Benefits for positioning brackets	Yes	x2=16.67, df 1, p<0.001	22
Began using	After training	x2=27, df 2, p<0.001	20
Magnification level	2.5x	x2=13, df 2, p<0.01	16
Key desired feature	Depth of field	x2=27, df 2, p<0.001	20

Table 2. Characteristics of Turkish Orthodontists Not Using Dental Loupes (N=261)

Variable	Outcomes	Result	N
Gender	Woman	x2=20.42, df 1, p<0.001	167
Age group	Aged 26-30 years	x2=40.7, df 4, p<0.001	91
Academic rank	Orthodontic trainee	x2=181.66, df 4, p<0.001	119
Institution	University	x2=134.51, df 2, p<0.001	158
Years of experience	0-5 years	x2=156.82, df 3, p<0.001	142
Information on dental loupes	No	x2=157.89, df 1, p<0.001	232
Reason for buying	To do my job better	x2=10.76, df 1, p<0.01	157
Back or neck pain	Yes	x2=7.08, df 1, p<0.01	152
Ergonomic understanding	Yes	x2=36.05, df 1, p<0.001	179
Wear glasses	No	x2=11.59, df 1, p<0.01	158
Type of glasses worn	Distance correction lenses	x2=33.80, df 1, p<0.001	81
Benefits for tooth cleaning	Yes	x2=215.21, df 1, p<0.001	249
Adding dental loupe use to training	Yes	x2=10.76, df 1, p<0.01	157
Consider buying dental loupe	I am not interested	x2=187.13, df 1, p<0.001	241
Reason for not buying	I don't have the opportunity to try or have enough information	x2=358.84, df 6, p<0.001	130

Dental Loupe Users

Among the 24 dental loupe users, significantly (p<0.01) more respondents endorsed using 2.5x magnification (66.67%), depth of field as the most important feature (83.33%), using dental loupes beginning after training (83.33%), and benefits of using dental loupes while positioning brackets (91.67%) (Table 1). All endorsed that they felt dental loupes could be beneficial for tooth cleaning. There were no other significant differences.

Dental Loupe Non-Users

Among the 261 dental loupe non-users, significantly (p<0.01) more endorse that they felt dental loupes could be beneficial for tooth cleaning (95.40%) and that dental loupe use should be added to specialist training (60.15%) (Table 2). While significantly more non-users endorsed not being interested in buying dental loupes (92.34%), a significant number of non-users gave their reason for not buying dental loupes as not having the opportunity to try them or not having enough information (49.81%) (Table 2). There were no other significant differences.

Discussion

Despite a lack of evidence supporting an ergonomic benefit to dentists, dental loupe use continues to steadily rise, but very little is known from an orthodontic perspective. Our study sought to investigate among Turkish orthodontists the (1) prevalence of dental loupe use, (2) variables associated with dental loupe users and non-users, and (3) awareness level concerning dental loupes. While our study has significant methodological limitations, some interesting data resulted that will require future exploration in more robust studies involving larger sample sizes and better bias mitigation overall.

Our data show dental loupe use and awareness are very low among Turkish orthodontic trainees and orthodontists, our target population. Nonetheless, associated variables, especially age, were unsurprising. Similar to our study, Farook et al. [13] also reported that the rate of use of dental loupes is low among faculty and trainees in the UK. Aboalshamat et al. [14] reported that there are few dental professionals who use dental loupes in Saudi Arabia; however, in USA, it dental loupe use is required during endodontic training.[15] More recent global surveys corroborate this trend; for instance, a 2023 follow-up study by Aboalshamat et al. highlighted that while awareness has marginally improved over the last decade, routine clinical integration remains disproportionately low across various dental subspecialties unless mandated by institutional curricula.[16] Furthermore, a recent cross-sectional data demonstrates that specialized dentists are significantly more likely to utilize dental loupes than general practitioners. While current users adopt dental loupes primarily to enhance visual acuity and clinical efficacy,high financial costs and insufficient undergraduate training remain the major barriers to widespread adoption.[17]

Not surprisingly, significantly more dental loupe users in our sample were older and wore corrective lenses. This strong correlation is physiologically expected and directly tied to the onset of presbyopia—the age-related progressive loss of the eye's ability to focus on nearby objects. Forgie et al. [18] reported that dental loupes were used more frequently by dentists in practice for over 30 years. Perrin et al. [19] found that visual acuity can be significantly improved with optical magnification for dentists aged 40 and over. Another study revealed that many dentists were unaware that they had difficulty with visual activity, and optical magnification should be used as early as possible to compensate for the lack of individual or age-related visual activity loss.[20-21] Physiologically, as the crystalline lens loses elasticity with advancing age, the near point of distinct vision recedes, making clinical tasks in the restricted oral cavity increasingly strenuous. This correlation underscores that older orthodontists likely adopt loupes not merely as an ergonomic preference, but as a mandatory compensatory mechanism for presbyopic changes to maintain diagnostic and procedural precision. This finding is heavily supported by modern clinical optical studies, which emphasize that early proactive adoption of magnification—prior to the symptomatic onset of age-related visual degradation—significantly flattens the clinical performance drop-off curve in aging practitioners.[22]

There are two types of loupes: personalized ("through the lens") fixed on the lenses of the glasses[5] and movable ("flip-up"), which tend to be heavier, risk contamination or misalignment during adjustment, but more affordable. Regarding student preferences, Wajngarten et al. [23] reported that students use the personalized type, Pratha et al. [24] reported that 5% of students the personalized type and 95% use movable type. Student preference can reliably and readily be obtained, as many educational institutions encourage or require dental loupe use. Basunbul[25] reported that 20.7% of dental professionals preferred personalized versus movable type loupes. Contrasting these previous findings, our study found no statistically significant difference. This lack of alignment with historical student-preference data might be attributed to the contemporary evolution of ergonomic loupe manufacturing. Advances in lightweight frame materials and declination angle customizability have effectively balanced the pros and cons of both modalities, directly impacting user preferences in modern clinical practice.[26]

Over 90% of dental loupe users in our study felt that bracket placement was enhanced by dental loupe use. While the literature echos this opinion, Panayi et al.[9,12] reported that the use of a dental loupe does not significantly increase the accuracy of bracket position compared to unmagnified vision. An overwhelming number of all respondents in our study felt that cleaning the tooth surface after debonding would be improved with dental loupe use, consistent with the finding by Baumann et al. [10] that the use of dental loupes reduces the likelihood of the formation of enamel defects after bracket removal. This clinical advantage was further validated by Al-Adawi et al.[11] in 2021, whose controlled micro-morphological analysis demonstrated that clinicians utilizing magnification at least 2.5x achieved statistically cleaner enamel margins and significantly fewer micro-scratches during adhesive remnants removal compared to those operating under naked-eye conditions.

The most common magnification level across clinical specialties is 2.5x, with as much as 4.5x used in endodontics or prosthetics;[9] however, the best magnification level for caries determination was 2x and using higher magnification yielded false-positive results and led to unnecessary treatment, according to one study.[27-28] In our study, most of the dental loupe users preferred 2.5x magnification. While not a significant finding among dental loupe users in our sample, using a light source with a dental loupe can provide a shadow-free work area.[29-30]

Magnification, resolution, width of field, depth of field, and price are all important factors to evaluate when considering dental loupes.[9] Farook et al. [13] reported the most important factor when purchasing dental loupes for trainees was price; for faculty, magnification and price were equally important. Perhaps reflecting a different context or clinical need, respondents in our study cited "depth of field" as the most important feature. Clinicians should carefully investigate product options, avoid concentrate exclusively on a single feature, consider their needs, and, if possible, consult an experienced sales representative who can help advise them when considering the purchase of a dental loupe.[9] Unsurprisingly, back and neck pain is frequently reported in general dentistry and was a significant finding in our present study. It is postulated that dental loupes could allow dentists to avoid unnatural positions that can be associated with such discomfort.[31] Seemingly incongruently, our study in orthodontic trainees and orthodontists replicated findings by Hayes et al. [32] that most dental hygienists use a dental loupe to improve their work rather than improve posture.

Interestingly, our finding that the most common reason for non-use was an "inability to try dental loupes or a lack of information on dental loupes" contrasts Farook et al. [13], who found the most common reason for non-use was "price" for trainees and trainers. While not a significant finding in our study, Forgie et al. [18] found that the rate of attending any presentation or conference related to dental loupes was higher in those who used dental loupes compared to those who did not. This finding[18] and our data showing the main reason endorsed for non-use was a lack of exposure seem to suggest greater awareness of dental loupes may sometimes be related to dental loupe use.

Limitations

With a response of only 18.39%, the usability of these data is quite limited. Previous authors investigating dental loupe use among orthodontists also have observed that while electronic surveys can save time, these types of surveys may be plagued by low response rates. We had sought to blunt this effect by also conveying surveys in person to some participants, but this had minimal success. Out of 285 total responses received, 226 were electronic responses versus 71 conveyed by hand. Additionally, the generalizability of our data are limited by the single-nation sample. The skewing of the sample toward young orthodontic trainee non-users especially draws into question the usefulness of these data.

Furthermore, a notable methodological limitation concerns the validation process of the questionnaire.

Although the survey instrument underwent a rigorous forward and backward translation procedure based on two previously published instruments, a comprehensive psychometric validation, including reliability and construct validity analyses (such as Cronographic α testing or factor analysis), was not performed. Due to the exploratory and preliminary nature of this study, the questionnaire was utilized without full statistical cross-cultural adaptation testing, which may limit the standardized reproducibility of our findings.

While our questionnaire was translated from two previously published instruments, a failing of its construction was the lack of questions about posture while working. In the absence of observing participants' posture, questions about time spent in different unnatural positions and their frequency could serve as a proxy for evaluating the ergonomics of clinical work behavior. Future studies should incorporate a formal pilot testing phase and comprehensive psychometric validation of the survey tool, while also incorporating a simulated patient encounter during which a researcher could assess and record data on working posture. Clinical support staff could also be enlisted and trained to rate participants' posture during regular clinical activities in the participants' own setting. Such improvements in defining posture and validating measurement instruments could provide valuable insights that would allow better investigation of dental loupes as a possible remedy.

Conclusion

This study revealed that orthodontists in Turkey have low knowledge and use of dental loupes. While this is a small pilot study with a low response rate, it offers a first glimpse into the orthodontist's view on dental loupe use that may have importance in designing future studies on ergonomics in orthodontics and options for prevention of musculoskeletal discomfort in this dental specialty. It may be useful for further studies to investigate ergonomics of dental loupe users and non-users. Information from such studies may have important implications for patient care and orthodontist performance, health, and job satisfaction.

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Ethical Approval

The study was conducted in accordance with relevant regulations and ethical principles. Institutional review board approval was from Marmara University Non-Interventional Clinical Research Ethics Committee (decision no: 2018-206; date: 28 June 2018).

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Conflict of Interest

The author declares that there are no financial conflicts of interest with any institution, organization, or individual.

Authorship Contributions

Idea/Concept: H.K.O Design: H.K.O Control/Supervision: H.K.O Materials: H.K.O Data Collection and/or Processing: H.K.O Analysis and/or Interpretation: H.K.O Literature Review: H.K.O Writing the Article: H.K.O Critical Review: H.K.O.

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Displacement of Cephalometric Points A and B with Changes in Maxillary and Mandibular Incisor Inclination

Maksiller ve Mandibular Keser Eğimlerindeki Değişikliklere Bağlı Olarak 'A' ve 'B' Noktalarının Konum Değişiklikleri

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ABSTRACT

Objectives: This study aimed to evaluate whether treatment-induced changes in maxillary and mandibular incisor inclination are associated with sagittal and vertical displacement of cephalometric points A and B in skeletally mature, non-extraction patients.

Materials and Methods: Pre- (T0) and post-treatment (T1) lateral cephalograms of 90 skeletally mature patients (45 female, 45 male) were retrospectively analyzed. Inclusion required a complete incisor complement and a minimum 4° change in both UI-SN and IMPA. Tracings were performed with NemoCeph 2025; T0 and T1 cephalograms were superimposed on S-N, with a horizontal reference at 7° to S-N and a vertical reference through Sella. Method error was assessed by remeasuring 30 patients four weeks after the initial measurements, and intra-observer reliability was calculated using a two-way mixed-effects, absolute-agreement, single-measurement model- ICC(A,1). The threshold for statistical significance was set at $p < 0.05$.

Results: Linear regression analysis demonstrated that incisor inclination significantly influenced the sagittal positional change of both landmarks. A 1° increase in the UI-SN angle corresponded to approximately 0.043 mm of posterior displacement of point A, while a 1° increase in IMPA was associated with approximately 0.055 mm of posterior displacement of point B. Vertical changes were largely independent of incisor inclination, except for a statistically significant but clinically negligible association between IMPA and the vertical position of point B. The UI-SN–point A association was stronger in males.

Conclusion: Points A and B are not positionally stable during orthodontic treatment; both undergo sagittal displacement proportional to incisor inclination change, with measurable effects on SNA and SNB.

Keywords: *Anatomic landmarks, Cephalometry, Incisor, Tooth movement techniques.*

ÖZET

Amaç: Bu çalışmanın amacı, iskeletsel gelişimini tamamlamış ve çekimsiz tedavi gören hastalarda maksiller ve mandibular keser eğimindeki tedaviye bağlı değişikliklerin, sefalometrik A ve B noktalarının sagital ve vertikal yöndeki konum değişiklikleri ile ilişkili olup olmadığını değerlendirmektir.

Gereç ve Yöntemler: İskeletsel gelişimini tamamlamış 90 hastanın (45 kadın, 45 erkek) tedavi öncesi (T0) ve tedavi sonrası (T1) lateral sefalometrik radyografları retrospektif olarak incelendi. Çalışmaya dahil edilme kriteri olarak keserlerin tam bulunması ve hem UI-SN hem de IMPA değerlerinde en az 4°'lik değişim arandı. Çizimler NemoCeph 2025 yazılımı ile gerçekleştirildi; T0 ve T1 radyografları S-N düzlemi üzerine süperpoze edildi, S-N'ye 7° açıyla yatay referans ve Sella noktasından geçen dikey referans kullanıldı. Ölçüm hatası, 30 hastada dört hafta sonra tekrar ölçüm yapılarak gözlemci içi güvenirlik, iki yönlü karma etkiler, mutlak uyum ve tekli ölçüm modeli kullanılarak hesaplanmıştır. İstatistiksel anlamlılık düzeyi $p < 0{,}05$ olarak kabul edilmiştir.

Bulgular: Doğrusal regresyon analizinde keser eğiminin her iki noktanın sagital konum değişimini anlamlı düzeyde etkilediği görüldü. UI-SN açısındaki 1°'lik artış A noktası için yaklaşık 0,043 mm posterior hareket ile ilişkili bulundu. IMPA açısındaki 1°'lik artış B noktası için yaklaşık 0,055 mm posterior hareket ile ilişkili bulundu. Vertikal yöndeki konum değişimi çoğunlukla keser eğiminden bağımsızdı; yalnızca IMPA ile B noktasının vertikal konumu arasında istatistiksel olarak anlamlı ancak klinik olarak ihmal edilebilir düzeyde bir ilişki saptandı. UI-SN ile A noktası arasındaki ilişkinin erkeklerde kadınlara kıyasla anlamlı derecede daha güçlü olduğu görüldü.

Sonuç: A ve B noktaları ortodontik tedavi sırasında sabit kalmamakta; her iki nokta da keser eğimindeki değişimle orantılı olarak sagital yönde yer değiştirmekte ve bu durum SNA ile SNB ölçümlerine yansımaktadır.

Anahtar Kelimeler: *Anatomik işaretler, Dişleri hareketlendirme teknikleri, Kesici diş, Sefalometri.*

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Introduction

Lateral cephalometric radiography is the principal two-dimensional record used in orthodontic diagnosis and treatment planning, and most quantitative assessments of skeletal, dental, and soft-tissue relationships still rely on it.[1,2] Among the landmarks used in routine analysis, points A and B occupy a uniquely influential position: they define the anterior limits of the maxillary and mandibular skeletal bases and form the basis of the SNA, SNB, and ANB angles that drive sagittal skeletal classification.[3,4]

Point A, originally described by Downs, lies at the deepest concavity of the anterior maxillary alveolar process, between the anterior nasal spine and the cervical region of the maxillary central incisor.[3] Point B occupies the analogous concavity on the anterior mandibular alveolus, between the lower incisor apex and pogonion.[4] Because both landmarks lie on alveolar bone directly overlying the incisor root apices, their reliability as skeletal reference points has been debated in the cephalometric literature for decades.[5]

The angels derived from these landmarks also have well-documented limitations. Jacobson[6] introduced the Wits appraisal to circumvent the dependence of ANB on cranial-base orientation, Hussels and Nanda[7] demonstrated that ANB can vary substantially even when the underlying sagittal jaw relationship is unchanged, Taylor[8] showed that mandibular rotation alone produces clinically meaningful shifts in ANB, and Bishara et al.[9] documented longitudinal growth-related changes in ANB not paralleled by Wits. Any displacement of A or B itself would therefore propagate directly into the most widely used indices of skeletal discrepancy.

Landmark identification adds a further layer of variability. Although Zamora et al.[10] reported high observer agreement for major points on CBCT-derived images, two-dimensional studies have repeatedly identified point A as among the least reproducible landmarks; Grogger et al.[11] found its x-coordinate to be the dominant source of error variance in nearly every angular measurement examined. Comparative 2D/3D studies report improved reliability for point A on CBCT, and computer-assisted edge detection improves the reproducibility of point B but not point A.[12]

The central clinical question is whether incisor inclination changes during treatment actively displace these landmarks. Erverdi[13] was among the first to formalize a regression relationship between maxillary incisor inclination and the sagittal position of point A. Studies on Class II Division 2 proclination have since reported posterior displacement of A by 1–2 mm, with measurable effects on SNA.[14–16] Comparable findings emerge for incisor retraction following premolar extraction, where point A shifts in the direction of the retracted apex, while Class II Division 2 and Class III patients show markedly different A-point movement per degree of inclination change.[17] For point B, Al-Abdwani et al.[18] found only borderline associations with lower incisor inclination, whereas Neani et al.[19] reported approximately 0.17 mm of B-point retraction per millimeter of lower-incisor retraction in bimaxillary protrusion cases.

Despite this accumulated evidence, the literature remains inconsistent. Discrepancies have been attributed to residual craniofacial growth, differences between 2D and 3D imaging, variation in the type and magnitude of incisor movement, and heterogeneity of malocclusion samples. Few studies have simultaneously controlled for skeletal maturity, restricted treatment to non-extraction mechanics, and quantified the contribution of incisor inclination change using hierarchical statistical models.

The aim of this retrospective study was therefore to evaluate, in skeletally mature individuals treated without premolar extraction, whether changes in maxillary and mandibular incisor inclination are associated with sagittal and vertical displacement of cephalometric points A and B, and to quantify the variance attributable to incisor inclination versus the corresponding skeletal angles (SNA, SNB).

Materials and Methods

This retrospective study was conducted on pre-treatment (T0) and post-treatment (T1) lateral cephalometric radiographs of 90 patients (45 female, 45 male) selected from the archive of the Department of Orthodontics, Faculty of Dentistry, Istanbul Okan University. The required sample size was estimated as a priori for the study's primary analysis — a two-tailed bivariate correlation between treatment-induced incisor inclination change and the sagittal displacement of points A and B. Based on the moderate-to-strong associations reported in previous cephalometric studies, an expected correlation of $\rho = 0.48$ was assumed. At $\alpha = 0.05$ and 90% statistical power, a minimum of 42 patients was required. The final sample of 90 patients (180 cephalograms) comfortably exceeded this requirement. Ethical approval for the study was granted by the Istanbul Okan University Ethics Committee on 15 September 2025 (Decision no. 28).

Inclusion criteria were: (i) completed skeletal growth, defined as Cervical Vertebral Maturation stage CS 5 or CS 6; (ii) a full complement of maxillary and mandibular incisors; (iii) a treatment-induced change of at least 4°, in absolute terms and irrespective of direction (proclination or retroclination), in each of UI-SN and IMPA; and (iv) cephalograms of diagnostic quality. The 4° threshold was applied to the absolute magnitude of change in each angle so that both proclination and retroclination cases were represented and was chosen to ensure that only clinically meaningful inclination changes exceeding the intra-observer method error of the angular measurements were analysed, thereby minimizing the influence of measurement variability. Patients were excluded if they had a cleft lip or palate, any craniofacial syndrome, a history of premolar extraction or orthognathic surgery, prior orthodontic treatment, or evidence of marked root resorption during treatment.

All lateral cephalograms were obtained under standardized conditions with each patient's Frankfort horizontal plane parallel to the floor, the teeth in centric occlusion, and the lips at rest. Digital tracing and measurement were performed with NemoCeph 2025 software (Nemotec S.L., Madrid, Spain), a computer-assisted cephalometric program whose accuracy is comparable to manual tracing and to other widely used digital platforms.[20]

For each patient, T0 and T1 radiographs were superimposed on the anterior cranial base using the S–N line, an approach selected for its stability in skeletally mature individuals and its extensive use in the literature. An individualized coordinate system was then constructed from the S–N line. The horizontal reference axis (Hor.Ref.) was defined at 7° to S–N to approximate the Frankfort horizontal plane, and the vertical reference axis (Ver.Ref.) was drawn perpendicular to Hor. Ref. through Sella. This system allowed the sagittal and vertical components of landmark displacement to be evaluated independently: the perpendicular distance from a landmark to the vertical reference axis represents its sagittal (anteroposterior) position, whereas the perpendicular distance to the horizontal reference axis represents its vertical position. Accordingly, treatment-induced changes in A-Ver.Ref. and B-Ver.Ref. quantify sagittal displacement, while changes in A-Hor.Ref. and B-Hor.Ref. quantify vertical displacement.

The following angular measurements were recorded at T0 and T1: UI-SN, IMPA, SNA and SNB. Linear distances to the horizontal and vertical reference axes were measured in millimeters for the maxillary incisor edge (UI) and apex (UI-Apex), the mandibular incisor edge (LI) and apex (LI-Apex), and points A and B. For every parameter, the treatment-induced change was calculated as T1 − T0.

Statistical Analysis

Method error was assessed by remeasuring 30 patients four weeks after the initial measurements, and intra-observer reliability was calculated using a two-way mixed-effects, absolute-agreement, single-measurement model — ICC(A,1). The threshold for statistical significance was set at $p < 0.05$. Because the correlational analyses were exploratory and hypothesis-generating, no formal correction for multiple comparisons (e.g., Bonferroni) was applied; instead, exact p-values are reported throughout, and the results are interpreted with corresponding caution. All statistical analyses were performed using IBM Statistical Package for the Social Sciences (SPSS) for Windows, version 27 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were reported as mean, standard deviation, median, minimum–maximum, and 25th–75th percentile values for continuous variables, and as frequencies and percentages for categorical variables. The normality of distribution was evaluated with the Shapiro–Wilk test. Relationships between non-normally distributed continuous variables were examined using Spearman's rank correlation analysis. For the mathematical modelling of a dependent continuous variable in relation to its independent predictors, hierarchical linear regression analysis was applied using a block-entry design.

Results

The study sample comprised 90 skeletally mature patients (45 female, 45 male; mean age 26.0 ± 6.2 years). Descriptive statistics for all principal cephalometric variables at T0 and T1, together with the corresponding treatment-induced changes, are presented in Table 1. Method-error analysis demonstrated excellent intra-observer reliability, with ICC(A,1) values ranging from 0.95 to 1.00 across all variables (Table 2); no systematic difference was observed between repeat tracings. Spearman correlations between treatment-induced changes and the displacement of points A and B are summarized in Table 3. The sagittal displacement of point A (Δ A-Ver. Ref.) was moderately negatively associated with the change in UI-SN ($r = -0.608$, $p < 0.001$), indicating that proclination of the upper incisor was accompanied by posterior movement of point A. The same outcome correlated positively with the changes in SNA ($r = 0.393$, $p < 0.001$) and strongly with the sagittal displacement of the maxillary incisor apex ($r = 0.668$, $p < 0.001$). The vertical displacement of point A (Δ A-Hor.Ref.) was related only to the vertical movement of the upper incisor apex ($r = 0.423$, $p < 0.001$). The scatter plot in Figure 1 illustrates the negative linear trend between Δ UI-SN and the sagittal displacement of point A.

Table 1. Descriptive statistics of the principal cephalometric variables (n = 90)

Variable	T0 (mean ± SD)	T1(mean ± SD)	ΔT (T1 − T0) (mean ± SD)
Angular measurements (°)			
UI-SN	101.86±9.56	104.6±11.91	4.02±13.29
IMPA	98.37±10.37	100.69±10.6	4.32±7.91
SNA	79.87±4.15	79.16±3.82	-0.71±1.83
SNB	77.7±4.63	77.66±4.47	-0.03±1.33
Linear measurements (mm)			
A – Hor.Ref. (vertical position of A)	47.51±3.96	47.81±3.92	0.3±1.52
A – Ver.Ref. (sagittal position of A)	63.11±5.11	62.6±5.34	-0.5±1.38
B – Hor.Ref. (vertical position of B)	90.8±6.75	90.55±6.61	-0.25 ±1.4
B – Ver.Ref. (sagittal position of B)	56.99±8.99	57.16±8.88	-0.17±0.94

Table 2. Method-error analyses results

		ICC	%95 CI		p
UI-SN (°)	t0	1.000	1.000	1.000	<0.001*
	t1	1.000	1.000	1.000	<0.001*
IMPA (°)	t0	1.000	1.000	1.000	<0.001*
	t1	1.000	1.000	1.000	<0.001*
HOR.REF-UI APEKS (mm)	t0	1.000	0.999	1.000	<0.001*
	t1	0.999	0.999	1.000	<0.001*
HOR.REF-LI APEKS (mm)	t0	1.000	0.999	1.000	<0.001*
	t1	0.999	0.999	1.000	<0.001*
VER.REF-UI APEKS (mm)	t0	0.999	0.999	1.000	<0.001*
	t1	0.999	0.998	1.000	<0.001*
VER.REF-LI APEKS (mm)	t0	1.000	0.999	1.000	<0.001*
	t1	1.000	0.999	1.000	<0.001*
SNA (°)	t0	1.000	1.000	1.000	<0.001*
	t1	0.999	0.998	1.000	<0.001*
SNB (°)	t0	0.999	0.998	1.000	<0.001*
	t1	0.999	0.998	1.000	<0.001*
A-HOR.REF. (mm)	t0	0.999	0.998	1.000	<0.001*
	t1	0.998	0.997	0.999	<0.001*
A-VER.REF. (mm)	t0	0.999	0.998	1.000	<0.001*
	t1	0.999	0.998	1.000	<0.001*
B-HOR.REF. (mm)	t0	1.000	0.999	1.000	<0.001*
	t1	0.999	0.998	1.000	<0.001*
B-VER.REF. (mm)	t0	1.000	1.000	1.000	<0.001*
	t1	1.000	0.999	1.000	<0.001*

*p<0.05

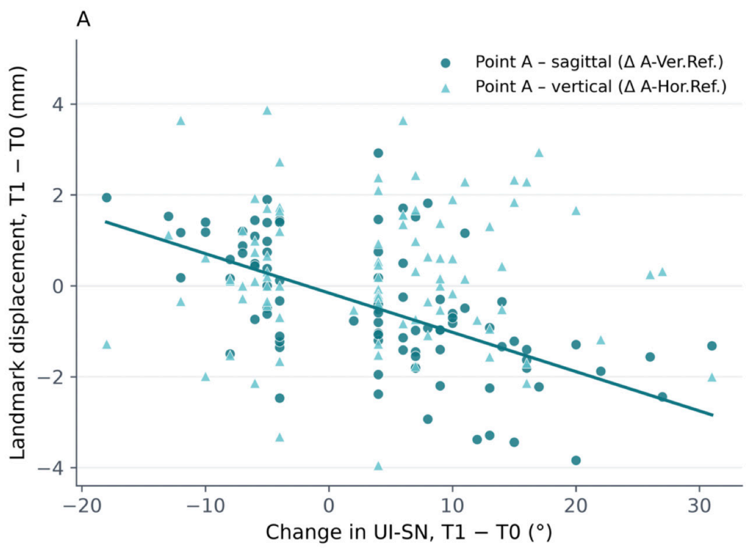

Figure 1. Scatter plot of the relationships between the changes in A-Hor. Ref. (Vertical Position) and A-Ver. Ref. (Sagittal Position) and the changes in UI-SN (T1−T0)

The sagittal displacement of point B (Δ B-Ver. Ref.) correlated negatively with the change in IMPA ($r = -0.488$, $p < 0.01$) and positively with the change in SNB ($r = 0.407$) and with the sagittal displacement of the lower incisor apex ($r = 0.653$, $p < 0.001$) (Table 3). The vertical displacement of point B (Δ B-Hor.Ref.) showed a moderate positive correlation with the vertical movement of the lower incisor apex ($r = 0.530$, $p < 0.001$). In correlation analysis it was not meaningfully associated with IMPA; however, in the hierarchical regression model IMPA reached statistical significance as a predictor of the vertical position of point B, while explaining only a negligible fraction of its variance (adjusted $R^2 \approx 4\%$, $p = 0.014$). The negative linear trend between Δ IMPA and the sagittal displacement of point B is shown in Figure 2.

Table 3. Spearman correlations between treatment-induced cephalometric changes and the displacement of points A and B.

Predictor (ΔT1 − T0)	Outcome	r
Δ UI-SN	Δ A-Ver.Ref. (sagittal A)	−0.608* p<001*
Δ SNA	Δ A-Ver.Ref. (sagittal A)	0.393* p<001*
Δ Ver.Ref. – UI Apex	Δ A-Ver.Ref. (sagittal A)	0.668* p<001*
Δ Hor.Ref. – UI Apex	Δ A-Hor.Ref. (vertical A)	0.423* p<001*
Δ IMPA	Δ B-Ver.Ref. (sagittal B)	−0.488* p<001*
Δ SNB	Δ B-Ver.Ref. (sagittal B)	0.407* p<001*
Δ Ver.Ref. – LI Apex	Δ B-Ver.Ref. (sagittal B)	0.653* p<001*
Δ Hor.Ref. – LI Apex	Δ B-Hor.Ref. (vertical B)	0.530* p<001*

r values; * p < 0.05, Δ A-Ver.Ref. and Δ B-Ver.Ref. = sagittal displacement; Δ A-Hor.Ref. and Δ B-Hor.Ref. = vertical displacement.

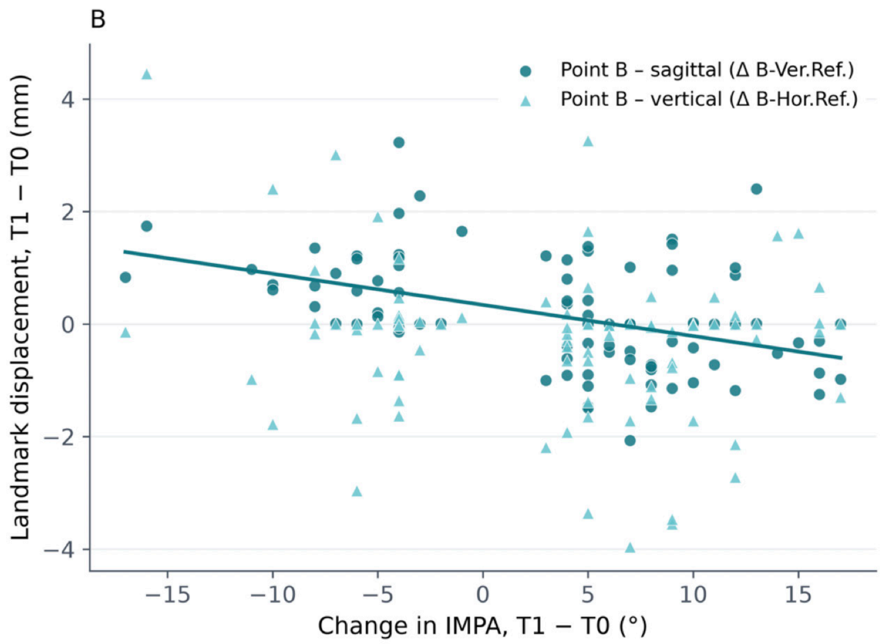

Figure 2. Scatter plot of the relationships between the changes in B-Hor. Ref. (Vertical Position) and B-Ver. Ref. (Sagittal Position) and the changes in IMPA (T1−T0)

As shown in Table 4, the change in UI-SN was strongly and inversely related to the sagittal displacement of the maxillary incisor apex (r = −0.716, p < 0.01), and the change in IMPA was inversely related to that of the mandibular incisor apex (r = −0.674, p < 0.01), that incisor inclination change was driven predominantly by apical movement in the opposite direction.

Table 4. Spearman correlations among incisor inclination, apex displacement, and skeletal angle changes.

Variable pair (ΔT1 − T0)	r
ΔUI-SN ↔ Δ Ver.Ref. – UI Apex	−0.716* p<0.001*
Δ IMPA ↔ Δ Ver.Ref. – LI Apex	−0.674* p<0.001?

* p < 0.05.

When the analysis was stratified by sex (Table 5), the negative association between Δ UI-SN and the sagittal displacement of point A was substantially stronger in males (r = −0.792) than in females (r = −0.454); this difference between the two correlations was statistically significant (Fisher r-to-z, z = 2.69, p = 0.007). The corresponding IMPA–point-B relationship was similar in both sexes (males r = −0.497; females r = −0.439; Fisher r-to-z, z = 0.34, p = 0.73, not significant).

Hierarchical linear regression models are presented in Table 6. For the sagittal displacement of point A, UI-SN alone explained 16.9% of the variance (Model 1: $R^2 = 0.169$, $p < 0.001$); adding age, sex and SNA in Block 2 significantly increased the explained variance to 40.1% ($p < 0.001$). The sagittal displacement of point B, IMPA alone explained 21.5% of the variance (Model 1: $R^2 = 0.215$, $p < 0.001$), rising to 42.8% after Block 2 ($p< 0.001$). In contrast, the vertical displacement of point A was not significantly explained by either model and the vertical displacement of point B was only marginally related to IMPA (Model 1: $R^2 = 0.052$, adjusted $R^2 = 0.044$, $p = 0.014$), with no significant improvement after Block 2.

Table 5. Sex-stratified Spearman correlations between incisor inclination change and the sagittal displacement of points A and B.

Male		UI-SN (T1-T0)	Male		IMPA (T1-T0)
A-HOR. REF. (T1-T0) (mm)	r	0.078	B-HOR. REF.(T1-T0)(mm)	r	-0.090
	p	0.552		p	0.494
A-VER. REF. (T1-T0) (mm)	r	-0.792	B-VER. REF.(T1-T0)(mm)	r	-0.497
	p	<0.001*		p	<0.001*
Female		UI-SN (T1-T0)	Female		IMPA (T1-T0)
A-HOR. REF. (T1-T0) (mm)	r	-0.080	B-HOR. REF.(T1-T0)(mm)	r	-0.249
	p	0.563		p	0.067
A-VER. REF. (T1-T0) (mm)	r	-0.454	B-VER. REF.(T1-T0)(mm)	r	-0.439
	p	<0.001*		p	0.001*

Fisher r-to-z comparison of the male vs female correlations: UI-SN/point A z = 2.69, p = 0.007 (significant); IMPA/point B z = 0.34, p = 0.73 (not significant), A-Ver.Ref. and B-Ver.Ref. = sagittal displacement; A-Hor.Ref. and B-Hor.Ref. = vertical displacement.

Table 6. Hierarchical regression analyses

	β	S.E.	St. β	t	p	%95 CI Lower Limit	%95 CI Upper Limit	VIF
1.Model(B-Ver.Ref). (T1-T0)								
Constant	0.300	0.081		3.693	<0.001*	0.139	0.460	
IMPA (T1-T0) (°)	-0.055	0.010	-0.463	-5.558	<0.001*	-0.074	-0.035	1.000
F:30.895 and p<0.001*				R^2:0.215. Adjusted R^2:0.208				
2.Model								
Constant	0.512	0.297		1.725	0.087	-0.076	1.100	
IMPA (T1-T0) (°)	-0.056	0.009	-0.473	-6.519	<0.001*	-0.073	-0.039	1.003
Age at treatment initiation	-0.007	0.012	-0.048	-0.623	0.534	-0.030	0.016	1.129
Sex	0.003	0.141	0.002	0.022	0.983	-0.275	0.282	1.077
SNB (T1-T0) (°)	0.316	0.059	0.449	5.339	<0.001*	0.199	0.434	1.347
F:16.286 and p<0.001*				R^2:0.428. Adjusted R^2:0.401				
1.Model(B-Hor.Ref). (T1-T0)								
Constant	-0.145	0.146		-0.992	0.323	-0.434	0.144	
IMPA (T1-T0) (°)	-0.044	0.018	-0.228	-2.489	0.014*	-0.079	-0.009	1.000
F:6.193 and p=0.014*				R^2:0.052 Adjusted R^2:0.044				
2.Model								
Constant	0.029	0.622		0.047	0.962	-1.204	1.263	
IMPA (T1-T0) (°)	-0.045	0.018	-0.232	-2.494	0.014*	-0.081	-0.009	1.003
Age at treatment initiation	-0.002	0.024	-0.010	-0.101	0.920	-0.051	0.046	1.129
Sex	-0.281	0.295	-0.092	-0.952	0.343	-0.865	0.304	1.077
SNB (T1-T0) (°)	0.017	0.124	0.014	0.133	0.894	-0.230	0.263	1.347
F:1.442 and p=0.215				R^2:0.062. Adjusted R^2:0.019				
1.Model (A-Ver.Ref.)								
(T1-T0)								
Constant	-0.387	0.121		-3.211	0.002*	-0.626	-0.148	
UI-SN (T1-T0) (°)	-0.043	0.009	-0.411	-4.791	<0.001*	-0.060	-0.025	1.000
F:22.956 and p<0.001*				R^2:0.169. Adjusted R^2:0.161				
2.Model								
Constant	-0.072	0.448		-0.160	0.873	-0.959	0.816	
UI-SN (T1-T0) (°)	-0.018	0.009	-0.176	-2.133	0.035*	-0.035	-0.001	1.245
Age at treatment initiation	-0.009	0.018	-0.038	-0.484	0.629	-0.043	0.026	1.139
Sex	0.267	0.213	0.097	1.249	0.214	-0.156	0.690	1.090
SNA (T1-T0) (°)	0.427	0.071	0.564	6.047	<0.001*	0.287	0.566	1.585
F:14.592 and p<0.001*				R^2:0.401. Adjusted R^2:0.373				
1.Model(A-Hor.Ref.) (T1-T0)								
Constant	0.297	0.146		2.040	0.044*	0.009	0.586	
UI-SN (T1-T0) (°)	-4.321E-08	0.011	0.000	0.000	1.000	-0.021	0.021	1.000
F:0.000 p:1.000								
2.Model								
Constant	1.363	0.627		2.176	0.032*	0.122	2.605	
UI-SN (T1-T0)	0.004	0.012	0.031	0.292	0.771	-0.020	0.027	1.245
Age at treatment initiation	-0.040	0.025	-0.164	-1.631	0.106	-0.089	0.009	1.139
Sex	-0.005	0.299	-0.002	-0.016	0.988	-0.596	0.587	1.090
SNA (T1-T0) (°)	0.037	0.099	0.045	0.378	0.706	-0.158	0.233	1.585
F:0.764 and p=0.578								

*p<0.05. S.E.: Standart Error and St.: Standart

Discussion

The present study evaluated whether changes in maxillary and mandibular incisor inclination are associated with sagittal and vertical displacement of cephalometric points A and B in skeletally mature, non-extraction patients. The sagittal displacement of both landmarks correlated negatively with the inclination change of the adjacent incisor: point A moved posteriorly during proclination, and point B behaved similarly in relation to the lower incisor. In both cases the landmark moved almost in parallel with the corresponding incisor root apex. Adding SNA and SNB to the hierarchical regression models roughly doubled the explained variance in landmark displacement, which suggests that incisor-driven movement of A and B is reflected in the skeletal indices derived from them. Points A and B therefore do not appear to be positionally stable during orthodontic treatment; their displacement is predominantly sagittal and is quantitatively linked to incisor mechanics.

The inverse correlation between Δ UI-SN and the sagittal displacement of point A ($r = -0.608$) is consistent with the regression relationship first described by Erverdi[13] and with the proclination studies on Class II Division 2 patients reported by Bicakci et al.[14], Chen et al.[15], Al-Nimri et al.[16], and Prakash et al.[21] The magnitude of A-point retraction observed in our sample falls within the 1–2 mm range described by these authors. Prakash et al.[21] further reported that the SNA reduction following proclination was approximately equal in millimeters to the A-point retraction, a finding that mirrors our regression result in which SNA emerged as a significant Block 2 predictor of A-point displacement. Chen et al.[15] demonstrated this displacement on CBCT and observed a corresponding statistically significant decrease in SNA, whereas Bicakci et al.[14], using lateral cephalograms, did not detect a statistically significant change in SNA or A-point position.

The retraction studies of An et al.[22], Hassan et al.[23], and Amasyalı et al.[24] - the latter using mini-implant-supported torque-arch mechanics in a Turkish cohort - likewise reported posterior movement of point A with a measurable decline in SNA and ANB.

The strong correlation observed in our study between sagittal displacement of point A and that of the upper incisor apex ($r = 0.668$) is therefore consistent with the alveolar remodeling mechanism described by Hong et al.[25], the large-sample analysis of Sun et al.[26], and the systematic CBCT review by Kuc et al.[27]

For point B, the negative association with IMPA ($r = -0.488$) and the strong correlation with the sagittal displacement of the lower incisor apex ($r = 0.653$) align closely with the proportional displacement (approximately 0.17 mm per millimeter of incisor retraction) reported by Neani et al.[19] and with the lingual displacement of point B described by Marques and Siqueira[28] in dolichofacial Class II Division 1 patients. They contrast, however, with the more attenuated effect described by Al-Abdwani et al.[18], whose generalized estimating equation model accounted for skeletal growth and therefore diluted the inclination effect. Because our sample was restricted to skeletally mature individuals (CS 5 or 6), the influence of residual growth was eliminated as a confounder, which may explain why our model yielded a clearer association. Chen et al.[15], using CBCT in Class II Division 2 patients, similarly reported posterior displacement of point B with effects on SNB, and Xu et al.[29] documented buccolingual narrowing of the mandibular alveolar bone proportional to the retraction distance, with cortical resorption exceeding apposition.

In contrast to the sagittal findings, regression models for the vertical displacement of point A were not significant, and the vertical displacement of point B was only weakly related to IMPA — a statistically significant but clinically negligible association (adjusted $R^2 \approx 4\%$, $p = 0.014$). This pattern resembles the asymmetric outcome reported by Hassan et al.[23], who found that incisor inclination changes affected mainly the vertical position of point A in a small, predictable way (≈ 0.6 mm per 10° of retroclination) but contributed to a much larger combined vertical and forward displacement that was not driven by inclination alone. The limited sensitivity of vertical displacement to inclination in our sample may reflect the well-documented difficulties of identifying the vertical coordinate of point A on two-dimensional cephalograms, as well as the contribution of vertical alveolar remodeling mechanisms (extrusion, intrusion, occlusal plane changes) that are not captured by a single angular variable.[11,12,30]

The substantially stronger UI-SN/A-point correlation in males ($r = -0.792$) than in females ($r = -0.454$) was statistically significant on formal testing (Fisher r-to-z, $z = 2.69$, $p = 0.007$) but remains a tentative observation. Mandibular and maxillary alveolar bone density, cortical thickness, and remodeling capacity have been reported to differ by sex and facial growth pattern in the orthodontic literature; in particular, Kalina et al.[31] showed that the bone-to-tooth (B/T) ratio differs markedly between vertically and sagittally growing individuals, with vertically growing patients exhibiting a substantially lower B/T ratio and therefore a less predictable correspondence between incisor inclination change and overlying alveolar remodeling. Because vertical growth pattern was not stratified in the present study and tends to be unevenly distributed between sexes, part of the observed sex effect may in fact reflect underlying differences in facial divergence rather than sex per se. Because neither age nor sex reached statistical significance in the multivariate regression, this finding should be treated with caution and confirmed in CBCT-based studies on prospectively matched samples before being accepted as a true sex effect.

This study relied exclusively on two-dimensional lateral cephalograms, and small landmark displacements (< 1 mm) may be under- or over-estimated relative to three-dimensional CBCT analysis.[15,30,32] Das et al.[30] specifically showed that point A, which is among the most challenging landmarks to identify on 2D records, is reproduced more reliably on CBCT-derived cephalograms. We did, however, use a digital, computer-assisted workflow (NemoCeph 2025) whose reliability is comparable to manual tracing and to other widely used digital platforms, and we adopted an individualized coordinate system based on S–N superimposition with reference axes constructed at 7° to S–N to minimize the influence of cranial-base orientation.[20] Method-error analysis confirmed acceptable reproducibility. Other limitations include the retrospective design, the restriction to non-extraction treatment, the absence of a control group, and the inability to quantify alveolar remodeling directly; in addition, restricting inclusion to cases with an inclination change of at least 4° may introduce a selection bias toward more pronounced tooth movement, so the associations reported here should not be extrapolated to patients with minimal inclination change. Finally, while we controlled for growth by including only skeletally mature individuals, our findings cannot be extrapolated to growing patients, in whom condylar and sutural changes may independently influence A- and B-point position.[5,18]

The clinical message of these findings is that changes in SNA and SNB observed between pre- and post-treatment cephalograms cannot be interpreted purely as skeletal changes. Soft-tissue outcomes are also affected: Valentim et al.[33] reported a strong correlation between B-point displacement and lower lip position following maxillary incisor retraction, indicating that landmark displacement has both skeletal and aesthetic consequences.

Clinicians should therefore exercise caution when interpreting small post-treatment changes in SNA, SNB, and ANB, particularly when significant proclination or retroclination has been performed. Although the per-degree displacement is small (≈ 0.043–0.055 mm per degree), a clinically common inclination change of 10–15° translates into roughly 0.5–0.8 mm of A- or B-point movement, which is sufficient to shift SNA, SNB and ANB by a few tenths of a degree and thus to affect borderline skeletal classification. The use of additional reference measurements less dependent on incisor-adjacent alveolar landmarks — such as the Wits appraisal or alternative landmarks (the L point, Y point, or related substitutes) — may be considered alongside conventional analyses in cases where substantial incisor inclination change is anticipated.[9,12,34]

Conclusion

In skeletally mature, non-extraction patients, cephalometric points A and B underwent predominantly sagittal displacement proportional to the inclination change of the adjacent incisor. Simple linear regression indicated that point A moved approximately 0.043 mm posteriorly per degree of increase in UI-SN, and point B moved approximately 0.055 mm posteriorly per degree of increase in IMPA. Vertical displacement of both landmarks was largely independent of inclination, with only a weak, clinically negligible association between IMPA and the vertical position of point B. Post-treatment changes in SNA and SNB should therefore be interpreted with caution whenever substantial incisor inclination change has occurred.

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Ethical Approval

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Conflict of Interest

The authors declare that they have no conflict of interest related to this study, including no affiliations with or relationships to any scientific or medical committee members, no consultancy or expert witness roles, no employment in any related company, no shareholdings, or any similar interests.

Authorship Contributions

Idea/Concept: Z.A.A Design: Z.A.A Control/ Supervision: A.E Materials: S.S.Ş.D Data Collection and/ or Processing: S.S.Ş.D Literature Review: S.S.Ş.D Analysis and/or Interpretation: S.S.Ş.D Writing the Article: S.S.Ş.D Critical Review: Z.A.A, A.E

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Trueness and Precision of Conventional vs Digital Impressions in a Kennedy Class III Case

Kennedy Sınıf III Bir Olguda Konvansiyonel ve Dijital Ölçü Yöntemlerinin Doğruluk ve Hassasiyetlerinin Değerlendirilmesi

Dila Polat[1], Alper Aktosun[2*], Sina Saygılı[3], Tonguç Sülün[4]

ABSTRACT

Objectives: This study compared the trueness and precision of conventional alginate impressions (metal tray and custom tray) and a digital impression method in a Kennedy Class III partially edentulous model.

Materials and Methods: A reference model was obtained from a polyether impression and Type III stone cast and scanned to generate reference STL data. As a single-patient repeated-measures study thirty-six impressions were allocated to three groups (n=12): metal tray alginate, custom tray alginate, and digital intraoral scanning. Test STL files were superimposed onto the reference STL, and RMS deviations were calculated for the edentulous area, teeth, palate, and whole arch. Trueness was defined as deviation from the reference model, and precision as within-group repeatability. Data were analyzed using Welch ANOVA/Games-Howell or Kruskal-Wallis/Dunn tests (α=0.05).

Results: No significant difference in trueness was found for the edentulous area (P=0.077). Significant differences were observed for teeth (P<0.001), palate (P=0.029), and whole arch (P=0.011); the digital method showed the highest deviations for teeth and whole arch but the lowest for the palate. For precision, the digital method showed significantly lower deviations in the edentulous area (P=0.004), teeth (P<0.001), and palate (P=0.046), while no difference was found for the whole arch (P=0.172).

Conclusion: The digital method demonstrated trueness comparable to conventional techniques in the edentulous area and superior precision in most regions, supporting its use for Kennedy Class III removable prosthodontic applications despite reduced trueness in tooth-bearing and whole-arch regions.

Keywords: *Prosthodontics, Reproducibility of results, Three-dimensional imaging.*

ÖZET

Amaç: Bu çalışmanın amacı, Kennedy Sınıf III bir modelde konvansiyonel aljinat ölçü yöntemlerinin (prefabrik kaşık ve bireysel kaşık) ve dijital ölçü yönteminin doğruluk ve hassasiyetini karşılaştırmalı olarak değerlendirmektir.

Gereç ve Yöntemler: Referans model, polieter ölçü ve Tip III alçı kullanılarak elde edilmiş ve referans STL verisi oluşturmak amacıyla taranmıştır. Tek hastada ve tekrarlı ölçü alınan bu çalışmada otuz altı ölçü üç gruba ayrılmıştır (n=12): prefabrik kaşık ile aljinat ölçü, bireysel kaşık ile aljinat ölçü ve ağız içi tarayıcı ile dijital ölçü. Test STL verileri referans STL verisi ile çakıştırılmış ve dişsiz bölge, dişler, damak ve tüm ark için RMS sapmaları hesaplanmıştır. Doğruluk, referans modele göre sapma; hassasiyet ise grup içi tekrarlanabilirlik olarak tanımlanmıştır. Veriler Welch ANOVA/Games-Howell veya Kruskal-Wallis/Dunn testleri ile analiz edilmiştir (α=0,05).

Bulgular: Dişsiz bölgede doğruluk açısından anlamlı fark bulunmamıştır (P=0,077). Dişler (P<0,001), damak (P=0,029) ve tüm ark (P=0,011) için anlamlı farklılıklar saptanmıştır; dijital yöntem dişler ve tüm arkta en yüksek, damakta ise en düşük sapmayı göstermiştir. Hassasiyet açısından dijital yöntem dişsiz bölgede (P=0,004), dişlerde (P<0,001) ve damakta (P=0,046) anlamlı derecede daha düşük sapma göstermiş, tüm arkta ise anlamlı fark bulunmamıştır (P=0,172).

Sonuç: Dijital yöntem, dişsiz bölgede konvansiyonel yöntemlerle benzer doğruluk ve çoğu bölgede üstün hassasiyet göstermiştir. Bu bulgular, Kennedy Sınıf III hareketli protez vakalarında dijital ölçülerin kullanılabileceğini desteklemektedir. Ancak dişler bölgesinde ve tüm ark değerlendirmesinde gözlenen daha yüksek sapmalar, tarama ve görüntü birleştirme süreçlerinin genel doğruluğu sınırlayabileceğini düşündürmektedir.

Anahtar Kelimeler: *Protetik diş tedavisi, Sonuçların tekrarlanabilirliği, Üç boyutlu görüntüleme.*

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Introduction

The success of prosthetic treatment in dentistry depends on the biological, functional, and esthetic compatibility of the restorations. Accurate transfer of the form and function of intraoral tissues onto the working model is of major importance in achieving this compatibility. The impression procedure, at this stage of treatment, ensures detailed recording of the teeth and surrounding tissues, thereby influencing the accuracy of the restorations to be fabricated in the laboratory.[1-3]

Kennedy Class III partial edentulism is defined as a unilateral edentulous area bounded by natural abutment teeth on both sides and is planned as a tooth-supported restoration.[4-7] The biomechanical success of this design depends on the accurate recording of the position of the abutment teeth and the rest seats. An impression error may prevent the rests from fully seating in their preparations and may create undesirable lateral forces on the abutment teeth, thereby jeopardizing the long-term success of the prosthesis.

Among conventional impression materials, alginate is the most frequently preferred material owing to its ease of use and cost-effectiveness; however, it has disadvantages such as limited dimensional stability, syneresis, and technique sensitivity.[8,9] Polyether impression material, on the other hand, is regarded as the gold standard among conventional methods because of its high hydrophilicity, detail-reproduction capacity, and dimensional stability, and is frequently used as the reference impression in comparative studies.[8,10,11]

With the integration of digital technologies into dentistry in recent years, intraoral scanners have become increasingly common in clinical practice. Digital impression systems offer advantages such as elimination of material-related errors, increased patient comfort, and direct integration into the digital workflow.[12-14] Nevertheless, the accuracy performance of digital impressions in removable partial denture applications remains an actively investigated topic.

The aim of this study was to comparatively evaluate the trueness and precision values of conventional alginate impressions (prefabricated metal tray and custom tray) and a digital impression method in four different regions in a Kennedy Class III partially edentulous case.

The null hypothesis was that no significant differences would be found among the prefabricated metal tray alginate, custom tray alginate, and digital impression methods in terms of trueness and precision in the edentulous area, teeth, palate, and whole arch regions.

Materials and Methods

This clinical study was conducted at the Department of Prosthodontics, Faculty of Dentistry, Istanbul University; the study protocol was approved by the Istanbul University, Faculty of Dentistry Clinical Research Ethics Committee (ID number: 3902227 decision date: 03/02/2026). Informed consent was obtained from the volunteer patient. One volunteer was included in the study, who fulfilled the criteria of having a Kennedy Class III edentulous arch configuration, preserved periodontal health of the abutment teeth, and the absence of any pathological condition in the intraoral tissues that could affect impression accuracy. This dental arch is classified as Kennedy Class III, Modification 1, with tooth 16 forming a tooth-bounded edentulous space between teeth 15 and 17 on the right side, and teeth 23-26 forming a second tooth-bounded space between teeth 22 and 27 on the left side, with no free-end spaces present in the arch.

A custom impression tray was fabricated from chemically polymerized polymethyl methacrylate (PMMA) (SC Cold Cure Acrylic, Imicryl Dental, Konya, Türkiye) on a model produced from an impression taken with a prefabricated metal tray; the peripheral borders of the tray, the depth of the vestibular sulcus, and the frenum areas were clinically checked and adjusted as needed. The reference impression was obtained using a polyether material (Impregum, 3M ESPE, Seefeld, Germany) with the single-step technique and was poured in Type III dental stone to obtain the reference stone model. This model was scanned with a desktop laboratory scanner (3Shape E4, 3Shape, Copenhagen, Denmark) to generate the reference STL data.

A total of 36 test impressions were divided into the following three groups:

Group I – Prefabricated metal tray, alginate (n=12): An irreversible hydrocolloid material (Zhermack Tropicalgin, Zhermack, Italy) was used with an appropriately sized (No. 3) perforated prefabricated metal tray. The impressions were poured without delay in Type III dental stone (Type III Dental Stone, Cerestone, Turkey) to obtain stone models.

Group II – Custom tray, alginate (n=12): Custom impression trays were fabricated from PMMA on a preliminary model obtained with a prefabricated metal tray and alginate and were tried in clinically with the necessary adjustments. Twelve impressions were taken with the same alginate material and poured by the same method in Type III dental stone.

Group III – Digital impression (n=12): A standardized protocol was followed by the same operator using an intraoral scanner (Allied Star AS260E, Alliedstar Co, Shanghai, China) directly in the patient's mouth. The scanning sequence was as follows: occlusal surfaces first, followed by palatal, and finally buccal surfaces. Each scan was saved in STL format and transferred to the digital environment.

All test STL data were superimposed onto the reference STL using computer software (Geomagic Control X, 3D Systems, Rock Hill, SC, USA) by first applying an “Initial Alignment” and then a “Best-Fit Alignment” algorithm. Analyses were performed separately for four different anatomical regions: (1) whole arch (Figure 1A), (2) edentulous area (Figure 1B), (3) palate (Figure 1C), (4) teeth (Figure 1D). Deviation values for each region were calculated using the Root Mean Square (RMS) method. Trueness was defined as the mean deviation of each test group from the reference model, and precision was defined as the repeatability consistency within each group.[15]

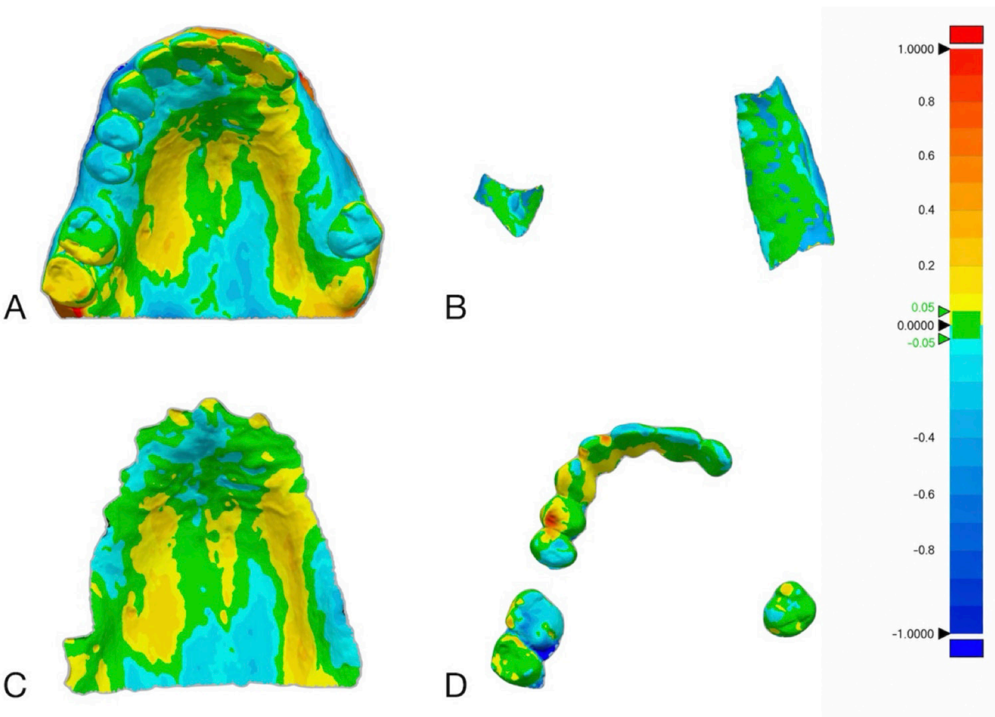

Figure 1. Regions selected for trueness and precision analyses. (A) Whole arch, (B) edentulous area, (C) palate, and (D) Teeth.

The adequacy of the sample size was evaluated using GPower software (GPower version 3.1.9.7; Heinrich Heine University Düsseldorf, Düsseldorf, Germany). The calculation was based on a medium effect size commonly used in repeated-measures method-comparison studies (Cohen's f = 0.25; equivalent to Cohen's d ≈ 0.5). A significance level of α = .05, a statistical power of 80% (1−β = 0.80), and three impression methods (conventional impression with a prefabricated tray, conventional impression with a custom tray, and digital impression) were assumed. The G*Power analysis indicated that a minimum of 10 repeated measurements per group was required to reliably detect differences among the methods. Therefore, 12 repeated measurements were performed for each impression method. This sample size exceeded the minimum requirement in order to increase statistical power and better account for measurement variability.

The normality of data distribution was assessed with the Shapiro-Wilk test, and homogeneity of variances with the Levene test. For normally distributed data, Welch ANOVA and the Games-Howell post hoc test were used; for non-normally distributed data, the Kruskal-Wallis test with Bonferroni-corrected Dunn post hoc test was used. The level of statistical significance was set at α=0.05 for all analyses.

Results

The regional trueness values of the different impression methods are presented in Table 1. A significant difference was found for the whole arch region (P=0.011) (Figure 2A). The digital impression showed the highest deviation (0.269±0.0113 mm). No statistically significant difference was found among the three methods for the edentulous area (P=0.077) (Figure 2B). The deviation values for Groups I, II, and III were 0.125±0.0496 mm, 0.108±0.0360 mm, and 0.0932±0.0112 mm, respectively. A significant difference was found among the methods for the palate region (P=0.029) (Figure 2C). The digital impression yielded the lowest deviation (0.246±0.0126 mm). A significant difference was found among the methods for the teeth region (P<0.001) (Figure 2D). The highest deviation was observed in Group III (0.183±0.00891 mm), and the digital method differed statistically significantly from the other two groups.

Table 1. Effect of different impression types on impression trueness

	Impression Type							
	Group I		Group II		Group III		Test Statistic	*P*
Region	mean±sd	median (min-max)	mean±sd	median (min-max)	mean±sd	median (min-max)		
Edentulous area	0.125 ± 0.0496	0.116 (0.0725–0.227)	0.108 ± 0.0360	0.0983 (0.0676–0.172)	0.0932 ± 0.0112	0.0955 (0.0748–0.105)	3.01	0.077
Teeth	0.174 ± 0.0750	0.159 (0.131–0.410)[b]	0.172 ± 0.0229	0.166 (0.149–0.234)[ab]	0.183 ± 0.00891	0.186 (0.164–0.193)[a]	14.72	<0.001
Palate	0.261 ± 0.0277	0.259 (0.218–0.308)[ab]	0.271 ± 0.0234	0.282 (0.241–0.310)[b]	0.246 ± 0.0126	0.244 (0.227–0.270)[a]	7.05	0.029
Whole Arch	0.258 ± 0.0433	0.251 (0.220–0.389)[b]	0.264 ± 0.0232	0.260 (0.239–0.313)[ab]	0.269 ± 0.0113	0.268 (0.256–0.298)[a]	8.96	0.011

[a-b]Groups sharing the same letter in the same row are not significantly different from each other.

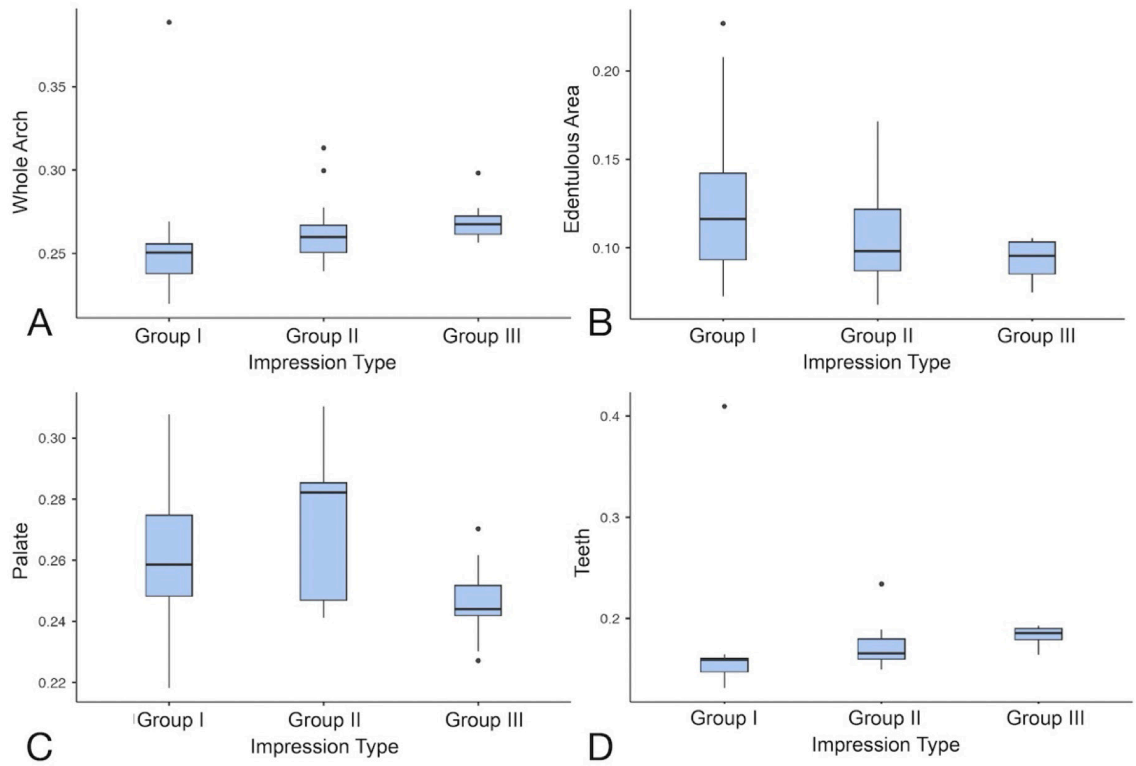

Figure 2. Trueness values of the different impression methods. (A) Whole arch, (B) edentulous area, (C) palate, and (D) teeth.

The precision values of the different impression methods are presented in Table 2. For the whole arch, although the deviation values of the digital impression were lower (0.008±0.008 mm), the difference among the methods was not significant (P=0.172) (Figure 3A). A significant difference was found among the groups for the edentulous area (P=0.004) (Figure 3B). The lowest deviation (highest precision) was observed in Group III (0.010±0.004 mm). A significant difference was found for the palate region (P=0.046) (Figure 3C). The digital impression showed a significantly lower deviation (0.009±0.008 mm). A significant difference was found among the methods for the teeth (P<0.001) (Figure 3D). Group III exhibited the highest precision (0.007±0.005 mm).

Table 2. Effect of different impression types on impression precision

	Impression Type							
	Group I		Group II		Group III		Test Statistic	*P*
Region	mean±sd	median (min-max)	mean±sd	median (min-max)	mean±sd	median (min-max)		
Edentulous area	0.037 ± 0.031[c]	0.023 (0.004–0.102)	0.028 ± 0.021[b]	0.026 (0.005–0.063)	0.010 ± 0.004[a]	0.010 (0.002–0.018)	8.13	0.004
Teeth	0.039 ± 0.063	0.020 (0.009–0.236)[b]	0.016 ± 0.016	0.012 (0.003–0.062)[ab]	0.007 ± 0.005	0.006 (0.001–0.019)[a]	15.02	<0.001
Palate	0.021 ± 0.017	0.014 (0.002–0.046)[ab]	0.021 ± 0.009	0.019 (0.011–0.040)[b]	0.009 ± 0.008	0.005 (0.001–0.024)[a]	6.15	0.046
Whole Arch	0.024 ± 0.035	0.013 (0.003–0.131)	0.017 ± 0.016	0.012 (0.000–0.050)	0.008 ± 0.008	0.007 (0.000–0.029)	3.52	0.172

[a-c]Groups sharing the same letter in the same row are not significantly different from each other.

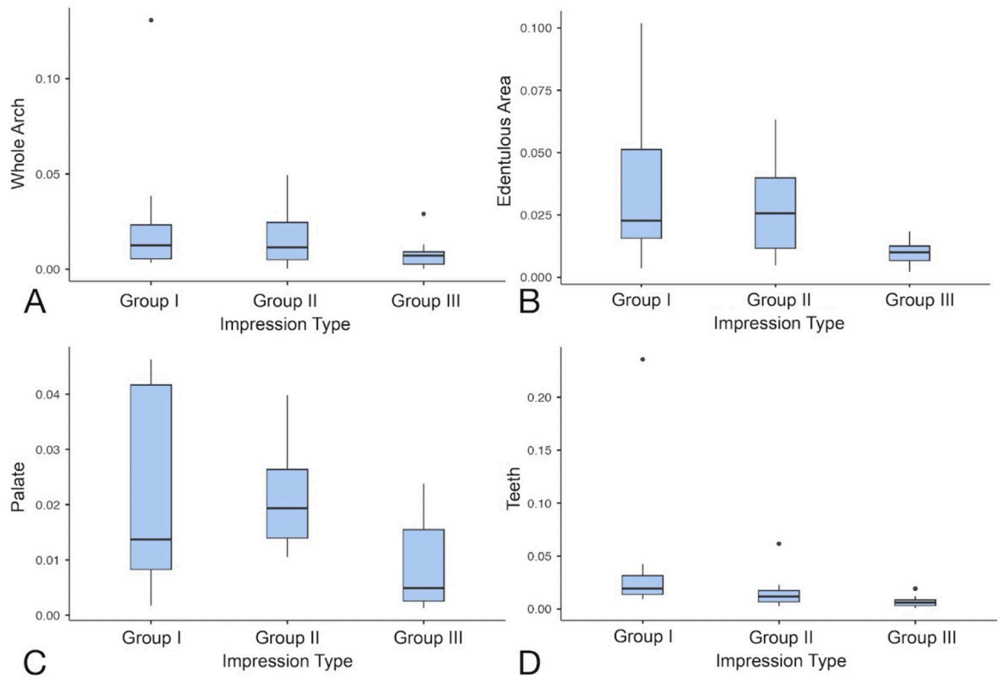

Figure 3. Precision values of the different impression methods. (A) Whole arch, (B) edentulous area, (C) palate, and (D) teeth.

Discussion

The null hypothesis was partially rejected, as significant differences among the impression methods were identified in several regions for both trueness and precision analyses.

The digital method exhibited high precision; however, it did not demonstrate the same superiority in terms of trueness in every region. In Kennedy Class III, the edentulous space is bounded by teeth on both sides; this may facilitate the image-stitching process during digital scanning, as the adjacent teeth provide additional anatomical references. Indeed, Hayama et al.[16] reported that digital impressions showed higher trueness compared with conventional impressions in the partially edentulous mandible. Diker and Tak[17], and Lee et al.[18], emphasized that the number of missing teeth, the length of the edentulous span, and the scanning strategy can affect the trueness of digital impressions, and that trueness may decrease in wider and more complex edentulous areas. In this context, the absence of a significant difference for the edentulous area in the present study suggests that digital and conventional methods may converge in a short and limited Kennedy Class III span.

The highest deviation in the teeth region was reported for the digital impression. This finding indicates that the digital dataset exhibits a consistent but lower trueness profile. The literature reports that scanning strategy, image stitching algorithm, and operator experience can affect trueness.[17,19,20] Therefore, the deviation observed in the tooth bearing regions cannot be explained by material differences alone; scanning strategy and software algorithms are also considered to play a determining role.

In the palate region, the digital impression yielded the most favorable results in terms of both trueness and precision. This may be explained by the elimination, in the digital workflow, of the cumulative error sources present in the conventional chain, such as material deformation, tray pressure, model pouring, and stone expansion. However, Frank et al.[21] showed that the trueness of the palatal vault in models obtained from irreversible hydrocolloid impressions depends not only on the tray type but also on the pouring steps. In addition, in the in vivo study by Yao et al.[22], the deviation of the palate region was found to be higher than that of the tooth bearing area. Therefore, the palatal superiority observed in the present study indicates that the digital method is advantageous in this specific anatomy and workflow, and a universal generalization should not be made.

In the whole arch trueness analysis, the digital method showed the highest mean deviation, whereas Group I showed the lowest value. This may be explained by the fact that the whole arch analysis evaluates the teeth, edentulous area, and palate as a single entity, which renders the cumulative errors of digital scanning more apparent.[17,18,23]

In terms of precision, the digital method yielded the lowest deviation in all regions, and this advantage reached statistical significance in the edentulous area, tooth, and palate regions. The elimination of the error margin arising from numerous variables in conventional methods—such as mixing the impression material, loading the tray, removal from the mouth, disinfection, and model pouring—explains the superior repeatability of the digital system. Indeed, Garrofé et al.[24] reported that time significantly affects the dimensional stability of irreversible hydrocolloid materials; this finding supports the wide distribution observed in repeated conventional impressions.

The findings of Schimmel et al.[20] and Alfaraj et al.[23] demonstrated that precision is highly dependent on the scanner used and the clinical scenario. Therefore, the precision data of the present study reflect only the repeatability obtained in this specific digital workflow and in this Kennedy Class III case.

From a clinical perspective, these data indicate that the digital approach is a strong candidate, particularly in terms of precision, for Kennedy Class III removable partial denture cases. The fact that the trueness of the edentulous area was comparable with conventional methods, together with the marked precision advantage in the edentulous area and palate region, supports the applicability of digital impressions in such cases.[16,20,22]

The main limitation of this study is that it was based on a repeated-measures design performed in a single patient. Therefore, the precision results obtained reflect repeatability within the same patient, whereas the trueness results reflect proximity to the reference model in this specific anatomy. Since the study represents only a single Kennedy Class III scenario, the findings cannot be generalized to different span lengths, palatal anatomies, scanner systems, or operators.

Conclusion

In this clinical study, comparing conventional and digital impression methods in a Kennedy Class III partially edentulous case, the following conclusions were reached:

1. In terms of edentulous-area trueness, the intraoral scanner exhibited a performance comparable to the conventional alginate methods; this finding indicates that digital systems can successfully record the morphology of the edentulous region in Kennedy Class III cases.

2. The digital impression exhibited statistically significantly higher precision than the conventional methods in the edentulous area, tooth, and palate regions. The minimization of operator- and material-related error sources explains this superiority of the digital system.

3. In the tooth region and over the whole arch surface, digital scanning showed higher deviation values compared with the polyether reference impression. This finding indicates that image-stitching errors in long-arch scans can adversely affect trueness.

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Ethical Approval

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Conflict of Interest

The authors declare no conflicts of interest regarding the subject matter or materials discussed in this article.

Authorship Contributions

Idea/Concept: S.S Design: S.S Control/ Supervision: S.S, T.S Materials: D.P, S.S, Data Collection and/ or Processing: D.P, A.A Literature Review: D.P, A.A Analysis and/or Interpretation: D.P, A.A Writing the Article: D.P, A.A Critical Review: S.S, T.S

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Temporomandibular Eklem Artrosentezi: Uygulama Teknikleri, İntraartiküler Ajanlar ve Dekstroz Proloterapisinin Güncel Rolü: Narratif Derleme

Temporomandibular Joint Arthrocentesis: Application Techniques, Intra-Articular Agents, and the Current Role of Dextrose Prolotherapy: A Narrative Review

Halil İbrahim Durmuş[1]*, Kağan Fatih Kuşan[2]

ÖZET

Temporomandibular eklem (TME) artrosentezi, özellikle redüksiyonsuz disk deplasmanı ve kapalı kilit gibi internal derangement olgularında ağrının azaltılması ve mandibular hareket açıklığının artırılması amacıyla kullanılan minimal invaziv bir tedavi yöntemidir. Bu teknik; eklem içi inflamatuar mediatörlerin uzaklaştırılması, eklem içi basıncın azaltılması ve adezyonların mekanik olarak çözülmesi yoluyla etki göstermektedir. Günümüzde artrosentez, konservatif tedaviler ile cerrahi girişimler arasında önemli bir tedavi basamağı olarak kabul edilmekte olup, uygun hasta seçimi ile yüksek klinik başarı oranları sunmaktadır. Artrosentez uygulaması çift girişli (double-puncture) ve tek girişli (single-puncture) tekniklerle gerçekleştirilebilmektedir. Çift girişli teknik, eklem boşluğunun daha etkin irrigasyonuna olanak sağlarken; tek girişli teknikler daha az invaziv olmaları ve hasta konforunu artırmaları nedeniyle son yıllarda daha fazla tercih edilmektedir. Bununla birlikte, mevcut literatürde teknikler arasında belirgin bir üstünlük gösterilememiştir ve klinik sonuçların büyük ölçüde eklem içi patolojinin derecesi ve cerrahın deneyimi ile ilişkili olduğu bildirilmektedir. Artrosentez sonrası eklem içi ajan uygulamaları tedavi etkinliğini artırmak amacıyla sıklıkla kullanılmaktadır. Hyaluronik asit, kortikosteroidler ve otolog biyolojik ürünler yaygın olarak araştırılmıştır. Son yıllarda dekstroz proloterapisi ise rejeneratif etkileri nedeniyle dikkat çekmektedir. Dekstrozun kontrollü inflamatuar yanıt oluşturarak fibroblast aktivasyonu ve kollajen sentezini artırdığı, böylece eklem stabilitesine katkı sağladığı bildirilmektedir. Bu derlemenin amacı, TME artrosentezi uygulama tekniklerini ve kullanılan eklem içi ajanları değerlendirmek, özellikle dekstroz proloterapisinin güncel rolünü ve klinik etkinliğini ortaya koymaktır.

Anahtar Kelimeler: *Artrosentez, Dekstroz proloterapisi, Hiyalüronik asit, İntraartiküler enjeksiyon, Temporomandibular bozukluklar.*

ABSTRACT

Temporomandibular joint (TMJ) arthrocentesis is a minimally invasive treatment modality used primarily to reduce pain and improve mandibular range of motion in cases of internal derangement, particularly nonreducing disc displacement and closed lock. This technique exerts its therapeutic effect through the removal of intra-articular inflammatory mediators, reduction of intra-articular pressure, and mechanical lysis of adhesions. Currently, arthrocentesis is regarded as an important treatment option between conservative therapies and surgical interventions, offering high clinical success rates when appropriate patient selection is performed. Arthrocentesis can be performed using double-puncture and single-puncture techniques. The double-puncture technique allows for more effective irrigation of the joint space, while single-puncture techniques are preferred more in recent years due to their less invasive nature and improved patient comfort. However, the current literature has not demonstrated a clear superiority between the techniques, and clinical outcomes are reported to be largely related to the degree of intra-articular pathology and the surgeon's experience. Intraarticular agent applications after arthrocentesis are frequently used to improve treatment efficacy. Hyaluronic acid, corticosteroids, and autologous biological products have been widely investigated. In recent years, dextrose prolotherapy has attracted attention due to its regenerative effects. Dextrose is reported to increase fibroblast activation and collagen synthesis by creating a controlled inflammatory response, thus contributing to joint stability. The aim of this review is to evaluate the techniques and intraarticular agents used in TMJ arthrocentesis, and to highlight the current role and clinical efficacy of dextrose prolotherapy in particular.

Keywords: *Arthrocentesis, Dextrose prolotherapy, Hyaluronic acid, Intra-articular injection, Temporomandibular disorders.*

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Giriş

Temporomandibular eklem bozuklukları (TMB), çiğneme kaslarını, temporomandibular eklemi ve ilişkili yapıları etkileyen heterojen bir hastalık grubudur ve toplumda %5–15 oranında semptomatik olarak görülmektedir.[1,2] Bu bozukluklar; travma, parafonksiyonel alışkanlıklar, inflamatuar süreçler, dejeneratif değişiklikler ve eklem biyomekaniğindeki bozulmalar gibi çok faktörlü etiyolojik nedenlerle ortaya çıkabilmektedir.[3,4] Klinik olarak en sık görülen semptomlar arasında ağrı, eklem sesleri, mandibular hareket kısıtlılığı ve fonksiyonel bozukluklar yer almakta olup, bu durum hastaların yaşam kalitesini önemli ölçüde etkilemektedir.[5,6]

TMB tedavisinde öncelikle konservatif yaklaşımlar tercih edilmekte olup; oklüzal splintler, farmakoterapi, fizik tedavi ve davranışsal tedaviler yaygın olarak uygulanmaktadır.[7] Ancak bu yöntemlere yanıt vermeyen olgularda minimal invaziv ve cerrahi tedavi seçenekleri gündeme gelmektedir. Temporomandibular eklem artrosentezi, bu tedavi basamakları arasında yer alan ve ilk kez Nitzan ve ark.[8] tarafından 1991 yılında tanımlanan etkili bir yöntemdir. Bu teknik, üst eklem boşluğunun irrigasyonu yoluyla inflamatuar mediatörlerin uzaklaştırılması, adezyonların çözülmesi ve eklem içi basıncın azaltılması prensibine dayanmaktadır.[9,10] Güncel kanıta dayalı derlemeler, artrosentezin ağrı kontrolü ve mandibular fonksiyonun iyileştirilmesinde etkili bir minimal invaziv yaklaşım olduğunu desteklemektedir.[11,12]

Artrosentez prosedürü zamanla çeşitli teknik modifikasyonlar ile geliştirilmiş olup, tek iğneli ve çift iğneli yöntemler en yaygın kullanılan teknikler arasında yer almaktadır.[13,14] Bununla birlikte, artrosentez sonrası eklem içi ajan uygulamaları, tedavi etkinliğini artırmak amacıyla yaygın olarak kullanılmaktadır. Hyaluronik asit, kortikosteroidler ve trombositten zengin plazma gibi ajanlar üzerine yapılan çalışmalar, ağrı kontrolü ve fonksiyonel iyileşme açısından olumlu sonuçlar bildirmiştir.[15-17]

Son yıllarda, dekstroz proloterapisi TMB tedavisinde yeni bir yaklaşım olarak öne çıkmaktadır. Dekstrozun, kontrollü inflamatuar yanıt oluşturarak fibroblast proliferasyonunu ve kollajen sentezini artırdığı, böylece ligamentöz yapıların güçlenmesine ve eklem stabilitesinin artmasına katkı sağladığı düşünülmektedir.[18,19] Ayrıca farklı konsantrasyonlarda dekstroz solüsyonlarının eklem içi veya periartiküler uygulanmasının ağrı ve fonksiyon üzerinde olumlu etkiler gösterdiği bildirilmiştir.[20]

Son yıllarda temporomandibular eklem artrosentezi ile ilgili çalışmaların sayısında belirgin bir artış gözlenmekte olup, özellikle eklem içi ajanların etkinliğine yönelik araştırmalar dikkat çekmektedir. Bununla birlikte, literatürde farklı teknikler ve ajanlar arasında klinik üstünlüğe dair net bir konsensüs bulunmamaktadır. Özellikle dekstroz proloterapisinin rejeneratif etkileri son dönemde ön plana çıkmış olmakla birlikte, bu ajanın artrosentez ile kombine kullanımına ilişkin kanıtlar sınırlı ve heterojendir. Bu nedenle, temporomandibular eklem artrosentezi ve artrosentez sonrası kullanılan ajanlara ilişkin mevcut literatürün güncel veriler ışığında değerlendirilmesi, tedavi seçeneklerinin etkinliğinin karşılaştırılması ve klinik uygulamalara yönelik çıkarımlar yapılması önem arz etmektedir.

Bu derlemenin amacı, temporomandibular eklem artrosentezi uygulama tekniklerini ve kullanılan eklem içi ajanları güncel literatür ışığında değerlendirmek, özellikle dekstroz proloterapisinin klinik etkinliğini ve potansiyel rolünü kapsamlı bir şekilde tartışmaktır.

Literatür Tarama Yöntemi

Bu çalışma narratif derleme olarak hazırlanmıştır. Literatür taraması PubMed, Scopus, Web of Science ve Google Scholar veri tabanlarında gerçekleştirilmiştir. Taramada "temporomandibular joint arthrocentesis", "TMJ arthrocentesis", "intra-articular injection", "hyaluronic acid", "platelet-rich plasma", "PRP", "ozone therapy", "botulinum toxin", "dextrose prolotherapy" ve "temporomandibular disorders" anahtar kelimeleri kullanılmıştır. Özellikle son 10 yıl içerisinde yayımlanan sistematik derlemeler, meta-analizler, randomize kontrollü çalışmalar ve yüksek düzeyde kanıt sunan araştırmalar değerlendirilmiştir. Konu ile ilişkili temel ve sık atıf alan klasik çalışmalar da derlemeye dahil edilmiştir.

Temporomandibular Eklem Patofizyolojisi

Disk Deplasmanı

Temporomandibular eklem (TME) iç bozukluklarının en önemli patofizyolojik bileşenlerinden biri artiküler diskin kondil ve temporal kemik arasındaki normal anatomik konumundan sapmasıdır. Disk deplasmanı genellikle anterior veya anteromedial yönde gerçekleşmekte olup, redüksiyonlu veya redüksiyonsuz formlarda görülebilmektedir. Redüksiyonsuz disk deplasmanı, kondilin translasyonunu mekanik olarak engelleyerek mandibular hareket kısıtlılığına ve kapalı kilit tablosuna yol açmaktadır. Bu durum, retrodiskal dokular üzerinde artmış yüklenme ve ağrı oluşumu ile ilişkilidir.[2,3]

İnflamasyon

TME bozukluklarında inflamasyon, ağrı ve fonksiyon kaybının temel belirleyicilerinden biridir. Eklem içi inflamatuar süreçlerde interlökin-1β (IL-1β), tümör nekroz faktör-α (TNF-α) ve prostaglandinler gibi mediatörlerin artışı gösterilmiştir. Bu mediatörler sinovyal membranda inflamasyonu artırarak kıkırdak dejenerasyonu ve ağrı oluşumuna katkıda bulunmaktadır. Ayrıca kronik inflamasyon, eklem içi adezyonların gelişmesine ve eklem hareketlerinin daha da kısıtlanmasına neden olabilmektedir.[11,12]

Sinovyal Değişiklikler

TME'de sinovyal sıvı ve sinovyal membranda meydana gelen değişiklikler, eklem fonksiyonunun bozulmasında önemli rol oynamaktadır. Normalde lubrikasyon sağlayan sinovyal sıvının viskozitesinde azalma ve biyokimyasal içeriğinde değişiklikler meydana gelmektedir. Bu durum eklem yüzeyleri arasındaki sürtünmeyi artırarak dejeneratif süreçleri hızlandırmaktadır. Ayrıca sinovyal hiperplazi ve vasküler değişiklikler, inflamatuar sürecin devamlılığını destekleyerek eklem içi patolojinin kronikleşmesine katkı sağlamaktadır.[11,12]

Artrosentezin Etki Mekanizması

Temporomandibular eklem (TME) artrosentezi, eklem içi patolojilerin yönetiminde temel olarak mekanik ve biyokimyasal etkiler yoluyla terapötik fayda sağlamaktadır. Bu yöntem, üst eklem boşluğunun izotonik solüsyonlar ile irrigasyonu sayesinde eklem içi basıncın azaltılmasına, inflamatuar mediatörlerin uzaklaştırılmasına ve eklem içi adezyonların mekanik olarak çözülmesine katkıda bulunmaktadır.[8,11]

Artrosentez sırasında uygulanan hidrolik basınç, özellikle sinovyal sıvı dolaşımını artırarak eklem içindeki toksik ve proinflamatuar maddelerin uzaklaştırılmasını kolaylaştırmaktadır. Bu süreçte interlökinler ve prostaglandinler gibi ağrı ve inflamasyondan sorumlu mediatörlerin konsantrasyonu azalmakta, böylece hem ağrı kontrolü sağlanmakta hem de fonksiyonel iyileşme desteklenmektedir.[11,12]

Ayrıca artrosentez, eklem boşluğunda oluşan fibröz adezyonların mekanik olarak ayrılmasına yardımcı olarak kondil-disk hareketinin yeniden kazanılmasını sağlamaktadır. Bu durum özellikle kapalı kilit ve internal derangement olgularında mandibular hareket açıklığının artmasına katkıda bulunmaktadır.[8,12]

Bazı klinik uygulamalarda, artrosentez sonrasında eklem içine hiyalüronik asit, kortikosteroidler veya trombositten zengin biyolojik ajanlar gibi ek tedavi edici maddeler enjekte edilmektedir. Bu ajanlar, sinovyal lubrikasyonu artırarak eklem yüzeyleri arasındaki sürtünmeyi azaltmakta ve inflamatuar sürecin baskılanmasına katkıda bulunarak tedavi etkinliğini artırabilmektedir.[12,15]

Artrosentezin Endikasyonları

Temporomandibular eklem (TME) artrosentezi, konservatif tedaviye yanıt vermeyen hastalarda minimal invaziv bir tedavi seçeneği olarak öne çıkmakta olup, çeşitli klinik durumlarda etkinliği gösterilmiştir. En sık endikasyonlar arasında redüksiyonsuz disk deplasmanı (closed lock), ağrı ile birlikte mandibular hareket kısıtlılığı ve konservatif tedaviye dirençli olgular yer almaktadır.[21,22] Bununla birlikte, literatürde artrosentezin kullanım alanı daha geniş bir klinik spektrumu kapsamaktadır.

Redüksiyonsuz Disk Deplasmanına Bağlı Kapalı Kilit ve Mandibular Hareket Kısıtlılığı
Redüksiyonsuz disk deplasmanına bağlı gelişen kapalı kilit tablosu, ani ağız açma kısıtlılığı ve ağrı ile karakterizedir. Artrosentez, eklem içi adezyonların çözülmesi ve eklem içi basıncın azaltılması yoluyla mandibular hareket açıklığını artırmaktadır. Hem akut hem de kronik çene açıklığı kısıtlılıklarında etkili olduğu bildirilmiştir.[23-25]

Ağrı ile Birlikte İçsel Eklem Bozuklukları
Kronik ağrı ile birlikte diskin anterior yönde yer değiştirdiği, ancak redüksiyonun kısmen devam ettiği olgularda da artrosentez uygulanabilmektedir. Bu hastalarda eklem içi inflamasyonun azaltılması ve sinovyal dolaşımın iyileştirilmesi ile ağrı kontrolü ve fonksiyonel iyileşme sağlanmaktadır.[21,24]

Dejeneratif Osteoartrit
TME osteoartriti, eklem yüzeylerinde dejenerasyon, kıkırdak kaybı ve inflamasyon ile karakterize ilerleyici bir hastalıktır. Artrosentez, eklem içi yıkama ile katabolik mediatörlerin uzaklaştırılması ve sinovyal ortamın iyileştirilmesi sayesinde osteoartritli hastalarda ağrının azaltılmasına ve fonksiyonun artırılmasına katkı sağlamaktadır. Bu nedenle dejeneratif eklem hastalıklarında destekleyici bir tedavi seçeneği olarak değerlendirilmektedir.[22,26]

Açık Kilit (Open Lock)
Açık kilit, mandibular kondilin artiküler diskin önünde sıkışması sonucu ağız kapama fonksiyonunun bozulduğu bir durumdur. Nadir görülmekle birlikte, uygun vakalarda artrosentez ile eklem içi basıncın düzenlenmesi ve mekanik engelin ortadan kaldırılması hedeflenebilir.[26]

Eklem İçi Enfeksiyon ve İnflamatuar Hastalıklar
Seçilmiş vakalarda artrosentez, eklem içi enfeksiyonların drenajı ve inflamatuar yükün azaltılması amacıyla da kullanılabilmektedir. Ayrıca romatoid artrit gibi inflamatuar eklem hastalıklarında, sinovyal inflamasyonun kontrol altına alınmasına yardımcı olabileceği bildirilmiştir. Ancak bu durumlarda hasta seçimi ve aseptik koşullar büyük önem taşımaktadır.[21,26]

Konservatif Tedaviye Yanıtsız Olgular
Splint tedavisi, farmakoterapi ve fizik tedavi gibi konservatif yaklaşımların başarısız olduğu hastalarda artrosentez önemli bir ara basamak tedavi olarak kabul edilmektedir. Düşük morbiditeye sahip olması ve cerrahi girişim ihtiyacını azaltabilmesi nedeniyle klinik pratikte sık tercih edilmektedir.[22,25]

Artrosentez Uygulama Teknikleri
Temporomandibular eklem (TME) artrosentezi, üst eklem boşluğuna minimal invaziv girişimle ulaşılarak eklem lavajının sağlanması, eklem içi adezyonların giderilmesi ve inflamatuar mediatörlerin uzaklaştırılması amacıyla uygulanan etkili bir tedavi yöntemidir. Günümüzde artrosentez teknikleri, eklem boşluğuna erişim şekline göre temel olarak tek girişli ve çift girişli teknikler şeklinde sınıflandırılmakta olup, klinik gereksinimlere göre çeşitli modifikasyonlar geliştirilmiştir.[21,26,27]

Tek İğne Tekniği
Tek iğne tekniği, üst eklem boşluğuna tek bir giriş noktası üzerinden ulaşılarak hem sıvı enjeksiyonu hem de aspirasyon işlemlerinin aynı kanül aracılığıyla gerçekleştirildiği bir yöntemdir. Bu teknikte basınç altında verilen sıvı ile eklem boşluğu genişletilmekte ve ardından aynı iğne aracılığıyla sıvı geri aspire edilmektedir.

Bu yaklaşımın en önemli avantajları arasında işlem süresinin kısalığı, teknik uygulama kolaylığı ve hasta konforunun yüksek olması yer almaktadır. Ayrıca tek giriş noktası kullanılması, cerrahi travmayı azaltarak postoperatif ağrı ve komplikasyon riskini düşürebilmektedir. Bununla birlikte, sürekli akışlı bir lavaj sağlanamaması nedeniyle irrigasyon etkinliğinin sınırlı olabileceği bildirilmektedir.[26,28]

Özellikle ileri derecede adezyon bulunan veya ikinci iğne yerleştirilmesinin zor olduğu olgularda tek iğne tekniği klinik olarak avantaj sağlayabilmektedir.[26]

Çift İğne Tekniği
Çift iğneli artrosentez tekniği, TME artrosentezinde en yaygın kullanılan klasik yöntem olup, üst eklem boşluğuna iki ayrı iğne

yerleştirilmesi esasına dayanır.[8] Bu teknik, eklem içine verilen irrigasyon sıvısının ikinci iğne aracılığıyla sürekli olarak dışarı alınmasına olanak sağlayarak etkin bir lavaj oluşturur.

Giriş noktalarının belirlenmesinde genellikle Holmlund–Hellsing hattı referans alınır. Posterior giriş noktası tragusun yaklaşık 10 mm anteriorunda ve 2 mm inferiorunda, anterior giriş noktası ise bunun yaklaşık 10 mm önünde konumlandırılır. İşlem çoğunlukla lokal anestezi altında gerçekleştirilir ve aurikulotemporal sinir blokajı uygulanır.

Lavaj sırasında genellikle 100–300 mL arasında Ringer laktat veya fizyolojik serum kullanılmakta olup, basınçlı irrigasyon sayesinde:

- İnflamatuar mediatörler uzaklaştırılır
- Eklem boşluğu genişletilir
- Fibröz adezyonlar mekanik olarak çözülür

Bu özellikleri nedeniyle çift iğneli teknik, özellikle internal derangement ve osteoartrit olgularında etkili bir yöntem olarak kabul edilmektedir.[11,21,23]

Bununla birlikte, iki iğnenin yerleştirilmesinin teknik zorluk oluşturabilmesi ve bazı hastalarda toleransın sınırlı olması bu yöntemin dezavantajları arasında yer almaktadır.[22]

Modifiye Artrosentez Teknikleri

Klasik tekniklerin sınırlamalarını azaltmak ve klinik başarıyı artırmak amacıyla çeşitli modifiye artrosentez yöntemleri geliştirilmiştir. Bunlar arasında en yaygın kullanılan yaklaşımlardan biri, Alkan ve Etöz tarafından tanımlanan modifiye artrosentez tekniğidir. Bu teknikte, ilk iğne ile eklem boşluğuna sıvı verilerek üst eklem kompartmanında hidrostatik basınç oluşturulmakta ve ikinci giriş noktası bu basıncın oluşturduğu distansiyon yardımıyla daha kolay belirlenmektedir. Bu yaklaşım, özellikle dar eklem boşluğuna sahip hastalarda ikinci iğnenin yerleştirilmesini kolaylaştırmakta ve işlem süresini kısaltabilmektedir. Ayrıca tekniğin uygulanabilirliği yüksek olup günümüzde klinik pratikte yaygın olarak kullanılmaktadır. Yapılan çalışmalar, modifiye tekniğin ağrı azalması ve ağız açıklığındaki artış açısından klasik çift iğne tekniği ile benzer klinik sonuçlar sağladığını göstermektedir.[10]

Basınçlı Lavaj (Pumping) Tekniği

Bu teknikte tek giriş noktası kullanılarak yüksek basınç altında sıvı verilmesi ile eklem boşluğu genişletilmekte ve adezyonların mekanik olarak ayrılması hedeflenmektedir. Özellikle hipomobil eklemlerde etkili olduğu bildirilmektedir.[26]

Tek Kanül – Çift Lümen Sistemler

Bu yaklaşımda tek giriş noktasına rağmen ayrı giriş ve çıkış kanalları kullanılarak sürekli akış sağlanmakta ve böylece klasik çift iğne tekniğine benzer bir lavaj etkinliği elde edilmektedir.[21]

Görüntüleme Rehberli Teknikler

Ultrason rehberli artrosentez gibi yöntemler, iğne yerleşiminin daha doğru yapılmasını sağlayarak komplikasyon riskini azaltmakta ve işlem güvenliğini artırmaktadır.[24]

Kombine Tedavi Yaklaşımları

Artrosentez sonrası hyaluronik asit, PRP veya dekstroz gibi ajanların uygulanması ile kombine tedavi protokolleri geliştirilmiş olup, bu yaklaşımların klinik sonuçları iyileştirebileceği bildirilmektedir.[15,19,25]

Klinik Değerlendirme

Güncel çalışmalar, tek ve çift iğne teknikleri arasında belirgin bir üstünlük olmadığını, her iki yöntemin de uygun endikasyonlarda etkili olduğunu göstermektedir. Bununla birlikte, çift iğneli tekniğin daha etkin bir lavaj sağladığı; tek iğneli tekniğin ise daha iyi hasta toleransı sunduğu bildirilmektedir.[24,28]

Artrosentezde Kullanılan Eklem İçi Ajanlar

Temporomandibular eklem artrosentezi, tek başına uygulandığında eklem boşluğundaki inflamatuar mediatörlerin uzaklaştırılması, eklem içi basıncın azaltılması ve mandibular fonksiyonun iyileştirilmesi açısından etkili bir minimal invaziv yaklaşımdır. Bununla birlikte, artrosentez sonrasında eklem içine uygulanan farmakolojik veya biyolojik ajanların ağrı kontrolünü artırabileceği, fonksiyonel iyileşmeyi destekleyebileceği ve bazı hasta gruplarında daha kalıcı klinik yarar sağlayabileceği bildirilmektedir.[12,15,16] Güncel literatürde en sık değerlendirilen ajanlar salin/Ringer solüsyonları, hyaluronik asit, kortikosteroidler, otolog kan ürünleri, ozon ve dekstroz proloterapisidir.[12]

Artrosentez sonrası klinik sonuçların iyileştirilmesine yönelik çalışmalar yalnızca eklem içi ajanlarla sınırlı değildir. Abdallah ve ark.[29], artrosentez ile birlikte kullanılan duloksetinin bazı hastalarda ağrı kontrolü ve fonksiyonel iyileşmeye katkı sağlayabileceğini bildirmiştir. Ancak bu yaklaşım eklem içi ajanlardan farklı olarak sistemik adjuvan tedavi kapsamında değerlendirilmelidir.

Salin / Ringer Solüsyonu

Artrosentez sırasında kullanılan temel irrigasyon sıvıları serum fizyolojik ve Ringer laktat solüsyonudur. Bu ajanların başlıca işlevi eklem boşluğunun mekanik olarak yıkanmasını sağlamak, katabolik artık ürünleri ve proinflamatuar mediatörleri ortamdan uzaklaştırmak ve üst eklem boşluğunda oluşmuş adezyonların çözülmesine yardımcı olmaktır. Bu nedenle salin veya Ringer solüsyonu daha çok “taşıyıcı ve temizleyici” ajan olarak değerlendirilmekte, tek başına biyolojik rejeneratif etkilerinin sınırlı olduğu kabul edilmektedir. Bununla birlikte, artrosentezin temel terapötik etkisinin önemli bir kısmı zaten bu mekanik lavajdan kaynaklanmaktadır.[8,11,12]

Hyaluronik Asit

Hyaluronik asit, sinoviyal sıvının viskoelastik özelliklerinden sorumlu başlıca bileşenlerden biridir. TMB'de sinoviyal sıvının kalitesinin azalması, eklem yüzeyleri arasındaki sürtünmenin artmasına ve dejeneratif sürecin hızlanmasına katkıda bulunur. Artrosentez sonrası uygulanan hyaluronik asit enjeksiyonlarının eklem lubrikasyonunu artırdığı, ağrıyı azalttığı ve mandibular hareketleri desteklediği gösterilmiştir.[16] Klinik pratikte en sık kullanılan ajanlardan biri olmasına karşın, düşük ve yüksek molekül ağırlıklı preparatlar arasında kesin bir üstünlük henüz ortaya konmamıştır. Hyaluronik asit özellikle kısa ve orta vadede semptomatik rahatlama sağlamakta, ancak bazı olgularda tekrarlayan enjeksiyon gereksinimi doğurabilmektedir.[12,16] PRP ile kombinasyonunun ağrı giderimi açısından umut verici olabileceği de bildirilmiştir.[30]

Kortikosteroidler

Kortikosteroidler, güçlü antiinflamatuar etkileri nedeniyle artrosentez sonrası eklem içi olarak uygulanabilen klasik ajanlardandır. Özellikle sinovyal inflamasyonun baskın olduğu olgularda erken dönem ağrı kontrolü sağlayabildikleri ve fonksiyonel rahatlama oluşturabildikleri bildirilmektedir.[12,16] Bununla birlikte, tekrarlayan kortikosteroid enjeksiyonlarının kıkırdak dokuda olası dejeneratif etkileri nedeniyle bu ajanların seçilmiş hastalarda, sınırlı sayıda ve dikkatli endikasyonla kullanılması önerilmektedir. Bu nedenle kortikosteroidler daha çok kısa dönem semptom kontrolü amacıyla düşünülen ajanlar arasında yer almaktadır.[12]

Trombositten Zengin Plazma / PRF / i-PRF

Otolog kan ürünleri son yıllarda TME tedavisinde en fazla dikkat çeken ajan gruplarından biri haline gelmiştir. Enjekte edilebilir trombositten zengin fibrin (i-PRF), antikoagülan kullanılmadan elde edilen ve büyüme faktörlerinin kontrollü salınımını sağlayan yeni nesil bir otolog kan ürünüdür.[31] Trombositten zengin plazma (PRP) ise PDGF, TGF-β ve VEGF gibi büyüme faktörleri açısından zengin olup doku onarımı, anjiyogenez, hücresel proliferasyon ve inflamasyonun modülasyonu üzerinde etkili kabul edilmektedir.[30,32] Meta-analiz verileri, platelet-rich plasma (PRP) enjeksiyonlarının TME osteoartritinde özellikle ağrı azaltımı açısından olumlu sonuçlar verdiğini düşündürmektedir.[30] PRP’nin artrosentez sonrası uygulanmasının ağrı kontrolünü destekleyebileceği ve bazı çalışmalarda hyaluronik asit ile kombinasyonunun ağrı giderimi açısından umut verici sonuçlar sağlayabileceği bildirilmiştir.[33] Güncel sistematik derlemeler de PRP’nin ağrı ve fonksiyon üzerine yararlı etkilerini desteklemektedir.[32]Platelet-rich fibrin (PRF) ve Injectable platelet-rich fibrin (i-PRF) ise daha yavaş ve kontrollü büyüme faktörü salınımı sağlayabilen, biyolojik stabilitesi daha yüksek alternatifler olarak öne çıkmaktadır. i-PRF’nin hazırlanma tekniği tanımlanmış olmakla birlikte, TME içi kullanıma yönelik klinik kanıt düzeyi PRP’ye göre daha sınırlıdır.[31] Genel eğilim, PRP’nin daha hızlı semptomatik iyileşme, PRF/ i-PRF’nin ise daha uzun süreli biyolojik etki potansiyeli sunduğu yönündedir.[15,31,32]

Ozon

Ozon tedavisi, antiinflamatuar, analjezik ve dolaşımı düzenleyici etkileri nedeniyle TME bozukluklarında araştırılan tamamlayıcı ajanlardan biridir. Artrosentez sırasında ozonize su ile irrigasyon veya işlem sonrasında medikal ozon uygulaması şeklinde kullanılabilmektedir. Mevcut derlemeler, ozon tedavisinin ağrıyı azaltabileceğini ve maksimum ağız açıklığını artırabileceğini düşündürse de, mevcut çalışmaların çoğunda örneklem büyüklüğünün küçük ve metodolojik kalitenin sınırlı olduğu bildirilmektedir. Bu nedenle ozon umut verici bir seçenek olmakla birlikte, henüz standart bir artrosentez ajanı olarak kabul edildiği söylenemez.[34]

Botulinum Toksin

Botulinum toksin, TMB tedavisinde özellikle kronik ağrı, kas hiperaktivitesi ve dirençli temporomandibular bozukluk olgularında kullanılan bir nöromodülatör ajandır. Temel etkisi asetilkolin salınımını inhibe ederek kas aktivitesini azaltmak olmakla birlikte, ağrı mediatörlerinin salınımını baskılayarak analjezik etki de gösterebilmektedir.[35] Son yıllarda bazı çalışmalarda artrosentez sonrası eklem içi veya periartiküler botulinum toksin uygulamalarının ağrı kontrolüne katkı sağlayabileceği bildirilmiştir. Bununla birlikte, mevcut kanıtlar sınırlı olup uygulama protokolleri arasında belirgin farklılıklar bulunmaktadır. Bu nedenle botulinum toksin, seçilmiş olgularda umut verici bir seçenek olarak değerlendirilmekle birlikte rutin kullanımını destekleyen yüksek düzeyde kanıt henüz yeterli değildir.

Dekstroz Proloterapisi

Dekstroz proloterapisi, hipertonik dekstroz solüsyonlarının eklem içi veya periartiküler dokulara uygulanmasıyla kontrollü bir biyolojik yanıt oluşturmayı amaçlayan rejeneratif bir tedavi yaklaşımıdır. Bu yönüyle hyaluronik asitten farklı olarak yalnızca lubrikasyon sağlamayı değil, bağ-kapsül kompleksinin biyolojik olarak güçlenmesini ve eklem stabilitesinin artırılmasını hedefler.[18,19,36] Literatürde dekstrozun özellikle kronik TME ağrısı, internal derangement, hipermobilite ve tekrarlayan dislokasyon olgularında kullanıldığı bildirilmektedir.[19,36] Dekstrozun etki mekanizması tam olarak açıklığa kavuşmamış olmakla birlikte, mevcut görüş bunun çok faktörlü olduğu yönündedir. Hipertonik dekstrozun ozmotik etkisiyle kontrollü bir lokal uyarı oluşturduğu, bunun fibroblast aktivasyonu, kollajen sentezi ve doku yeniden yapılanmasını desteklediği düşünülmektedir. Ayrıca daha yeni yayınlarda dekstrozun yalnızca proliferatif değil, aynı zamanda sensörinöral bir analjezik etki de gösterebileceği; nosiseptif iletimi azaltarak ağrı kontrolüne katkı sağlayabileceği öne sürülmektedir.[18,19,36] Bu nedenle dekstroz; steroidlerin inflamasyonu baskılayan, hyaluronik asidin lubrikasyon sağlayan ve PRP'nin biyolojik iyileşmeyi destekleyen etkilerinden farklı olarak daha çok yapısal stabilizasyon ekseninde değerlendirilmektedir.

Klinik uygulamada dekstrozun farklı konsantrasyonları kullanılmıştır. Düşük konsantrasyonlar özellikle ağrı kontrolü ve bazı kapalı kilit olgularında değerlendirilirken, %10–%25 aralığındaki hipertonik çözeltiler daha klasik proloterapi protokollerinde tercih edilmiştir. Özellikle %12.5–%20 aralığındaki uygulamalar literatürde daha sık bildirilmektedir; ancak ideal konsantrasyon, uygulama aralığı ve seans sayısı konusunda henüz tam bir fikir birliği yoktur.[19,36]

Sit ve ark.'nın[19] sistematik derleme ve meta-analizinde, temporomandibular eklem disfonksiyonunda hipertonik dekstroz enjeksiyonlarının plasebo enjeksiyonlarına kıyasla ağrı şiddetini azaltmada üstün olduğu ve 12. haftada orta-büyük etki büyüklüğüne ulaştığı bildirilmiştir. Aynı çalışmada fonksiyonel parametrelerde de olumlu eğilimler saptanmış, ancak protokoller ve enjeksiyon bölgeleri arasındaki heterojenlik nedeniyle sonuçların dikkatli yorumlanması gerektiği vurgulanmıştır.[19] Güncel derlemeler de dekstrozun düşük maliyetli, kolay uygulanabilir ve umut verici bir seçenek olduğunu, ancak standart protokol ve uzun dönem üstünlük açısından daha fazla randomize kontrollü çalışmaya ihtiyaç bulunduğunu belirtmektedir.[36]

Sonuç olarak dekstroz proloterapisi, TMB tedavisinde düşük maliyetli, güvenli ve potansiyel rejeneratif etkileri bulunan bir seçenek olarak öne çıkmaktadır. Bununla birlikte, ideal uygulama protokollerinin belirlenebilmesi için daha yüksek kalitede klinik çalışmalara ihtiyaç vardır.

Artrosentez ile Dekstroz Proloterapisi Kombinasyonu

Dekstroz proloterapisi tek başına uygulanabilen bir tedavi yöntemi olmakla birlikte, son yıllarda artrosentez ile kombine kullanımı da giderek daha fazla ilgi görmektedir. Bu yaklaşım, artrosentezin eklem içi inflamatuar mediatörleri uzaklaştıran ve adezyonları çözen mekanik etkilerini, dekstrozun rejeneratif ve stabilite artırıcı biyolojik etkileri ile birleştirmeyi amaçlamaktadır. Böylece hem semptomların azaltılması hem de eklem biyomekaniğinin iyileştirilmesi hedeflenmektedir.[11,12,18]

İlk yaklaşım, artrosentez sonrası eklem içi dekstroz enjeksiyonudur. Bu yöntemde artrosentez ile eklem içi inflamatuar yük azaltıldıktan sonra dekstroz uygulanarak rejeneratif süreçlerin başlatılması hedeflenir. Böylece inflamasyonun uzaklaştırılması ile biyolojik iyileşmenin uyarılması aynı tedavi protokolünde birleştirilmiş olur.[19,36,37]

İkinci yaklaşım ise periartiküler proloterapidir. Bu yöntemde dekstroz solüsyonu eklem kapsülü ve ligamentöz yapılara uygulanarak bağ dokusu proliferasyonu ve kollajen sentezi artırılır. Özellikle hipermobilite ve rekürrent dislokasyon olgularında bu yaklaşımın eklem stabilitesini artırabileceği bildirilmektedir.[18,36,38]

Bu bağlamda artrosentez ile kombine dekstroz proloterapisi, yalnızca semptomatik tedavi sağlayan bir yöntem olmaktan öte, eklem biyomekaniğini iyileştirmeyi hedefleyen çift yönlü bir yaklaşım olarak değerlendirilmektedir.

Klinik Etkinlik

Güncel çalışmalar, dekstroz proloterapisinin TMB'de klinik olarak anlamlı iyileşmeler sağlayabileceğini göstermektedir. Özellikle ağrı şiddetinde azalma, maksimum ağız açıklığında artış ve eklem fonksiyonunda düzelme en sık bildirilen bulgular arasındadır.[19,36,39]

Sit ve ark.[19] tarafından yapılan sistematik derleme ve meta-analizde, hipertonik dekstroz enjeksiyonlarının plaseboya kıyasla ağrı üzerinde anlamlı üstünlük sağladığı ve fonksiyonel parametrelerde iyileşme eğilimi gösterdiği bildirilmiştir. Bununla birlikte, farklı çalışma protokolleri ve uygulama teknikleri nedeniyle sonuçların heterojen olduğu vurgulanmıştır.

Bazı karşılaştırmalı çalışmalarda dekstrozun hyaluronik asit ile benzer klinik sonuçlar verdiği, bazı çalışmalarda ise PRP gibi biyolojik ajanlara alternatif olabileceği ifade edilmektedir.[30,32,39] Ancak bu karşılaştırmaların çoğunda örneklem büyüklüğünün sınırlı olması ve takip sürelerinin farklılık göstermesi nedeniyle kesin bir üstünlükten söz etmek mümkün değildir.

Avantajlar ve Dezavantajlar

Dekstroz proloterapisi, diğer eklem içi ajanlarla karşılaştırıldığında çeşitli avantajlar sunmaktadır. En önemli avantajları arasında düşük maliyetli olması, kolay uygulanabilirliği ve güvenli bir yan etki profiline sahip olması yer almaktadır. Ayrıca yalnızca semptom kontrolü sağlamayı değil, aynı zamanda bağ dokusu iyileşmesini destekleyen rejeneratif bir etki göstermesi önemli bir üstünlük olarak değerlendirilmektedir.[18,36]

Bununla birlikte, mevcut literatürde standart bir uygulama protokolünün bulunmaması önemli bir sınırlılıktır. Kullanılan dekstroz konsantrasyonları, enjeksiyon bölgeleri ve seans sayıları çalışmalar arasında değişkenlik göstermektedir. Ayrıca mevcut çalışmaların bir kısmında metodolojik heterojenlik bulunmakta ve uzun dönem sonuçlara ilişkin veriler sınırlı kalmaktadır.[19,36,40]

Bazı hastalarda optimal klinik yanıtın elde edilebilmesi için birden fazla seans gerekebilmesi de dekstroz proloterapisinin dezavantajları arasında yer almaktadır.

Güncel Literatürde Eğilim

Son yıllarda dekstroz proloterapisi, TMB tedavisinde giderek daha fazla ilgi görmektedir. Özellikle artrosentez ile kombine uygulamalar, hem eklem içi inflamatuar mediatörlerin uzaklaştırılması hem de ligamentöz yapıların güçlendirilmesi açısından çift yönlü bir etki sunmaktadır.[36,41]

Bununla birlikte, farklı çalışma protokolleri, enjeksiyon teknikleri ve hasta grupları nedeniyle henüz standart bir tedavi yaklaşımı tanımlanmamıştır. Güncel literatür, dekstroz proloterapisinin umut verici bir seçenek olduğunu desteklemekle birlikte, optimal doz, uygulama sıklığı ve uzun dönem etkinliğin belirlenmesi için daha geniş kapsamlı randomize kontrollü çalışmalara ihtiyaç olduğunu vurgulamaktadır.[19,36,40,41]

Klinik Sonuçlar ve Başarı Oranları

Temporomandibular eklem artrosentezi, özellikle konservatif tedavilere yanıt vermeyen hastalarda ağrının azaltılması ve eklem fonksiyonunun iyileştirilmesi açısından etkili bir minimal invaziv tedavi seçeneği olarak kabul edilmektedir.[12,22] Mevcut literatür, artrosentezin hem semptomatik rahatlama sağladığını hem de fonksiyonel parametrelerde anlamlı iyileşmelere katkıda bulunduğunu göstermektedir.

Ağrı Azalması

Artrosentezin en belirgin klinik etkilerinden biri ağrı şiddetinde azalmadır. Eklem boşluğunun irrigasyonu ile inflamatuar mediatörlerin uzaklaştırılması, eklem içi basıncın düşürülmesi ve sinovyal ortamın düzenlenmesi, ağrının azalmasında temel mekanizmalar olarak kabul edilmektedir.[8,12,22] Sistematik derleme ve meta-analizler, artrosentezin konservatif tedavilere kıyasla ağrı kontrolünde daha etkili olduğunu göstermektedir. Özellikle hyaluronik asit, PRP veya dekstroz gibi ajanlarla kombine uygulamalarda ağrı azalmasının daha belirgin ve uzun süreli olabileceği bildirilmektedir.[30,32]

Ağız Açıklığında Artış

Artrosentez sonrası maksimum ağız açıklığında artış, tedavinin önemli fonksiyonel göstergelerinden biridir. Eklem içi adezyonların mekanik olarak çözülmesi ve disk-kondil kompleksinin mobilitesinin artması, mandibular hareket açıklığının iyileşmesine katkı sağlar.[8] Klinik çalışmalar, özellikle kapalı kilit (closed lock) olgularında artrosentez sonrası anlamlı ağız açıklığı artışı elde edildiğini göstermektedir.[22] Bununla birlikte, elde edilen fonksiyonel kazanımın derecesi, eklem içi patolojinin şiddeti ve hastalığın kronisitesi ile yakından ilişkilidir.

Kısa ve Uzun Dönem Sonuçlar

Artrosentezin kısa dönem sonuçları genellikle oldukça başarılı olup, birçok hastada işlem sonrası ilk haftalar içinde ağrıda azalma ve fonksiyonel iyileşme gözlenmektedir.[12,22] Ancak uzun dönem sonuçlar hasta seçimi, uygulanan teknik ve kullanılan eklem içi ajanlara bağlı olarak değişkenlik gösterebilmektedir.

Uzun dönem takip çalışmalarında, artrosentezin etkisinin özellikle uygun endikasyonlarda kalıcı olabileceği, ancak bazı hastalarda semptomların zamanla tekrar edebileceği bildirilmiştir.[12,22] Buna karşın, biyolojik ajanlarla kombine uygulamaların uzun dönem klinik sonuçları iyileştirebileceği ve tedavi etkinliğini artırabileceği ifade edilmektedir.[30,32]

Genel olarak değerlendirildiğinde, artrosentez; TME osteoartriti ve internal derangement tedavisinde konservatif yöntemler ile açık cerrahi girişimler arasında etkili bir tedavi basamağı oluşturmaktadır. Bununla birlikte, işlem başarısı yalnızca teknik uygulamaya değil, aynı zamanda doğru hasta seçimine de bağlıdır.

Klinik Başarıyı Etkileyen Faktörler

Artrosentezin yüksek güvenilirlik profiline sahip olmasına rağmen, uygun endikasyonlarda uygulanmadığında klinik fayda sınırlı kalabilmektedir. Özellikle fibröz veya kemik ankiloz gibi eklem boşluğuna erişimin mümkün olmadığı durumlarda artrosentezin yeri bulunmamaktadır. Benzer şekilde, ağrı ve fonksiyon kaybının esas nedeninin ekstrakapsüler patolojiler olduğu hastalarda anlamlı bir klinik iyileşme beklenmemektedir.[12]

Bu durum, temporomandibular eklem hastalıklarında doğru tanı ve ayırıcı tanının kritik önemini ortaya koymaktadır. Ayrıca artrosentezin başarısının yalnızca lavaj işlemine bağlı olmadığı; kullanılan teknik, eklem içi patolojinin derecesi ve uygulama sonrası eklem içi ajanların da klinik sonuçları doğrudan etkilediği bilinmektedir.[12,22]

Çift girişli teknik, eklem boşluğunun daha etkin şekilde irrigasyonuna olanak sağlarken; tek girişli teknikler daha az invaziv olmaları ve hasta konforunu artırmaları nedeniyle son yıllarda daha fazla tercih edilmektedir. Bununla birlikte, randomize kontrollü çalışmalar teknikler arasında mutlak bir üstünlük bulunmadığını ve klinik sonuçların daha çok hasta faktörleri ve cerrahi deneyim ile ilişkili olduğunu göstermektedir.[22]

Artrosentezle İlişkili Komplikasyonlar

Temporomandibular eklem artrosentezi, minimal invaziv bir girişim olarak kabul edilmekte ve artroskopi ile karşılaştırıldığında daha düşük komplikasyon oranlarına sahiptir. Artroskopide komplikasyon oranları %1,8–7,8 arasında bildirilirken, artrosentez için bu oranın genellikle daha düşük olduğu ifade edilmektedir. Bununla birlikte artrosentez tamamen komplikasyonsuz bir işlem değildir ve literatürde komplikasyon oranı yaklaşık %2–10 arasında rapor edilmiştir.[12,23]

Artrosentez sırasında veya sonrasında gelişen komplikasyonlar; eklemin kompleks anatomik yapısı, çevre nörovasküler oluşumlarla olan yakın ilişkisi ve kullanılan teknik ile doğrudan ilişkilidir.[12] Komplikasyonlar genellikle hafif ve geçici nitelikte olmakla birlikte, nadir durumlarda daha ciddi klinik tablolar da görülebilmektedir.

Fasiyal Sinir Etkilenmeleri

Artrosentez sonrası en sık bildirilen komplikasyonlardan biri fasiyal sinirin geçici etkilenmesidir. Bu durum genellikle irrigasyon sıvısının eklem kapsülü dışına ekstravazasyonu sonucu gelişmekte ve fasiyal sinir dallarında geçici parezi veya paraliziye neden olabilmektedir. Klinik olarak özellikle frontal ve zigomatik dalların etkilenmesi sonucu göz kapağı kapanmasında güçlük ve yüz mimiklerinde geçici asimetri görülebilir.[12,24] Çoğu olguda bu durum birkaç saat ile birkaç gün içinde spontan olarak gerilemekte ve kalıcı hasar nadiren bildirilmektedir.[12,13]

Hematom ve Yumuşak Doku Şişliği

Preaurikular bölgede hematom oluşumu artrosentezin nispeten sık görülen komplikasyonlarından biridir. İğne girişine bağlı vasküler yaralanmalar veya irrigasyon sıvısının yumuşak dokulara yayılması sonucu gelişebilir. Genellikle kendini sınırlayan bir durum olmakla birlikte, uygun kompresyon ve takip gerektirir.[12,28] Literatürde nadir de olsa ekstradural hematom gibi ciddi komplikasyonlar da bildirilmiştir.

Enfeksiyon

Artrosentez sonrası enfeksiyon gelişimi oldukça nadir görülmekle birlikte, potansiyel bir komplikasyon olarak değerlendirilmelidir.[9,11,12] Preaurikular bölgede enfekte şişlik ve lokal hassasiyet ile kendini gösterebilir. Aseptik tekniklere dikkat edilmesi ve uygun hasta seçimi ile bu risk minimalize edilebilir.[9,11,12] Nitzan tarafından bildirilen preaurikular enfekte şişlik olguları, bu komplikasyonun nadir ancak mümkün olduğunu göstermektedir.[8]

Diğer Komplikasyonlar

Literatürde daha nadir görülen komplikasyonlar arasında işlem sırasında vagal yanıt gelişimine bağlı bradikardi, eklem kapsülünün medial duvar perforasyonu, dudak ve dilde parestezi, yanlış irrigasyon solüsyonlarının kullanımına bağlı lokal irritasyon ve yanma hissi yer almaktadır.[11,12] Ayrıca irrigasyon sıvısının çevre dokulara yayılması sonucu geçici ödem ve rahatsızlık hissi oluşabilmektedir.[10,13]

Dekstroz Proloterapisi ile İlişkili Komplikasyonlar

Dekstroz proloterapisi genel olarak güvenli bir yöntem olarak kabul edilmekle birlikte, artrosentez ile kombine uygulamalarda bazı spesifik komplikasyonlar göz önünde bulundurulmalıdır. En sık bildirilen yan etkiler enjeksiyon bölgesinde geçici ağrı artışı, hafif inflamasyon ve hassasiyettir.[19,36]

Hipertonik dekstroz solüsyonlarının osmotik etkisine bağlı olarak lokal irritasyon gelişebilir; ancak bu durum genellikle kısa süreli ve kendini sınırlayıcıdır.[19] Periartiküler uygulamalarda nadiren aşırı fibrotik yanıt ve buna bağlı hareket kısıtlılığı bildirilmektedir.[36] Bununla birlikte, mevcut sistematik derlemeler dekstroz proloterapisinin ciddi komplikasyon oranının oldukça düşük olduğunu ve güvenli bir tedavi seçeneği olduğunu göstermektedir[19].

Artrosentez ile kombine uygulamalarda, dekstrozun eklem içi dağılımı sırasında teknik hatalara bağlı olarak teorik olarak kapsül dışına yayılım riski bulunsa da, bu durum klinik olarak anlamlı komplikasyonlara nadiren yol açmaktadır.[36]

Genel Değerlendirme

Genel olarak değerlendirildiğinde, artrosentez uygun hasta seçimi, doğru anatomik referans noktalarının kullanılması ve deneyimli klinisyenler tarafından uygulanması durumunda güvenli ve etkili bir tedavi yöntemidir.[12] Komplikasyonların büyük çoğunluğu hafif ve geçici olup, ciddi komplikasyonlar oldukça nadir görülmektedir.

Bununla birlikte, fibröz veya kemik ankiloz gibi eklem boşluğuna erişimin mümkün olmadığı durumlarda artrosentez endike değildir. Ayrıca semptomların kaynağının ekstrakapsüler patolojiler olduğu hastalarda işlemden beklenen klinik fayda sınırlı kalabilmektedir.[14,21] Bu durum, doğru tanı ve uygun endikasyon belirlemenin tedavi başarısı ve komplikasyonların önlenmesi açısından kritik olduğunu göstermektedir.[1,2,11]

Sonuç

Temporomandibular eklem artrosentezi, konservatif tedavilere yanıt vermeyen hastalarda ağrı kontrolü ve fonksiyonel iyileşme sağlamak amacıyla güvenli ve etkili bir minimal invaziv tedavi seçeneği olarak öne çıkmaktadır. Eklem içi basıncın azaltılması, inflamatuar mediatörlerin uzaklaştırılması ve adezyonların mekanik olarak çözülmesi sayesinde özellikle ağrı azalması ve ağız açıklığında artış açısından anlamlı klinik kazanımlar elde edilmektedir. Bununla birlikte, tedavi başarısı yalnızca artrosentez uygulamasına değil; hasta seçimi, hastalığın evresi, uygulanan teknik ve işlem sonrası kullanılan eklem içi ajanlara da bağlıdır.

Son yıllarda, artrosentez ile kombine edilen biyolojik ve rejeneratif ajanlar arasında özellikle dekstroz proloterapisi dikkat çekmektedir. Dekstroz, yalnızca semptomatik iyileşme sağlamanın ötesinde, bağ dokusu iyileşmesini destekleyerek eklem stabilitesini artırabilen bir yaklaşım sunmaktadır. Mevcut veriler, dekstrozun ağrı kontrolü ve fonksiyonel sonuçlar açısından umut verici olduğunu göstermektedir; ancak farklı uygulama protokolleri ve sınırlı uzun dönem veriler nedeniyle standart bir kullanım yaklaşımı henüz belirlenmemiştir. Bu nedenle, artrosentez ile kombine dekstroz uygulamalarının etkinliğini ve optimal protokollerini ortaya koymak için daha geniş örneklemli ve uzun dönemli klinik çalışmalara ihtiyaç bulunmaktadır.

Etik Kurul Onayı

Makalemiz derleme türünde olduğu için etik kurul onayı gerekmemektedir.

Çıkar Çatışması

Bu çalışma kapsamında, yazarların çıkar çatışması olabilecek durumları kapsayan bilimsel ve tıbbi komite üyeliği veya üyeleri ile ilişkileri, bilirkişilik, danışmanlık, herhangi bir kuruluşta istihdam durumu, hissedarlık gibi bağlantıları bulunmamaktadır.

Finansal Kaynak

Bu araştırma sürecinde, araştırma konusu ile doğrudan ilgili olan herhangi bir ilaç şirketinden, tıbbi ekipman veya malzeme sağlayan ve/veya üreten bir firma veya ticari bir kuruluştan, çalışmanın değerlendirme sürecine etki edebilecek maddi veya manevi herhangi bir destek alınmamıştır.

Yazar Katkısı

Fikir: H.İ.D, K.F.K Tasarım: H.İ.D, K.F.K Denetleme: H.İ.D. Analiz: H.İ.D Literatür: K.F.K Yazı: K.F.K Eleştirel inceleme: H.İ.D

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REVIEW

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Artificial Intelligence and Dentistry: A Clinical Review and a Proposed CHAIR Framework

Yapay Zekâ ve Diş Hekimliği: Bir Klinik Derleme ve Çerçeve Önerisi (CHAIR)

Doğan Şengül*

ABSTRACT

Objective: Artificial intelligence (*AI*) is entering dental practice through imaging software, screening initiatives and patient-facing chatbots, yet clinicians have limited concise guidance on how to evaluate these tools. This review summarises where *AI* now meets dentistry and offers a practical method for appraising a tool before chairside use.

Materials and Methods: We conducted a narrative review of peer-reviewed studies, regulatory texts and reporting guidelines, favouring work that was validated beyond its own development sample, deployed in real settings or explicit about bias and governance. The evidence is organised along the clinical pathway and paired with a proposed five-point checklist (the *CHAIR* framework) and a worked example.

Results: The strongest evidence lies in radiographic image analysis. Convolutional neural networks detect caries on bitewings, measure periodontal and periapical bone loss and segment teeth and bone on cone-beam computed tomography at a level comparable with experienced clinicians. Photograph-based models screen for oral cancer and its precursor lesions, while other systems assist cephalometric analysis, extraction planning and implant identification. Language models are starting to help with documentation and patient communication. Accuracy is highest on tightly defined tasks and usually declines when the scanner, patient group or disease distribution differs from the system's training data; reliable testing in new clinical settings remains uncommon.

Conclusion: AI is most useful when framed as augmented intelligence: a support for the dentist's judgement, not a substitute. Safe adoption depends on appraising each tool against the local setting, monitoring for bias and putting clear governance in place.

Keywords: *Artificial intelligence, Clinical decision support systems, Dentistry, Risk management, Workflow integration.*

ÖZET

Amaç: Yapay zekâ (*YZ*), görüntüleme yazılımları, tarama girişimleri ve hastaya yönelik sohbet robotları aracılığıyla diş hekimliği pratiğine girmektedir. Diğer yandan, klinisyenlerin bu araçları nasıl değerlendireceğine ilişkin kısa ve uygulanabilir rehberlik hâlen sınırlıdır. Bu derleme, *YZ*'nin diş hekimliğiyle güncel kesişim alanlarını özetlemekte ve bir aracın klinik kullanım öncesinde değerlendirilmesi için pratik bir yöntem sunmaktadır.

Gereç ve Yöntemler: Hakemli çalışmalar, düzenleyici metinler ve raporlama kılavuzları temel alınarak anlatısal bir derleme yapılmıştır. Kendi geliştirme veri kümesi dışında doğrulanmış, prospektif olarak değerlendirilmiş, gerçek klinik ortamlarda uygulanmış ya da yanlılık ve yönetişim konularını açıkça ele almış çalışmalara öncelik verilmiştir. Kanıtlar klinik bakım akışı boyunca düzenlenmiş; önerilen beş maddelik bir kontrol listesi (*CHAIR* çerçevesi) ve uygulamalı bir örnekle birlikte sunulmuştur.

Bulgular: En güçlü kanıtlar radyografik görüntü analizinde yoğunlaşmaktadır. Evrişimli sinir ağları, bite-wing radyografilerinde çürük lezyonlarını saptamakta, periodontal ve periapikal kemik kaybını ölçmekte ve konik ışınlı bilgisayarlı tomografide diş ve kemik dokularının segmentasyonunu deneyimli hekimlerle karşılaştırılabilir doğrulukta gerçekleştirmektedir. Fotoğraf tabanlı modeller ağız kanseri ve öncül lezyonların taranmasına katkı sağlarken, diğer sistemler sefalometrik analiz, çekim planlaması ve implant tanımlamayı desteklemektedir. Dil modelleri klinik dokümantasyon ve hasta iletişiminde yardımcı olmaya başlamıştır. Doğruluğun dar tanımlı görevlerde en yüksek olduğu; tarayıcı, hasta grubu veya hastalık dağılımı sistemin eğitim verilerinden uzaklaştığında genellikle düştüğü anlatılmaktadır. Yeni bir klinik ortamda güvenilir doğrulama uygulamaları ise hâlen nadirdir.

Sonuç: *YZ* en yararlı biçimde, diş hekiminin kararını destekleyen ancak onun yerini almayan artırılmış zekâ olarak değerlendirilmelidir. Güvenli kullanım, her aracın yerel koşullara göre değerlendirilmesine, yanlılık açısından izlenmesine ve açık yönetişim mekanizmalarının kurulmasına bağlıdır.

Anahtar Kelimeler: *Diş hekimliği, İş akışı entegrasyonu, Risk yönetimi, Klinik karar destek sistemleri, Yapay zekâ.*

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Introduction

In recent years, artificial intelligence (AI) has transitioned from experimental research into active clinical practice. The medical field no longer views AI as a novel concept, but rather as a routine tool for diagnosis, documentation, and patient triage.[1] The dental profession is also actively participating in this technological shift. A practitioner may open a new version of an imaging package and find that caries are already outlined on the bitewing, receive a panoramic report in which every tooth has been numbered automatically or meet a patient who has rehearsed a diagnosis with a chatbot before sitting down. The question for the profession is no longer whether these tools will arrive, but how they should be evaluated and integrated safely.

Several features of dental practice make it unusually receptive to image-based computation. Much of the diagnostic day is spent reading standardised pictures, the bitewing, the periapical film, the panoramic radiograph and, increasingly, the cone-beam computed tomography (*CBCT*) volume, and these are produced in very large numbers and stored digitally.[2] Many dental images contain recurring visual patterns and measurable structures, such as interproximal lesions and crestal bone levels, that are well suited to computational support. It is therefore not surprising that some of the earliest and most convincing demonstrations of clinical *AI* in dentistry have concerned the radiograph.

This article is written for dental clinicians evaluating AI claims in practice, rather than for engineers developing the models. It does not set out to be the first survey of the field: broad overviews have already charted the spread of *AI* across the discipline,[2] systematic reviews have catalogued its applications and measured its accuracy,[3] and others have examined the ethical questions it raises.[4] The aim here is narrower and more practical. After a short glossary, the review follows the patient through the clinic, from the first radiograph to the conversation that closes the visit, and shows where the evidence is strongest and where it remains preliminary. It then turns to the weaknesses that recur across the field, sets out a proposed five-point method for appraising a tool before adoption (the *CHAIR* framework) and works through a concrete example. Throughout, the regulatory setting of Türkiye and the European Union is kept in view, because the safe use of these tools is as much a matter of governance as of accuracy. This review is not intended only as a broad survey of artificial intelligence in dentistry; its main contribution is a practical CHAIR checklist that helps dentists evaluate whether an AI tool is clinically relevant, locally valid, safe and governable before chairside use.

Scope And Literature Search

This is a narrative rather than a systematic review, and it makes no claim to completeness. Relevant work was identified in PubMed and Scopus and supplemented by following the reference lists of major reviews and by consulting regulatory and reporting-guideline sources. The queries paired artificial intelligence, machine learning, deep learning and large language models with dentistry, dental radiography, caries, periodontitis, cone-beam computed tomography, oral cancer, orthodontics, endodontics and dental implants. Studies were favoured when they were checked beyond the data on which they were built, whether externally or prospectively, when they reported use in real clinics or when they confronted questions of bias, transparency or governance directly; recent systematic reviews were also drawn upon. The final literature search was completed in June 2026. No starting-date restriction was applied, although the cited evidence concentrates on work published from 2016 onwards, and only publications in English were considered. Titles and abstracts were screened for clinical relevance to dentistry and full texts were then read against three informal criteria: a clearly described dental task, a stated reference standard and reported diagnostic or predictive performance. Where several studies addressed the same task, preference in the text was given to those that were externally or prospectively validated, multicentre or the largest of their kind and to systematic reviews and meta-analyses over single-centre reports. Because the synthesis is narrative, no formal selection diagram or risk-of-bias assessment is presented.

As the review rests only on published work and involved no patients, human participants or animals, ethics committee approval was not required.

Terminology And Core Concepts

A handful of terms recur throughout the literature, and a clear picture of how they fit together makes the rest of this review easier to read (Table 1, Figure 1). Artificial intelligence is the broad umbrella: software that performs tasks usually thought to require human judgement, such as recognising a pattern, interpreting language or supporting a decision.[1] Nested inside it is machine learning (*ML*), the family of methods that get better at a job by drawing patterns from examples rather than from rules a programmer writes by hand. Deeper still sits deep learning (*DL*), built on artificial neural networks with many layers.

Where images are concerned, the dominant tool is the convolutional neural network (*CNN*); it sits beneath almost every radiograph-based and photograph-based system discussed here. For words, a different design, the transformer, powers the large language models (*LLM*) now entering clinics, while natural language processing (*NLP*) is the wider field concerned with reading and generating human language[2]. Two further ideas matter at the chairside. Generative *AI* produces new content, whether a draft referral letter or the plain-language answer a patient receives from a chatbot. Foundation models are very large networks first trained on huge unlabelled collections and then tuned to a particular task with comparatively few labelled examples, which is appealing wherever expert annotation is hard to obtain.[5] Two cautions complete the picture. What is marketed as *AI* in medicine is better described as augmented intelligence, since the software is there to support the clinician rather than to take their place; and these systems are narrow, so a model that excels at grading caries knows nothing of periodontal bone, and strong performance on one task or in one clinic does not transfer automatically to another.

Table 1. A chairside glossary of artificial-intelligence terms used in this review.

Term	What it means	Example in dentistry
Artificial intelligence (*AI*)	Software performing tasks that usually need human judgement	Outlining caries on a bitewing
Machine learning (*ML*)	Methods that learn from examples rather than fixed rules	A model improving as more films are labelled
Deep learning (*DL*)	*ML* built on many-layered neural networks	Most current dental image systems
Convolutional neural network (*CNN*)	A network designed to read images	Detecting periapical lesions on *CBCT*
Natural language processing (*NLP*)	Methods that read and generate language	Structuring a free-text clinical note
Large language model (*LLM*)	A network trained on vast text that produces fluent answers	Drafting a referral or a patient leaflet
Generative *AI*	Systems that create new content	A chatbot answering a patient's question
Foundation model	A large pretrained model adaptable with few labels	Re-using a general image model for a niche task
Narrow *AI*	A model good at a single task only	A caries model that cannot grade bone
Augmented intelligence	*AI* that supports rather than replaces the clinician	A second-reader overlay on a radiograph
Receiver operating characteristic (ROC) curve	A plot of sensitivity against 1 − specificity across all decision thresholds	Comparing two caries detectors independently of any single threshold
Area under the curve (AUC)	A single figure summarising the ROC curve, from 0.5 (chance) to 1.0 (perfect discrimination)	A supplier reporting an AUC of 0.92 as its headline discrimination measure.
Calibration	Agreement between predicted probabilities and observed frequencies	Lesions flagged with 80% confidence proving real about eight times in ten
Internal validation	Testing on data held back from the same source used to build the model	A random split of one clinic's bitewings
External validation	Testing on independent data from other patients, centres or devices	Trying a model on another clinic's radiographs before purchase

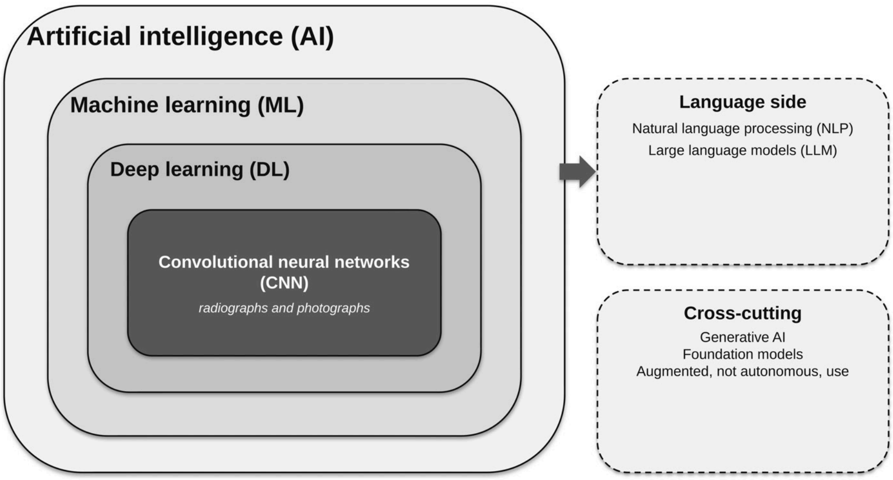

Figure 1. Nested families of artificial intelligence relevant to dentistry. Convolutional neural networks read images; a separate, language-oriented branch underlies large language models, and several ideas cut across both.

Current Applications of Artificial Intelligence in Dentistry

The clearest way to see what *AI* can and cannot yet do is to follow it along the clinical pathway, from the routine radiograph to the soft-tissue examination and the conversation that closes the visit (Table 2).

Caries Detection On Bitewing Radiographs

Caries detection on intraoral radiographs is the most thoroughly studied application in the field, and the results are consistent. Trained on thousands of annotated bitewings, a convolutional neural network reported higher sensitivity than independent dentists in that study population, and was particularly strong on the early, enamel-confined lesions that may be missed during routine interpretation.[6] Rather than replace the clinician, such a model is most useful as a second reader: when its output was shown to dentists, their own sensitivity rose without a collapse in specificity.[7] Systems developed on local data, including a Turkish model that both detects and outlines lesions, report comparable performance and show that the capability is not confined to a few large centres.[8] A meta-analysis confined to bitewing radiographs placed pooled sensitivity and specificity in a clinically useful range but again stressed how rarely these systems are tested outside their development data.[9]

Periodontal And Periapical Bone Assessment

The same modelling approach has been applied to the supporting structures of the tooth. A deep network trained to measure radiographic bone loss on panoramic images estimated the proportion of bone lost close to the assessment of experienced examiners, offering a route to faster and more consistent periodontal charting.[10] Building on this, hybrid systems have gone further and assigned a periodontitis stage from the radiograph, a step towards automated severity grading.[11] Systematic reviews and meta-analyses of these tools report good pooled accuracy for detecting bone loss and staging periodontitis, while noting wide variation between datasets and a continuing need for better reporting.[12] At the apex, a *CNN* applied to *CBCT* volumes detected periapical lesions with high reliability and estimated their size, a task in which small lesions are easily overlooked on two-dimensional films.[13] In each case the appeal is the same: a quantitative, reproducible assessment of structures that are currently evaluated visually, with recognised inter-observer variability.

Panoramic and Cone-Beam Imaging

Three-dimensional imaging is laborious to interpret, and this is where automation promises to save the most time. A large multicentre system segmented individual teeth and the surrounding alveolar bone from *CBCT* scans fully automatically and, for the teeth, performed at a level comparable with expert radiologists, producing the kind of three-dimensional model on which digital implant and orthodontic planning depend.[14] On panoramic radiographs, networks reliably detect and number teeth, a deceptively simple task that underpins automated charting and record-keeping.[15] Others map the relationship between an impacted lower third molar and the inferior alveolar nerve, the anatomical question that governs the risk of surgery in that region.[16] Even a notoriously difficult diagnosis, the vertical root fracture, has been approached with deep learning on panoramic images, though performance here is more modest and underlines the limits of the plain film.[17]

Oral Cancer and Soft-Tissue Screening

Beyond hard-tissue imaging, photograph-based models address a problem of real public-health weight: the late detection of oral cancer. A deep learning algorithm trained on tens of thousands of clinical photographs distinguished oral cavity squamous cell carcinoma (*OCSCC*) from normal mucosa with very high discrimination, raising the prospect of triage where a specialist is not immediately available.[18] Recognising that the greater clinical value lies upstream, other groups have classified and localised oral potentially malignant disorders (*OPMD*), the lesions that precede malignancy, again from ordinary photographs.[19] The promise is a low-cost aid to opportunistic screening; the caution, returned to below, is that a photograph captured on an unfamiliar device or in unfamiliar light may not resemble the images on which the model was trained.

Orthodontics, Endodontics and Prosthodontics

AI has also reached the planning side of dentistry. In orthodontics, automated cephalometric analysis locates the landmarks on which diagnosis depends, and a deep-learning system identified them with high reproducibility compared with repeat human tracings, which are known to show some intra-examiner variability.[20] An umbrella review of systematic reviews is more cautious, noting that automated landmarking still exceeds the accepted error for many points and continues to need an experienced orthodontist's oversight.[21] Machine-learning models trained on treated cases have gone on to predict the extraction decision, the central judgement of orthodontic planning, with accuracy approaching that of clinicians.[22] Endodontics has drawn comparable interest, and reviews of the field describe *AI* applied to periapical diagnosis, root canal anatomy, working-length determination and the prediction of treatment outcomes.[23] Elsewhere, networks recognise the brand and type of a dental implant from a radiograph, a small but genuinely useful problem when a patient presents years later with no record of the fixture they carry.[24] These examples share a theme: the algorithm handles a narrow, well-defined sub-task and hands the result back to the clinician, who keeps the wider decision.

Language Models in Clinical Practice

Recent systems increasingly work with text rather than images. Large language models can draft notes, summarise a history or answer a patient's question in plain language, and a scoping review finds them already applied across dental specialties, most often to patient queries and education though usually through a single general-purpose model.[25] In practice, the systems patients and clinicians most often encounter are general-purpose chatbots such as ChatGPT (OpenAI), Gemini (Google), Claude (Anthropic) and Copilot (Microsoft), rather than tools built for dentistry. Reported performance on dental knowledge tasks has improved in recent studies, and the choice of program matters: in the first head-to-head comparison of large language models on United States Integrated National Board Dental Examination questions, ChatGPT-4 answered 75.88% of items correctly, ahead of Claude-2.1 (66.38%) and Mistral-Medium (54.77%), although they remain uneven across topics and can be confident but incorrect.[26] Direct comparisons of these chatbots on diagnostic tasks, as distinct from examination-style knowledge, remain scarce in dentistry, and none of the general-purpose systems is authorised as a diagnostic medical device, so their output is best treated as text to be verified rather than as clinical advice. Because many patients now consult such a tool before the appointment, the dentist increasingly meets patients who have encountered information of variable reliability before the appointment. Looking further ahead, multimodal models that pair image with text could one day read a radiograph and explain it in plain language, though they sharpen rather than settle the questions of data privacy and bias.[27] The sensible posture is to treat these systems as a support for communication and paperwork, always checked by the clinician, and never as an unsupervised source of clinical advice, for reasons taken up in the next section.

Table 2. Representative applications of artificial intelligence across the dental care pathway.

Clinical area	Typical task	Illustrative evidence	Main caveat
Caries (bitewing)	Detect enamel and dentine lesions	More sensitive than dentists for early lesions; useful as a second reader	Hardest on incipient lesions; small datasets
Periodontal and periapical bone	Measure bone loss; stage disease; find apical lesions	Bone-loss and staging close to experts; reliable apical detection on *CBCT*	Definitions and reference standards vary
3D and panoramic imaging	Segment teeth and bone; number teeth; map the nerve	Multicentre *CBCT* segmentation matching expert radiologists	Heavy computation; sensitive to scanner
Oral cancer and *OPMD*	Screen photographs for malignant and pre-malignant lesions	High discrimination for carcinoma and precursor lesions	Lighting and camera differences; limited external testing
Orthodontics	Locate cephalometric landmarks; predict extraction	Highly reproducible landmarks; extraction decisions near clinicians	Trained on selected, treated cases
Endodontics	Detect vertical root fracture; assess canals	Workable detection on panoramic films	Modest on the plain film; stronger on *CBCT*
Implants and prosthetics	Identify implant brand and type	Accurate recognition from radiographs	Limited to systems seen in training
Documentation and communication	Draft notes; answer patient questions	Improving accuracy on board-style questions	Can be fluent but incorrect; needs checking

Across these applications, the quality of the underlying evidence deserves as much attention as the headline accuracies. Most published studies are retrospective, test their models on data drawn from the same source as the training material (internal validation) and rely on reference standards that vary from study to study; external validation on independent patients, devices or centres remains the exception, and prospective evaluation in routine care is rarer still.[9,28] Where AI has been compared with clinicians, the comparisons have often rested on bias-prone designs and small comparison groups[29] and even in the best-studied task, caries detection on bitewings, the pooled evidence comes from studies of heterogeneous design and quality.[9] Published accuracy therefore cannot be taken at face value: whether a result transfers depends on how closely the study population, equipment and workflow resemble those of the adopting clinic[30] and structuring that judgement, rather than reproducing any single reported figure, is the purpose of the appraisal framework proposed later in this review.

Barriers To Clinical Translation

Generalisability And Domain Shift

A central consideration for any clinical algorithm is that it learns the data it is shown, with all their particularities. A model trained on one scanner, one population or one mix of disease often performs worse when any of these changes, a failure known as domain shift (Figure 2). The pattern is well documented across medical imaging, where meta-analyses report excellent average accuracy alongside wide variation and frequent methodological weakness,[28] and where careful comparisons find the gap between algorithm and clinician to be smaller, and less consistent, than individual papers suggest.[29] The practical implication is clear: a published accuracy figure describes the test set on which it was measured, not the clinic about to adopt the tool, and the evidence that truly matters is testing carried out in patients and on devices that resemble the adopting practice's own.[30]

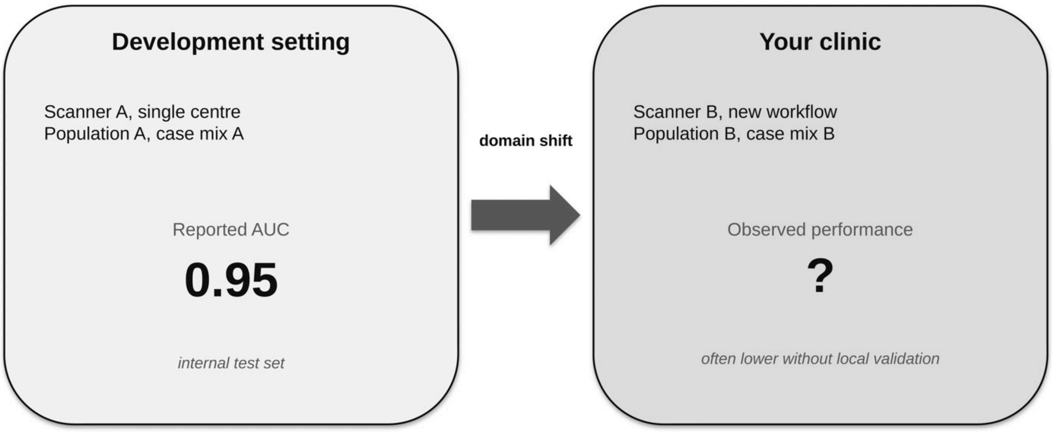

Figure 2. Why performance does not always transfer. A model can score highly on its own internal test set yet perform differently in another clinic with a different scanner, population and case mix, an effect known as domain shift.

Bias and Fairness

Because algorithms learn from their training data, they easily copy existing inequalities.[31] For example, deep neural networks can detect a patient's race from medical images without obvious features, unintentionally using demographic data.[32] Consequently, models trained on specific groups, such as adults or certain skin tones, often fail on others. Rather than rejecting AI, developers must provide clear data reporting. Clinics must test software across diverse patient groups before adoption and monitor it during daily use. Ultimately, institutions must actively measure fairness instead of assuming neutrality.

Model Opacity and Hallucination

Advanced AI systems often lack transparency. While "explainable *AI*" tools like heat maps provide visual clues, they do not guarantee correct logic; therefore, clinicians must never let AI override their own findings.[33] Additionally, language models frequently generate false information and fake references. Consequently, staff must manually verify all *AI*-generated facts, and clinics must strictly prohibit these systems from making independent patient decisions.

Privacy and Data Protection

Because dental images contain detailed, frequently shared personal data, strict protection is essential. In the *EU*, institutions must comply with the General Data Protection Regulation (*GDPR*) and the Artificial Intelligence Act, which classifies medical *AI* as high-risk and mandates rigorous safety measures.[34] Similarly, clinics in Türkiye must follow the Personal Data Protection Law (*KVKK*).[35] These rules are especially relevant in two situations: with children, for whom long-term data reuse raises special consent and stewardship concerns, and with any plan that moves images onto an external provider's servers. Because the dentist holds these records in trust, the handling of data should be spelled out plainly in the consent obtained for any service or study that involves *AI*, a duty underscored by reviews of the ethics of dental *AI*.[4]

Regulation and Reporting Standards

A growing number of *AI*-enabled devices have been authorised by regulators, including the United States Food and Drug Administration (*FDA*), yet authorisation is not the same as proof of patient benefit, and relatively few systems have been tested prospectively against clinical outcomes.[36] Reporting is a recurring weakness. When *AI* has been compared with clinicians systematically, the studies have tended to carry a high risk of bias, to lean on small comparison groups and to lack testing beyond the data on which the models were built,[29] which is why reporting standards such as the CONSORT-*AI* extension, with its companion guidelines for trial protocols and diagnostic-accuracy studies, were developed.[37] Related checklists extend the same discipline to the studies dentists most often meet, the Checklist for Artificial Intelligence in Medical Imaging for diagnostic-imaging work and the TRIPOD+*AI* statement for prediction models.[38,39] Familiarity with these standards supports critical appraisal of AI studies and marketing claims without requiring specialist computer-science training and helps clinicians recognise when the evidence behind a summary performance metric is limited.

The CHAIR Framework: A Five-Point Appraisal of Dental AI Tools

A new algorithm warrants the same care a clinician would give to any unfamiliar diagnostic test, and a short, memorable checklist turns that care into a habit. The five checks below can be recalled through the word *CHAIR*, and they follow a tool through its life, from the moment it is chosen to its long-term monitoring (Table 3, Figure 4).

CHAIR also occupies a different position from the reporting guidelines introduced above. CLAIM, CONSORT-AI and TRIPOD+AI are written primarily for researchers, reviewers and editors: across several dozen items each, they specify how a diagnostic-imaging study, a clinical trial or a prediction model should be reported, and they presume access to the full study report.[37-39] The dentist deciding whether to adopt a tool needs something shorter that answers a different question: not whether a study is well reported, but whether this tool should be used on these patients, with this equipment, in this workflow. The five domains of CHAIR were therefore distilled from the recurring failure points documented in the preceding section, mismatch between a tool's intended context and the clinic (C), undisclosed data and validation (H), opaque or single-figure accuracy claims (A), unresolved responsibility at integration (I) and absent monitoring after deployment (R), so that each check turns a documented weakness of the field into a question a clinician can put to a supplier. CHAIR is intended to complement rather than replace the reporting standards: a supplier able to answer its five questions should also be able to point to CLAIM- or TRIPOD+AI-compliant evidence, and a tool evaluated and transparently reported in accordance with CONSORT-AI should provide much of the information needed to assess the H and A checks.

Clinical question and context. Start from the decision the tool says it will sharpen, the patients and teeth it targets and the exact scanner, sensor or camera it assumes. A model proven on one manufacturer's bitewings is not automatically fit for another's.

Have the data and validation been shown? Ask how many images, from how many patients and centres, lie behind the tool, and whether their age range, case mix and equipment resemble the practice that will use it. The decisive question is whether the system has been tested externally or prospectively in a comparable setting, rather than only on a slice of its own development data. In the vocabulary of the field, testing on data held back from the tool's own development material is internal validation, and testing on independent data from other patients, centres or devices is external validation (Table 1).

Accuracy reported transparently. A single summary number, such as the area under the curve (*AUC*), does not provide enough clinical information. Developers must report sensitivity and specificity separately because these metrics trade off: maximizing detection increases false positives, while high specificity misses actual lesions (Figure 3). Evaluating accuracy across specific patient subgroups is equally crucial. The AUC is the area under the receiver operating characteristic (*ROC*) curve and summarises discrimination across all possible decision thresholds, from 0.5 (chance) to 1.0 (perfect); it does not show the trade-off actually chosen in use, which is why the paired measures matter. Where a tool outputs probabilities, their calibration, the agreement between predicted probabilities and the frequencies observed in reality, should also be reported (Table 1).

Integration and responsibility. Clinics must define who receives and has the authority to override *AI* results. If a system causes excessive false alarms or confuses medical responsibility, its disadvantages will outweigh its clinical benefits.

Risk monitoring after go-live. After implementing the software, institutions must actively track its performance. This requires assigning staff to regularly audit its accuracy and fairness across different patient populations. Facilities must also watch for any drop in performance when patient demographics or medical equipment change over time. If a developer does not provide clear guidelines for these ongoing checks, their tool is not ready for routine clinical use.

Diagnostic performance should be reported as sensitivity and specificity rather than as a single summary figure, because the two move in opposite directions as the operating threshold changes (Figure 3).

In practice, CHAIR is intended as a structured appraisal and a documentation habit rather than a scoring instrument. The five questions can be worked through with the supplier's evidence in a single sitting, the answers recorded briefly and kept, and the appraisal repeated whenever the tool, the imaging equipment or the patient profile changes materially. The checks do not carry equal weight. C, H and A concern the evidence itself and should be regarded as essential before adoption: a tool whose intended context does not match the clinic, whose data and validation cannot be shown or whose accuracy is not reported transparently should not be adopted, whatever its other attractions. I and R concern the conditions of use rather than the evidence: they do not rule a tool out in advance, but adoption should wait until the roles, override authority and audit schedule they require are in place. A tool that fails any one of the essential checks is better deferred than adopted provisionally.

$$\text{Sensitivity} = \frac{TP}{TP + FN} \qquad \text{Specificity} = \frac{TN}{TN + FP}$$

Figure 3. Sensitivity and specificity, the paired measures that a single accuracy figure conceals. TP, true positives; FN, false negatives; TN, true negatives; FP, false positives.

Table 3. The *CHAIR* framework for appraising a dental artificial-intelligence tool.

Check	Ask	What good looks like	Red flag
C: Clinical question and context	Which decision, patients, teeth and device?	A defined task on the equipment you actually use	Works for caries, with no specifics
H: Have the data and validation?	How many images, from where and tested how?	External or prospective testing in a similar population	Only internal test-set results
A: Accuracy reported transparently	Sensitivity, specificity, calibration and subgroups?	Separate metrics by lesion type and subgroup	A single *AUC* headline
I: Integration and responsibility	Who sees, who overrides and what alert burden?	Clear roles and a manageable workload	Unclear liability; constant alerts
R: Risk monitoring after go-live	Who audits drift and fairness and when?	A named owner and a fixed audit schedule	No plan once the tool is live

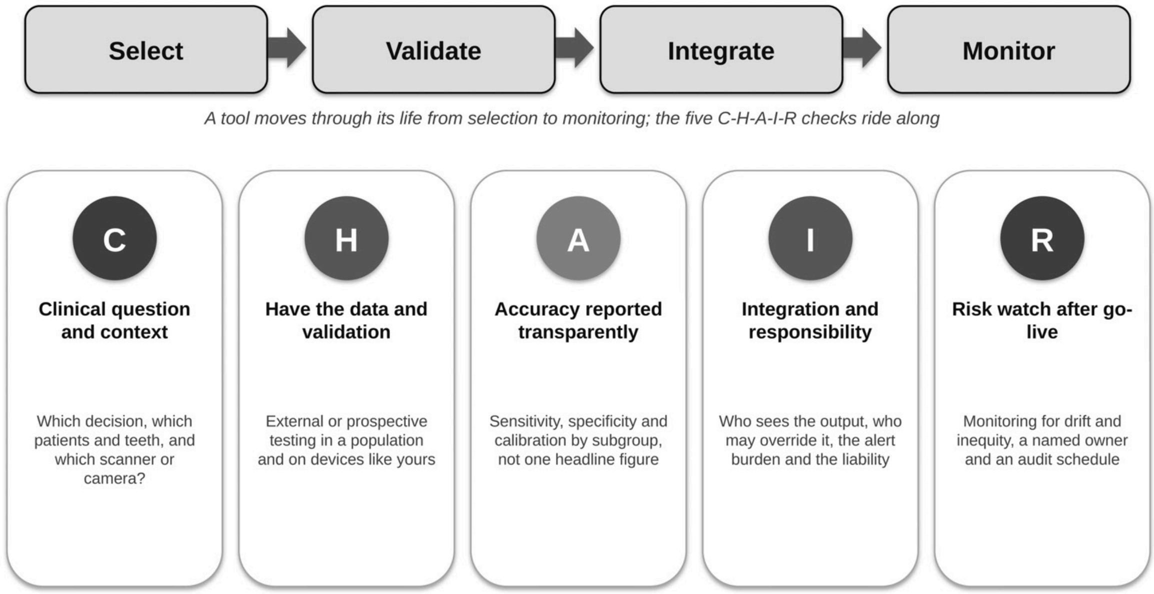

Figure 4. The *CHAIR* framework across the life of a dental *AI* tool. The five checks accompany a tool as it is selected, validated, integrated into the workflow and monitored after deployment.

CHAIR In Practice: A Worked Example in Bitewing Caries Detection

When a supplier offers an *AI* decay-detection tool claiming human-level accuracy (e.g., *AUC* 0.92), clinics should evaluate it using the *CHAIR* framework (Figure 5). The team must first confirm if the tool works on their specific patient demographic and X-ray sensors. Next, they must verify the training data and request sensitivity and specificity rates categorized by lesion depth. For workflow integration, staff must establish who reviews the *AI*'s results and how to handle clinical disagreements. Finally, the clinic must schedule performance monitoring at six and twelve months. If the supplier only provides the basic *AUC* score, the clinic should reject the tool. This evaluation process applies to any clinical *AI* software.

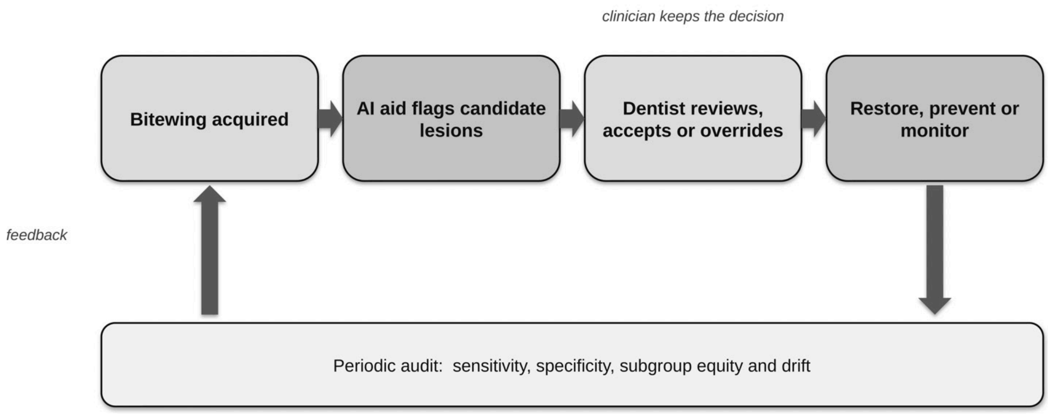

Figure 5. Where an artificial-intelligence aid sits in the bitewing workflow. The software flags candidate lesions, but the clinician keeps the decision, and a periodic audit feeds back into safe use.

Implications for the Profession: Education, Governance and the Turkish Context

While dental professionals show strong interest in AI, many lack formal evaluation training. To address this, universities and continuing education programs should introduce practical *AI* evaluation modules, using frameworks like *CHAIR* instead of complex mathematics.[3] For governance, every *AI* tool requires a designated manager, performance tracking, regular audits, and inclusive approval committees.[4] Additionally, evidence-based practitioners should help design clinical trials and advocate for independent testing.[37]

In Türkiye, researchers must collaborate to build diverse datasets using privacy-preserving federated learning, allowing hospitals to train shared models without transferring patient images.[40] Furthermore, clinics must re-test imported *AI* tools locally before use, and developers must establish strict safety benchmarks for Turkish-language *AI* compliant with the Personal Data Protection Law (*KVKK*).[35]

Relevance to Clinical Practice

This review provides direct practical value for clinical workflows. The *CHAIR* checklist offers a structured, non-technical framework for evaluating commercial *AI* tools. Furthermore, it establishes realistic expectations: while current *AI* excels at narrow diagnostic tasks, published accuracy frequently degrades in new environments, making independent local validation essential before adoption. Third, responsibility remains with the dentist, who keeps the final decision, records disagreements and watches for drift and inequity once a tool is live. A practitioner who adopts these habits can take up useful tools earlier and more safely, defer adoption of tools with insufficient evidence, and take part in the local governance that decides which systems reach the chair.

Limitations

A few limitations should be acknowledged. As a narrative synthesis, the choice of studies followed no preregistered protocol and no formal appraisal of bias, so it is unavoidably a matter of judgement. Because the field advances so fast, the approval status and measured accuracy of any particular tool may well have moved on by the time these words are read. The coverage also leans towards image-based work, which is the most developed, and so probably underplays the rapid progress of language and foundation models. Finally, *CHAIR* is intended as a practical aid rather than a validated instrument and would itself benefit from testing in real clinical decisions. Its five domains were likewise derived from recurring failure points in the published literature rather than through a formal consensus method such as a *Delphi* process, a further reason to treat the checklist as a starting point for appraisal rather than a standard.

Conclusion

Artificial intelligence is no longer a distant prospect in dentistry but a present and uneven reality, most visible at the radiograph and the photograph and now reaching the conversation with the patient. The shift required of the profession is as much conceptual as technical. *AI is best understood as augmented intelligence*: narrow in scope and only as good as the data and labels behind it, and a new tool deserves the same scrutiny as any diagnostic test, namely a requirement for evidence gathered in comparable patients, for candid reporting of accuracy, for attention to bias and for a clear plan of oversight once it is in use. The *CHAIR* framework is meant to make that judgement structured and practical. Dentists who take part early, in choosing, testing and governing these systems rather than adopting them only after deployment, will help ensure that the tools reaching the chair fit their patients, their equipment and their way of working.

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No patients, human participants, identifiable personal data or animals were involved. Therefore, ethical approval was not required.

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CASE REPORT

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Management of Class II Malocclusion with Fixed and Removable Functional Appliances: 3 Case Reports

Sabit ve Hareketli Fonksiyonel Apareyler ile Sınıf II Maloklüzyonun Tedavisi: 3 Olgu Sunumu

Büşra Kibar[1], Pamir Meriç[2*]

ABSTRACT

Objectives: This case report presents the treatment outcomes of 3 patients with skeletal Class II malocclusion managed using different functional appliances followed by fixed orthodontic treatment.

Case Report: Three patients diagnosed with skeletal Class II malocclusion were treated with different functional appliances according to their individual clinical characteristics. After completion of the functional phase, comprehensive fixed orthodontic treatment was performed. Treatment outcomes were evaluated using clinical photographs, dental models, radiographs, and cephalometric analyses.

Conclusion: All treatment protocols resulted in improvement of the sagittal skeletal relationship, correction of the Class II malocclusion, and achievement of functional occlusion with satisfactory facial esthetics. These cases suggest that individualized selection of functional appliances combined with fixed orthodontic treatment can provide successful outcomes in patients with skeletal Class II malocclusion.

Keywords: *Bionator, Class II malocclusion, Fixed functional appliance, Herbst appliance.*

ÖZET

Amaç: Bu olgu sunumunun amacı, farklı fonksiyonel apareylerle tedavi edilen ve ardından sabit ortodontik tedavi uygulanan iskeletsel Sınıf II maloklüzyonlu 3 hastanın tedavi sonuçlarını sunmaktır.

Olgu Sunumu: İskeletsel Sınıf II maloklüzyon tanısı alan 3 hasta, bireysel klinik özellikleri doğrultusunda farklı fonksiyonel apareylerle tedavi edildi. Fonksiyonel tedavi fazının tamamlanmasının ardından tüm hastalara kapsamlı sabit ortodontik tedavi uygulandı. Tedavi sonuçları; klinik fotoğraflar, dental modeller, radyografiler ve sefalometrik analizler kullanılarak değerlendirildi.

Sonuç: Tüm tedavi protokolleri sagittal iskeletsel ilişkide iyileşme, Sınıf II maloklüzyonun düzeltilmesi ve tatmin edici yüz estetiği ile fonksiyonel oklüzyonun elde edilmesini sağladı. Bu olgular, hasta özelliklerine göre bireyselleştirilerek seçilen fonksiyonel apareylerin sabit ortodontik tedavi ile kombine edildiğinde, iskeletsel Sınıf II maloklüzyonların tedavisinde başarılı sonuçlar sağlayabileceğini göstermektedir.

Anahtar Kelimeler: *Bionatör, Herbst apareyi, Sabit fonksiyonel aparey, Sınıf II maloklüzyon.*

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Introduction

Class II malocclusion is defined by an anteroposterior discrepancy between the dental arches, which originated from skeletal, dentoalveolar, or a combination of these.[1] Various skeletal patterns can contribute to the development of Class II malocclusion, including mandibular retrusion, maxillary protrusion, or posterior position of the glenoid fossa.[2,3] The most common etiological factor in skeletal Class II malocclusion is mandibular retrusion. To correct this malocclusion in growing patients, functional appliances are often used, as they promote forward movement of the mandible and stimulate sagittal growth.[4,5]

Functional appliances are generally classified into two categories: removable and fixed functional appliances.[6] In the early 1900s, removable functional appliances were introduced with Pierre Robin's Monoblock and Andreasen's Activator. Over the years, various types such as the Bionator, Frankel, Twin-block, Bimler appliance, Propulsor, Karwetzky appliance, and Vestibular plate have been developed.[6,7] Fixed functional appliances, first represented in the literature by the Emil Herbst appliance and developed by American researchers, can be categorized into three types: rigid intermaxillary appliances, flexible intermaxillary appliances, and hybrid intermaxillary appliances.[8]

The following case reports describe the management of Class II malocclusion in patients using Herbst, Forsus, and Twin Block appliances.

Figure 1. Pretreatment records of Case 1 included intraoral and extraoral photographs, panoramic and cephalometric radiographs, and hand–wrist radiographs.

Case-1

An 11-year-old female patient was admitted to our clinic with a complaint of a retruded lower jaw. Intraoral findings were as follows: Class II molar and canine relation, 2.8 mm overjet, 4.8 mm overbite, and lower dental midline shifted to the right side by 1.5 mm. Radiologic examination revealed that SNA: 82.0°, SNB: 78.4°, ANB: 3. Upper incisor inclination (U1-NA) was 20.9° and 1.6 mm, and mandibular plane-lower incisor inclination (IMPA) was 95.1°, and L1-NB was 2.7 mm. According to the hand wrist radiograph, the patient was in the stage of DP3u (Figure 1).

Treatment Objectives

The primary treatment goals were to achieve an ideal overbite, establish Class I molar and canine relationships, and enhance the facial profile.

Treatment Plan

Because the patient was approaching the completion of growth, a fixed functional appliance (Herbst) was used to achieve a Class I relationship. Due to the insufficient overjet and retroclination of upper incisors, braces were bonded to the upper incisors to increase the overjet before the Herbst treatment.

Table 1. Cephalometric measurements of the Herbst, Forsus FRD, and Twin Block treatment

	Herbst		**Forsus FRD EZ2**		**Twin Block**	
Cephalometric Measurements	T0	T1	T0	T1	T0	T1
SNA (°)	82.5	84.6	81.6	83.6	78.7	77.6
SNB (°)	78.4	82	76.5	81	73.9	74.6
ANB (°)	3.6	2.6	5.1	2.7	4.7	3
U1-NA (mm)	1.6	2.6	4.8	3.3	3.7	4.4
U1-NA (°)	20.9	28.8	21.2	20.9	20.7	21
L1-NB (mm)	2.7	2.8	5.2	3.4	5.4	5.6
L1-NB (°)	22.5	23.1	31.3	26.6	28.9	25.1
IMPA (°)	95.1	96.2	109.1	106.2	99.5	99.6
SNGoMe (°)	29	29.1	25.7	19.5	35.5	38.9
FMA (°)	21.4	22.4	18.6	17.1	27.9	30.6
SN-OP (°)	6.5	3.8	16.1	12.4	19.3	17.2
Overjet (mm)	2.8	2.7	6.6	3.5	4.8	2.8
Overbite (mm)	4.8	1.7	5.4	3.8	5.7	2.5
U-Lip/E line (mm)	-0.2	-0.7	-4.5	-6.7	0.5	-1
L-Lip/E line (mm)	-0.9	2.2	-2.2	-3.7	1.4	0.7

T0: Pretreatment, T1: Posttreatment.

Treatment Progress

After the informed consent was obtained from the patient, the upper part of the Herbst appliance was fabricated. Brackets were requested to be added in the premolar region of the upper part of the Herbst appliance to procline the upper incisors and advance the mandible. Once the maxillary part of the Herbst appliance was cemented, 0.022-inch MBT brackets (American Orthodontics, Sheboygan, WI) were bonded to the maxillary incisors, and leveling and alignment were carried out using a 0.014-inch Ni-Ti archwire. During the levelling and alignment stage, maxillary incisors were proclined using an open coil spring. After the ideal incisor inclination was achieved, a wax bite registration was taken with the mandibular arch positioned 5 mm forward, and the lower part of the Herbst appliance was fabricated and cemented.

After 6 months of Herbst treatment, an overcorrected Class I relationship was obtained, and the appliance was removed. In the second phase, treatment was continued with a fixed orthodontic appliance.

From the initial archwires, light Class II elastics (5/16”, 2.5 oz) were used only to maintain the anteroposterior occlusal correction obtained with the Herbst appliance. After 0.017x0.025” Stainless-Steel (SS) wire was placed in the lower arch, diastemas were closed using a power chain. In the upper arch, incisor retraction was performed using a 0.019x0.025” Beta-titanium (TMA) archwire.

Figure 2. Posttreatment intraoral and extraoral photographs, panoramic radiograph, and cephalometric records of Case 1.

Treatment Results

Following 24 months of treatment, a Class I occlusion was established, and the fixed appliances were removed. A fixed retainer (multistranded wire) was placed for retention purposes, and an Essix appliance was provided for nighttime wear. (Figure 2). Notable enhancement of the patient's soft tissue profile was achieved. Class I molar and canine relationship was obtained. The panoramic radiograph displayed acceptable root angulations, no signs of root resorption, and stable bone levels. Additionally, there were no signs or symptoms of muscle or joint involvement. Cephalometric measurements of the treatment were presented in Table 1.

Case-2

A 15-year-old female patient presented with a complaint of "crowded teeth". On extraoral examination, the patient had a convex profile, a retruded chin, and a moderately deep mentolabial sulcus. Intraoral findings were as follows: Overjet: 6.6 mm, Overbite: 5.4 mm, Class II canine and molar relation on both sides (Figure 3).

Cephalometric analysis revealed that SNA: 81.6°, SNB: 76.5°, ANB: 5.5. Upper incisor inclination (U1-NA) was 21.2° and 4.8 mm, and mandibular plane-lower incisor inclination (IMPA) was 109.1°, and L1-NB was 5.2 mm. The patient was in the CS4 stage.

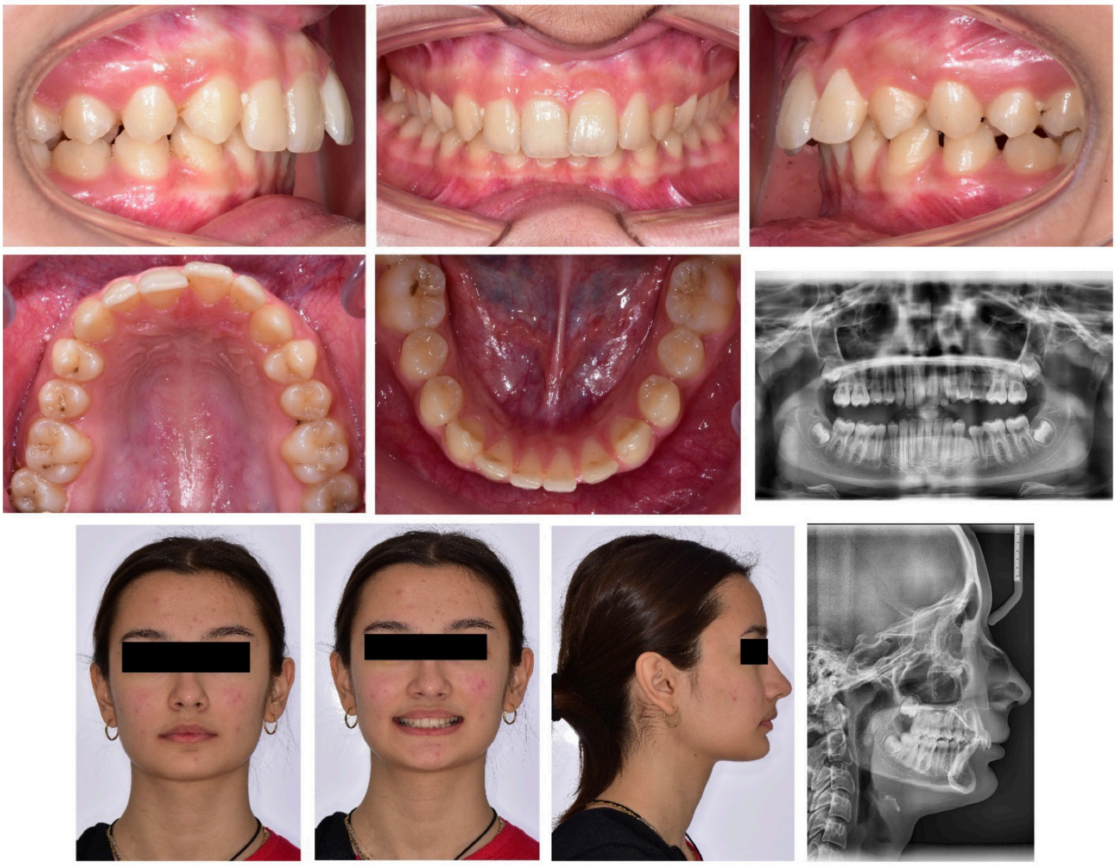

Figure 3. Pretreatment records of Case 2 included intraoral and extraoral photographs, panoramic and cephalometric radiographs, and hand–wrist radiographs.

Treatment Objectives

The treatment objectives were to correct the skeletal Class II relation to improve profile convexity and achieve Class 1 occlusion.

Treatment Progress

At the beginning of the treatment, informed consent was obtained from the patient. Leveling and alignment were performed in both the upper and lower arches until a 0.019 × 0.025" Stainless Steel wire could be placed passively. The anchorage was enhanced using a transpalatal arch in the maxillary arch. Arch was consolidated from molar to molar using a figure-eight ligature tie, and a cinch-back was applied to the archwire distal to the molar tube. The prefunctional phase of treatment lasted for 7 months. The distance between the distal of the lower canine bracket and the distal of the upper molar tube was measured using a special ruler, and the Forsus Fatigue Resistant Device EZ2 appliance was applied.

A power chain was applied between the lower canine to canine to close the diastema in the anterior region. This helped to close the diastema while preventing excessive proclination of the incisors. The Forsus FRD EZ2 appliance was actively used for 8 months, and activated every 2 months by adding a 1 mm crimpable stop to the pushrod. The occlusion was corrected to an edge-to-edge incisor relationship before the Forsus FRD EZ2 appliance was removed. Final occlusal finishing and detailing were completed in approximately 2 months. At the end of 17 months of treatment, the fixed appliances were removed, and fixed retainers were placed in both arches (Figure 4).

Treatment Results

The patient's soft tissue profile showed noticeable improvement. Spacings in the lower arch were closed, and crowding of the maxillary anterior teeth was resolved. A normal overbite and overjet were established, and a Class I canine and molar relationship was achieved bilaterally.

Post-orthodontic retention was achieved using a bonded multistranded wire, supplemented by an Essix retainer for nighttime use. Cephalometric measurements of the treatment were presented in Table 1.

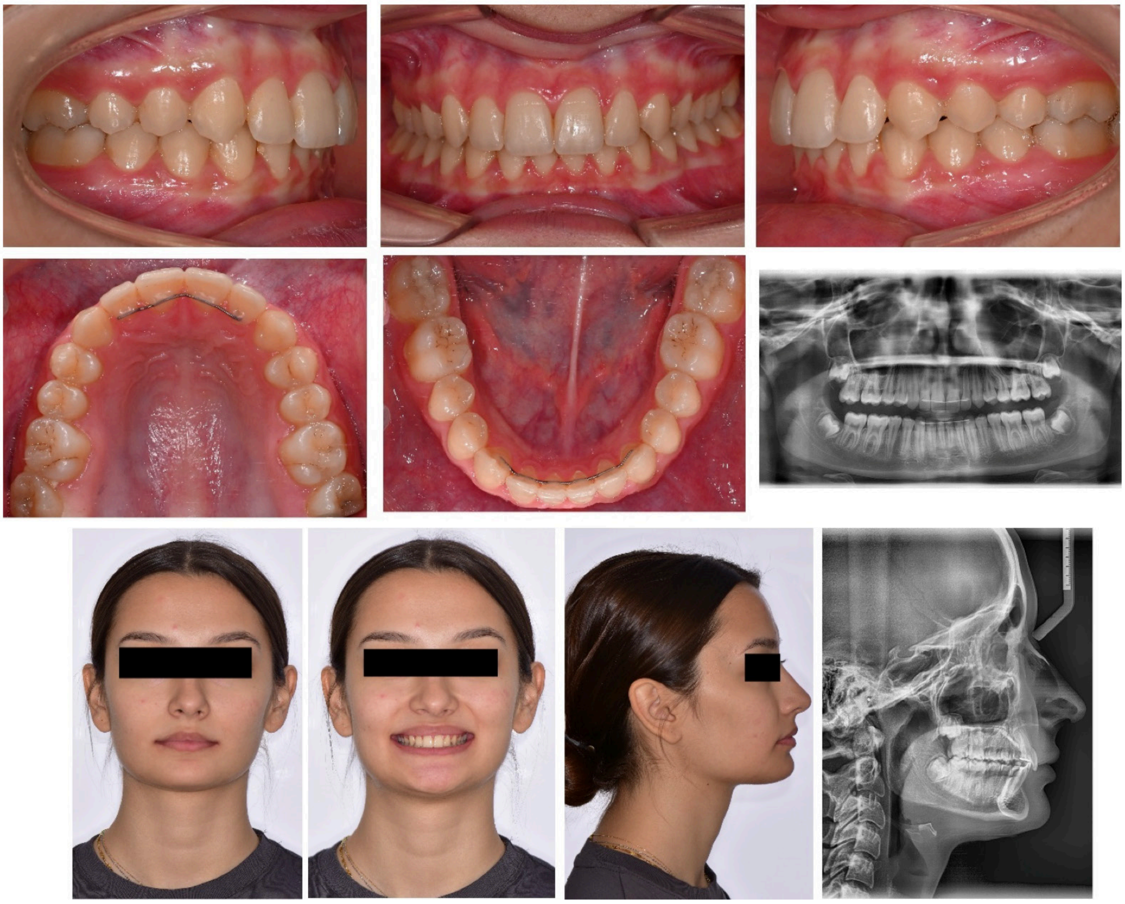

Figure 4. Posttreatment intraoral and extraoral photographs, panoramic radiograph, and cephalometric records of Case 2.

Case-3

An 11-year-old female patient was referred to our clinic due to a retruded mandible. Intraoral findings were as follows: Class II molar and canine relation, 4.8 mm overjet, 5.7 mm overbite, and lower dental midline shifted to the left side by 2 mm. Radiographic evaluation demonstrated that SNA: 78.7°, SNB: 73.9°, ANB: 4.7. Upper incisor inclination (U1-NA) was 20.4° and 3.7 mm, and mandibular plane-lower incisor inclination (IMPA) was 99.5°, and L1-NB was 5.4 mm (Figure 5).

Figure 5. Pretreatment documentation of Case 3 consisted of intraoral and extraoral photographs, panoramic and cephalometric radiographs, and hand–wrist records.

Treatment Objectives

The main objectives were to improve the convexity of the facial profile and retruded chin, improve the skeletal Class II relationship, and achieve optimum overjet and overbite.

Treatment Plan

Since the patient was in her active growth stage (MP3 cap) and exhibited both skeletal and dental Class II relationships, a two-phase treatment was planned. Phase I: Growth modification with a functional appliance (Twin Block); Phase II: Fixed mechanotherapy for occlusal refinement.

Treatment Progress

After informed consent was obtained from the patient, a wax bite registration was taken with the mandibular arch positioned 6 mm forward, and a twin block appliance was fabricated. The patient was instructed to wear the appliance for 24 hours a day. The duration of treatment with the functional appliance lasted 14 months. Patient cooperation was satisfactory throughout the course of treatment.

Once the functional appliance treatment was completed, multi-bracket treatment was initiated with the bonding of 0.022” MBT brackets (American Orthodontics, Sheboygan, WI), and 0.014” NiTi wires were placed in both arches. Light Class II 5/16 (2.5 oz) elastics were used from the initial arches for the stabilization of the anteroposterior occlusal correction achieved with the Twin-Block appliance. The second phase of treatment with a fixed orthodontic appliance lasted for 10 months.

Treatment Results

A harmonious facial profile was achieved. Class I molar and canine relationship was obtained. A normal overbite and overjet were established (Figure 6). Fixed retainer (multistranded wire) was fabricated for post-treatment stability, complemented by an Essix plate for nighttime wear. Cephalometric measurements of the treatment were presented in Table 1.

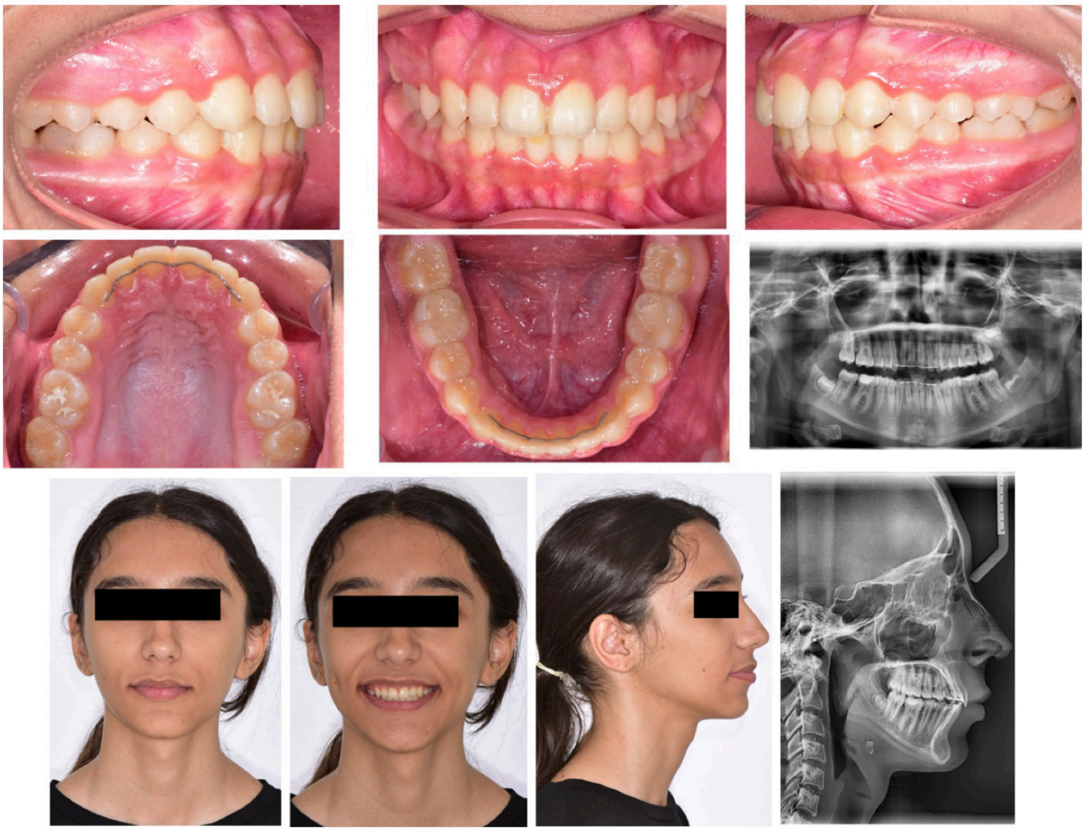

Figure 6. Posttreatment records comprised intraoral and extraoral photographs, panoramic and cephalometric radiographs of Case 3.

Intraoral images of the Herbst, Forsus FRD EZ2, and Twin Block appliances are presented in Figures 7a, 7b, and 7c, respectively.

Figure 7. (a) Case 1: Intraoral photos of Herbst appliance; (b) Case 2: Intraoral photos of Forsus FRD appliance; (c) Case 3: Intraoral photos of Twin Block appliance.

Conclusion

Class II malocclusion can present with different combinations of skeletal and dental discrepancies. Therefore, recognizing and understanding the etiology of Class II malocclusion, along with differential diagnosis, is essential for effective correction.

Treatment planning can vary based on the patient's age, remaining growth potential, severity of the malocclusion, and soft-tissue profile.[9,10] In children and adolescents with Class II malocclusion, growth modification is applied according to their growth and development stage. In young adults, camouflage treatment involving dentoalveolar movements is used, whereas orthognathic surgery is employed in adults. [9] In cases of Class II malocclusion resulting from mandibular deficiency, growth modification is achieved using functional appliances. These appliances position the mandible more anteriorly than its current position, stimulating development in the ramus height and overall mandibular length.[6]

The Herbst appliance is frequently used to treat Class II malocclusion and a retrusive mandible, as it functions effectively without depending on patient cooperation. The appliance advances the mandible forward, acting as an artificial joint between the jaws and inducing a bite-jumping effect.[11] Herbst treatment studies have reported restriction of maxillary growth, mandibular rotation changes, as well as anterior positioning of the glenoid fossa.[12] However, in Case 1, an increase in the SNA angle was observed. We hypothesize that this unexpected finding may be attributed to the protrusion of initially retrusive incisors during the course of treatment.

Constructed of nickel–titanium coil springs, the Forsus FRD EZ2 is a semi-rigid fixed functional appliance that attaches to the maxillary molar headgear tube and the mandibular archwire at the canine bracket. It passively advances the mandible while allowing lateral mandibular movements.[13] The average active treatment duration with Forsus FRD EZ2 is approximately 6.2 months, and it primarily produces dentoalveolar effects for the correction of Class II malocclusion.[14] In Case 2, the increase in the SNB angle from 76.5° to 81.0° (+4.5°) is particularly noteworthy. We hypothesize that this substantial change may be attributed to a posteriorly displaced mandibular position at the beginning of treatment, likely caused by the retrusive position of tooth 11, which may have forced the mandible into a more retruded position than its true functional position. The marked decrease in the SNGoMe angle suggests a counterclockwise rotation of the mandible, resulting in a more horizontal growth pattern. However, given the magnitude of this change, it is likely that this finding reflects a functional repositioning of the mandible rather than a true skeletal alteration. When evaluating the effects of fixed functional appliances, such as the Forsus device, in the treatment of Class II malocclusions, it is observed that skeletal changes remain considerably limited, particularly during the late stages of the pubertal growth spurt (CS4 and beyond).

Twin Block is an appliance that provides functional mandibular protrusion for skeletal Class II correction. The inclinations of the occlusal ramps direct the mandible to a downward and forward position. The aim of the Twin Block is to achieve dental and skeletal correction by utilizing all functional forces, including masticatory forces, with continuous use for 24 hours.[15] Although Twin Block appliances are traditionally recommended for patients with favorable vertical patterns, several studies have demonstrated their successful use in high-angle Class II cases, where the primary treatment objective is the correction of sagittal discrepancy.[16,17] Functional appliances, including Twin Block, primarily act by enhancing mandibular advancement and improving the anteroposterior relationship (increase in SNB and reduction in ANB), even in patients with vertical growth tendencies. Therefore, in selected cases, sagittal correction may be prioritized over vertical considerations, justifying the use of Twin Block therapy in hyperdivergent patients. Removable functional appliances offer advantages such as easier oral hygiene maintenance and lower costs compared to fixed functional appliances. However, their main disadvantage is that treatment success is largely dependent on patient compliance.[7] For patients who have completed growth, especially those with Class II mandibular retrusion, fixed functional appliances that require limited patient cooperation are the treatment of choice.[18] Fixed functional appliances have the advantages of requiring no patient cooperation and providing continuous force, but they come with drawbacks such as high costs, breakage, limited opening capacity, and potential tissue injuries.[8]

Notwithstanding current controversies surrounding functional appliances and growth modification, these appliances remain effective treatment options for Class II malocclusions. Growth modification may help minimize the need for permanent tooth extractions and future orthognathic surgical intervention.[19]

As a result, this case report shows that the effect of the different functional appliances for the advancement of the mandible depends on patient cooperation and case selection. The use of these devices in the growing phase, with good patient cooperation, creates a positive skeletal and dentoalveolar effect.

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Ethical approval is not necessary. Informed consent forms are available.

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CASE REPORT

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Current Surgical Management of Anterior Periapical Lesions: Case Series

Anterior Periapikal Lezyonların Güncel Cerrahi Yönetimi: Vaka Serisi

Şükran Acıpınar[1]*, Taha Yasin Erdoğan[2]

ABSTRACT

Introduction: Root canal treatment is widely regarded as the primary therapeutic approach for the management of periapical diseases. Nevertheless, owing to the intricate anatomy of the root canal system, as well as the possible development of extraradicular bacterial biofilms and true cystic lesions, nonsurgical treatment may not always result in complete healing. Surgical intervention may be required to achieve effective infection control. Available surgical modalities include apical root resection, retrograde root-end filling, and open flap debridement. These procedures may be further enhanced by the adjunctive use of bone graft materials and platelet-rich fibrin (PRF) to promote bone regeneration in the apical region.

Case reports: Five cases of single-rooted periapical lesions in the maxillary anterior region which showed no radiographic signs of healing following endodontic treatment were treated with open flap debridement under local anesthesia (LA). Three of these cases underwent apical resection. In two cases, open flap debridement of the affected area was performed without apical resection. All bone defects were treated with allograft material and PRF application. The six-month radiographic follow-up of the patients is presented.

Conclusion: Endodontic treatment is generally highly effective in treating apical lesions. However, periapical lesions that do not heal despite treatment are challenging for clinicians to manage, requiring detailed diagnosis and planning. In such cases, a multidisciplinary approach is necessary, and open flap debridement can increase the likelihood of success and bone fill. Performing periapical surgery with an allograft and PRF can successfully treat the lesion while preserving the natural tooth structure.

Keywords: *Allografts, Debridement, Periapical diseases, Platelet-rich fibrin.*

ÖZET

Giriş: Kök kanal tedavisi şu anda periapikal hastalıkları tedavi etmek için en yaygın ve etkili yöntemdir ve %80'den fazla bir başarı oranına sahiptir. Ancak kök kanal sisteminin karmaşıklığı, ekstraradiküler bakteriyel biyofilmlerin oluşumu ve gerçek kistlerin oluşumu nedeniyle bazı periapikal hastalıklar cerrahi tedavi gerektirir. Endodontik tedavinin ardından iyileşme gözlenmeyen periapikal lezyonların tedavisi enfeksiyonun mümkün olan en iyi şekilde ortadan kaldırılmasına yol açacak apikal rezeksiyon, retrograt dolgu ve açık flep debridmanı gibi çeşitli cerrahi tedavi seçeneklerini içerir. Bu cerrahi tedaviler apikal bölgedeki kemik dolumu için greft materyalleri, trombositten zengin fibrin (TZF) gibi materyallerle desteklenebilmektedir.

Olgu Sunumları: Çalışmamızda tüm vakalarda öncelikle endodontik tedavi uygulanmıştır. Endodontik tedaviyi takiben radyografik iyileşme gözlenmeyen maksiller anterior bölgede tek köklü apikal lezyona sahip 5 vaka lokal anestezi altında güncel yaklaşım olan submarjinal insizyon ile açık flep debridmanı ile tedavi edilmiştir. Bunlardan üçüne apikal rezeksiyon uygulanmış, kök ucu retrograt doldurulmuştur. İki vakada ise apikal rezeksiyonsuz ilgili bölge açık flep debridmanı uygulamıştır. Tüm kemik defektleri allogreft materyali ve PRF uygulaması ile tedavi edilmiştir. Hastaların 6 aylık radyografik takibi sunulmaktadır.

Sonuç: Endodontik tedavi, apikal lezyonların tedavisinde önemli ölçüde iyi performans gösterir; ancak endodontik tedaviye rağmen iyileşme gözlenmeyen apikal lezyon durumları detaylı tanı ve planlama gerektiren, klinisyenin üstesinden gelmesi zor olan durumlardır. Multidisipliner tedavi yaklaşımı gerektiren bu durumlarda açık flep debridmanı ile tedavi başarıyı ve radyografik kemik dolumunu artırmaktadır. Greftleme prosedürü, ilgili iyileşmeyi desteklemek ve prognozu iyileştirmek için ek fayda sağlar. Allogreft ve TZF ile uygulanan periapikal cerrahi, doğal diş yapısını koruyarak lezyonun başarılı bir şekilde tedavi edilmesini sağlar.

Anahtar Kelimeler: *Allogreft, Debridman, Periapikal hastalıklar, Trombositten zengin fibrin.*

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Introduction

The periodontal tissues and pulp are related at embryonic, anatomical and functional levels. Cross-infection can develop horizontally and/or vertically between the root canal and periodontium via various contact routes, including the apical foramen, lateral and accessory canal systems, dentinal tubules, development grooves, treatment-related perforation and radicular fracture.[1] If the pulp tissue becomes affected by factors such as trauma, caries, inflammation can develop in the periodontium via these aforementioned pathways. Infections caused by pulpal-derived bacteria at the root apex are known as periapical diseases (PAD).

Root canal treatment (RCT) is widely accepted as the primary therapeutic approach for the management of PAD. A success rate in excess of 80% has been demonstrated for the treatment of apical lesions.[2] Notwithstanding the advancement of technology and equipment related to RCT, there may be instances of periapical lesions that do not heal. Given the intricacies inherent to the root canal system, the establishment of extraradicular bacterial biofilms, and the genesis of true cysts, certain periapical diseases may necessitate apical surgical intervention. This intervention can employs a combination of resective and regenerative methodologies to ensure the most efficacious eradication of the infection.[3] Apical surgery is indicated for teeth that demonstrate symptoms and/or positive signs following RCT and retreatment, or for teeth exhibiting symptoms and/or positive signs that cannot be accessed coronally for endodontic treatment.[4] A detailed and accurate diagnosis is imperative, as is careful planning, due to the challenges associated with management and the questionable prognoses of these lesions. Consequently, periapical surgery is a promising alternative treatment method that has the potential to preserve natural teeth.

In contemporary practice, apical surgery, periradicular surgery, and intentional replantation are employed in the management of periapical lesions. Apical surgery is a surgical procedure that involves the following: osteotomy, root tip resection, root tip preparation, retrograde obturation, and debridement of the surrounding defect. Despite the technical precision required for this procedure, its complications are minimal and its success rate is high.[5] It is imperative to consider the feasibility of apical surgery in cases where inadequate periodontal support is present, or where the coronal-to-radicular proportion exceeds 1:1 following apical root resection.[4] Periradicular surgery, which includes root resection and hemi-section, is a surgical approach that is performed to remove the root or rootlets of a tooth. In cases where apical surgery is not a viable option, intentional replantation can be performed. This procedure involves extracting the tooth, followed by the implementation of a root-end filling or perforation repair, and subsequent reinsertion into the dental alveolus. According to the protocol recommended by the European Endodontic Society, periapical surgery is indicated in cases of painful and inflammatory PAD affecting a mature tooth undergoing good-quality RCT, periapical pathology with difficult-to-remove prosthetic or conservative restorations, radiotransparent lesions larger than 8–10 mm in diameter, symptomatic gutta-percha extrusion, the presence of a foreign body that cannot be removed orthogradely, perforation of the pulp chamber floor, and other indications such as patients requiring a single-visit endodontic treatment and periapical surgery or fracture of the apical third of teeth.[6]

Von Arx and Cochran[7] proposed a classification system based on the morphology of defects, distinguishing between location, extent, and route of infection. This classification was based on the preservation of the bone crypt walls. Within this framework, class I defects are confined to the apical region and are subdivided into class Ia lesions, characterized by four intact bony walls, and class Ib lesions, defined as through-and-through defects involving loss of the buccal and/or palatal or lingual cortical plate. In addition, apicomarginal, or endoperiodontal, lesions are described as defects in which periapical pathology communicates with a concomitant marginal periodontal lesion.

Apical surgical methods involve the utilization of numerous techniques and materials, which are selected based on the morphology of the defect and the condition of the tooth. These treatments can be supplemented with materials such as graft materials, membranes, and platelet-rich fibrin (PRF) for bone filling in the apical region to preserve the natural tooth structure. The present study presents the healing processes observed at the 6-month follow-up following periapical surgery with periodontal flaps and apical curettage in five cases of maxillary anterior single-rooted teeth with four-walled periapical lesions.

Case Reports

Informed consent was obtained from all participants included in this study. It is imperative to employ an interdisciplinary approach during treatment planning for cases with periapical lesions to ensure the efficacy and favorable outcomes of treatment. As endodontic infection has been demonstrated to have a detrimental effect on periodontal healing, all cases were initially treated with gutta percha, a primary endodontic material, along with root canal sealer. This case series includes a total of five systemically healthy, non-smoking patients aged 20 to 55 years diagnosed with a single-rooted maxillary anterior tooth exhibiting a four-walled periapical lesion with a greatest diameter ≤10 mm and Periapical Index (PAI) score ≥3. Complete radiographic healing was not observed in these lesions during the 6-month follow-up period after endodontic treatment. Patients with probing pocket depth >5 mm, vertical root fracture, previous periapical surgery, uncontrolled systemic diseases, pregnancy, breastfeeding, and anticoagulant use were excluded from the study. The treatment of these patients involved open flap debridement, performed under LA. The location of the root apex was determined on the basis of preoperative cone-beam computed tomography (CBCT) images, the working length of the RCT, the position of the sinus tract, and the height of the alveolar bone at the root. In all cases, a submarginal incision was preferred to avoid causing gingival recession in the aesthetic zone and osteotomies were performed in the apical region of the involved teeth because the cortical bone in this region was found to be intact. Following submarginal incision and full-thickness flap elevation, an osteotomy was performed using a round steel bur (size 4, diameter 2.1 mm) attached to a high-speed handpiece under copious sterile saline irrigation to prevent thermal bone injury. The osteotomy diameter was approximately 3-4 mm, extending 2-3 mm beyond the root apex to ensure complete exposure of the periapical lesion. Periapical curettage was performed using Gracey curettes (Nos. 5/6, 7/8, 11/12) and Prichard curretes (Nos.1/2 and 3/4) to remove all granulation tissue. In the three cases requiring apical resection, the root apex was resected 3 mm perpendicular to the long axis of the root using a fissure bur. Retrograde cavity preparation was performed to a depth of 3 mm using a fissure bur with continuous water irrigation. The cavity was dried with sterile paper points, and MTA (ProRoot MTA, Dentsply, USA) was mixed according to the manufacturer's instructions (powder-to-liquid ratio of 3:1) and condensed into the retrograde cavity using MTA carrier and pluggers. The MTA was allowed to set for 10 minutes before soft tissue closure. In two cases, open flap debridement was applied to the affected area without apical resection. The treatment of all bone defects was accomplished through the utilization of demineralized freeze-dried bone allograft (DFDBA) material and PRF, which was obtained by centrifuging 10 mL of venous blood at 2700 rpm for a duration of 12 minutes at room temperature in plain glass tubes without anticoagulant.

After centrifugation, the resulting fibrin clot was carefully removed from the tube using sterile tweezers and scissors, and the red blood cell layer was separated from the fibrin clot. The PRF clot was then compressed between two moist sterile gauze pads to obtain a membrane form. The DFDBA allograft used in this study is a demineralized freeze-dried bone allograft with particle sizes ranging from 500 to 1000 μm (Maxxeus, USA). Following periapical curettage, the granulation-like tissue was dispatched to the pathology laboratory for pathological examination. Histopathological examination revealed (periapical granuloma in 3 cases, periradicular cyst in 1 case and dentigerous cyst in 1 case) with no evidence of dysplasia or malignancy. All patients were advised to use chlorhexidine mouthwash to maintain oral hygiene after surgery, and antibiotics and analgesics were prescribed for 5-7 days to prevent infection. It was recommended that intermittent application of cold compresses to the surgical site should be continued for a period of 24 hours. Postoperatively, mild pain and mild swelling occurred in all cases. Regular clinical and radiographic checks were performed 3 and 6 months after surgery, revealing radiographic bone filling in all periapical lesions. Postoperative radiographic evaluation was performed using periapical radiographs at 6 months postoperatively. All radiographic images were anonymized and evaluated independently by two periodontologist (Ş.A.,T.Y.E.) who were blinded to the clinical data. Periapical bone healing was assessed based on bone filling of the periapical defect and restoration of the lamina dura.[2] Periapical bone healing was assessed as (1) complete healing (complete bone filling with lamina dura restoration), (2) partial healing (>50% reduction in lesion size), (3) indeterminate healing (50% or less reduction or no change), and (4) failure (increase in lesion size or persistence of symptoms). Each examiner independently assigned one of these four categories to each of the 5 cases. Inter-observer agreement was calculated based on these categorical assessments. Two examiners agreed in 4 out of 5 cases (80%). In cases of disagreement, a consensus was reached through discussion. Lesion size at baseline and follow-up was measured in millimeters using digital calipers integrated into the imaging software (Planmeca Romexis).

Table 1. Clinical characteristics, diagnoses, surgical treatments, and 6-month postoperative outcomes of the five cases.

Case	Patient	Tooth	Diagnosis	Surgical Treatment	Outcome
Case 1	23, Female	#11	Periapical granuloma	Debridement + Allograft + PRF (no apical resection)	Complete healing
Case 2	31, Female	#11	Periapical granuloma	Apical resection + Retrograde MTA + Allograft + PRF	Complete healing
Case 3	35, Male	#22	Periradicular cyst	Apical resection + Retrograde MTA + Allograft + PRF	Complete healing
Case 4	55, Male	#12	Periapical granuloma	Debridement + Allograft + PRF (no apical resection)	Complete healing
Case 5	21, Female	#12	Dentigerous cyst	Apical resection + Retrograde MTA + Allograft + PRF	Complete healing

Case 1: A 23-year-old female patient was referred to the periodontology clinic because of a periapical lesion on tooth #11 that failed to heal throughout the course of endodontic follow-up. Subsequent clinical and radiographic examinations following Phase 1 periodontal treatment revealed that the periodontal parameters of the involved tooth were consistent with normal health, and apical surgery was planned. Following the administration of LA, a full-thickness (FT) flap was raised through a submarginal and two vertical incisions, encompassing both adjacent teeth. The defect was meticulously cleared of granulation tissue and thoroughly irrigated with a sterile saline solution. Following a comprehensive evaluation of the crown-to-root ratio, the defect was augmented with an allograft, with no apical resection, and subsequently covered with a PRF membrane. The flap was then repositioned without tension. The pathological result of the lesion revealed a periapical granuloma. Histopathological examination revealed a periapical granuloma characterized by a solid proliferation of inflamed granulation tissue and scattered cholesterol clefts. Consistent with its non-cystic nature, the epithelial lining or lumen formation is completely absent. Periapical radiographs from the patient's 6-month follow-up are presented in Figure 1.

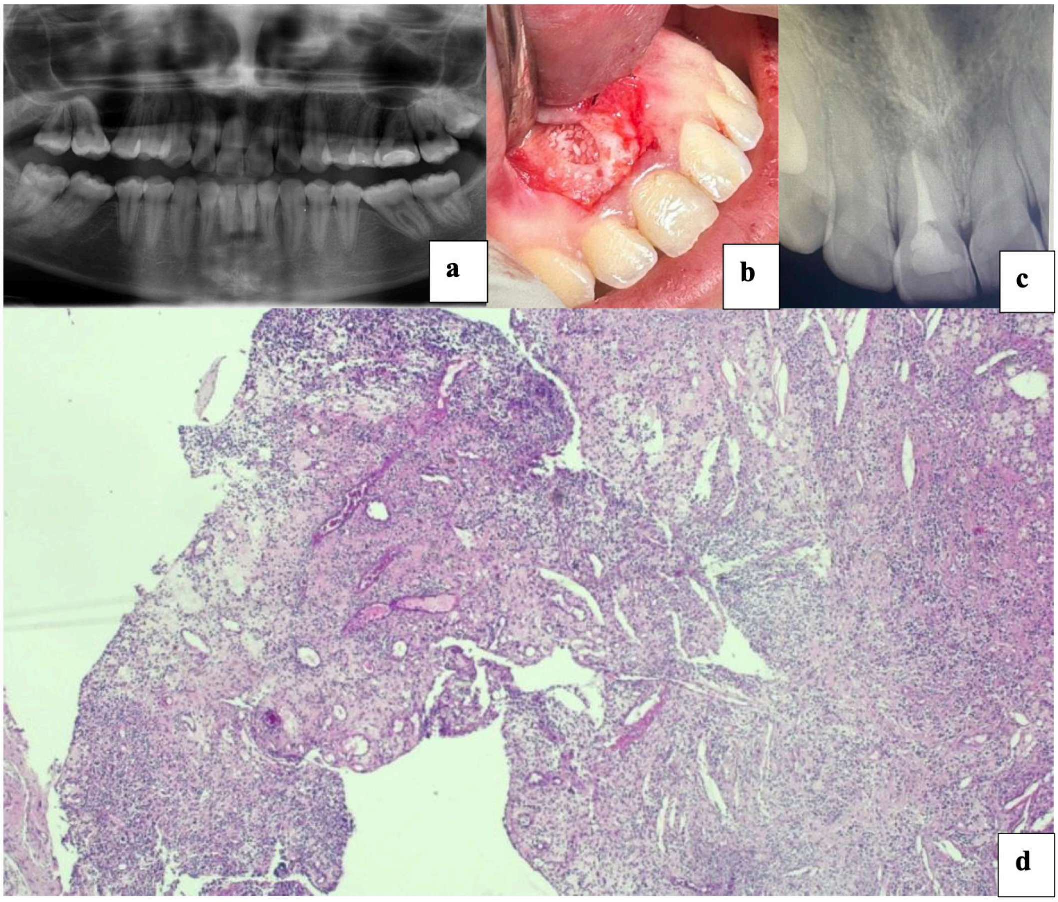

Figure 1. Preoperative panoramic radiograph (a) shows the periapical lesion associated with tooth #11, intraoperative view during apical surgery (b) demonstrates the exposed root apex and the allograft material in the surgical field, postoperative periapical radiograph (c) was taken at the 6-month follow-up, and histopathological hematoxylin-eosin staining image (d) shows the lesion diagnosed as periapical granuloma in Case 1.

Case 2: A 31-year-old female patient was referred to the periodontology clinic due to a periapical lesion in tooth number 11 that did not show improvement during the endodontic follow-up period after re-treatment. Following phase 1 periodontal treatment, the tooth was determined to be periodontally healthy and was scheduled for apical surgery. Following the administration of LA, a FT flap was raised through a submarginal incision and two vertical incisions. The defect was then meticulously cleansed of granulation tissue using periodontal curettes, followed by irrigation with a sterile saline solution. Following a comprehensive evaluation of the crown-to-root ratio, a meticulous apical resection procedure was undertaken. The root surface was resected at a distance of approximately 3 mm perpendicular to the long axis of the tooth, with the use of piezosurgical tips. The resected root surface was flattened, and hemostasis was achieved through mechanical compression. The resected surface was then rinsed with a saline solution, dried, and examined for vertical root fractures, perforations, and other abnormalities. A Class I cavity was prepared on the resected root surface using piezosurgical tips of appropriate diameter and bending direction, reaching a depth of 3 mm. The root canal was then meticulously cleaned and dried. Following this, the cavity was filled with MTA retrograde plug using hand instruments. The excess material located outside the root canal was then removed. The defect was then augmented with an allograft and covered with a PRF membrane. The flap was then replanted, this time without tension. The pathology of the lesion revealed a periapical granuloma. Radiographic images from the patient's 6-month follow-up are presented in Figure 2.

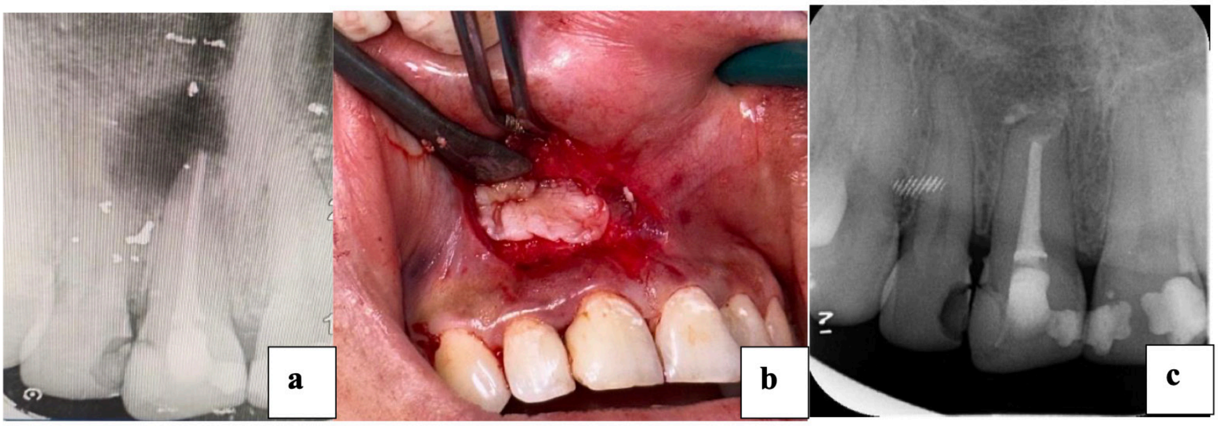

Figure 2. Preoperative periapical radiograph (a) shows the periapical lesion associated with tooth #11, intraoperative view during apical surgery (b) demonstrates the exposed root apex and the PRF membrane in the surgical field, and postoperative periapical radiograph (c) is the 6-month periapical radiograph in Case 2.

Case 3: A 35-year-old male patient presented with a non-healing periapical lesion on tooth 22. He was referred to the periodontology clinic for further evaluation. Subsequent clinical and radiographic examinations following Phase 1 periodontal treatment revealed that the clinical periodontal parameters of the involved tooth were consistent with clinical health and that no pathological conditions were present. Apical surgery was planned. Following the administration of LA, a FT flap was elevated using a submarginal incision and two vertical incisions extending to cover the involved tooth and two adjacent teeth. A minimal osteotomy was performed, with the preservation of adjacent tooth structures being crucial to facilitate access to the defect and improve visualization. The defect was then cleared of granulation tissue using periodontal curettes, after which it was irrigated with a solution of sterile saline. Following a comprehensive evaluation of the crown-to-root ratio, the decision was made to proceed with an apical resection. Under conditions of sterile water cooling, approximately 3 mm of the root apex was resected, with meticulous attention paid to the positioning of the root cross-section to ensure its perpendicularity to the long axis of the root or its inclination at an angle of $\leq 10°$ in the buccal direction. A retrograde Class 1 cavity was created using piezosurgical tips, and a retrograde filling was applied with MTA. The defect was then augmented with an allograft and covered with a PRF membrane. The flap was then repositioned without tension. The pathology result of the lesion revealed a periradicular cyst. Histopathological examination reveals a radicular cyst lined with non-keratinized stratified squamous epithelium exhibiting a characteristic arcading pattern. The underlying fibrous wall exhibits a prominent inflammatory infiltration consistent with its odontogenic origin. Periapical radiographs from the patient's 6-month follow-ups are presented in Figure 3.

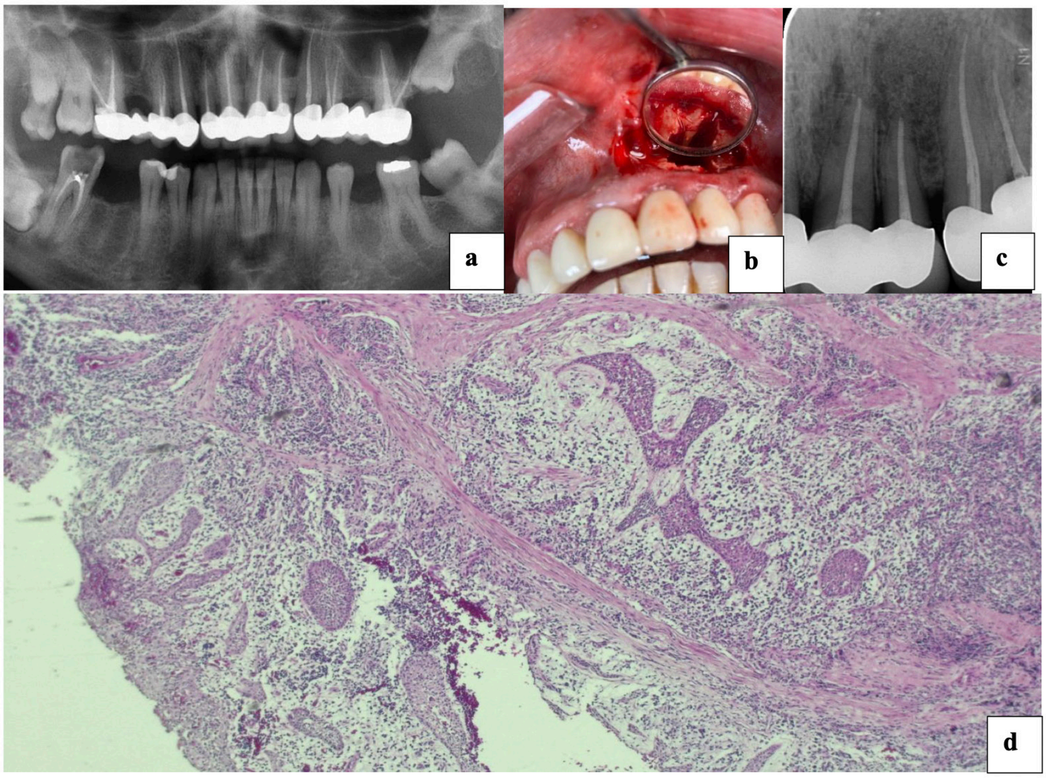

Figure 3. Preoperative panoramic radiograph (a) shows the periapical lesion associated with tooth #22, intraoperative view during apical surgery (b) demonstrates the surgical osteotomy, postoperative periapical radiograph (c) is the 6-month periapical radiograph, and histopathological hematoxylin-eosin staining image (d) shows the lesion diagnosed as periapical cyst in Case 3.

Case 4: A 55-year-old male patient with a non-healing periapical lesion on tooth number 12 was referred to the periodontology clinic for pathological migration in the involved tooth and for evaluation for periapical surgery. Following Phase 1 periodontal treatment, it was noted that the clinical periodontal parameters of the affected tooth corresponded to the clinical health of the diminished periodontium, and apical surgery was planned. Following the administration of LA, a FT flap was raised through a submarginal incision and two vertical incisions. The defect was meticulously cleansed of granulation tissue and foreign material using periodontal curettes, followed by irrigation with a sterile saline solution. In the case of the tooth with diminished periodontium, it was decided to perform apical surgery without apical resection. The defect was augmented with an allograft and covered with a PRF membrane. The flap was then repositioned without tension. The pathological findings for the affected lesion revealed a periapical granuloma. Periapical radiographs from the patient's 6-month follow-up are presented in Figure 4.

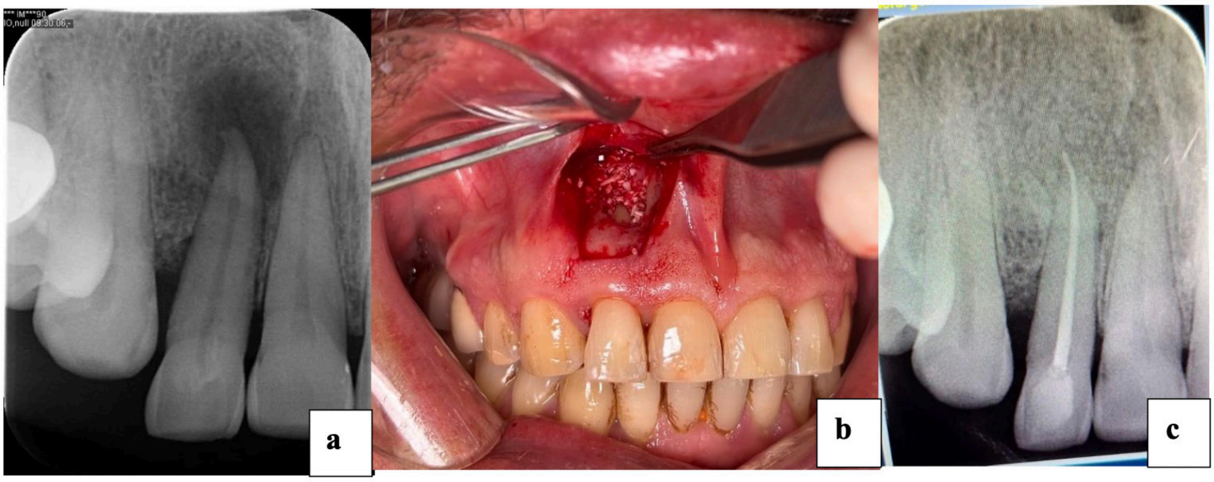

Figure 4. Preoperative panoramic radiograph (a) shows the periapical lesion associated with tooth #12, intraoperative view during apical surgery (b) demonstrates the allograft material in the surgical field, and postoperative periapical radiograph (c) is the 6-month periapical radiograph in Case 4.

Case 5: A 21-year-old female patient was referred to the periodontology clinic following the development of a non-healing periapical lesion on tooth number 12. Phase 1 periodontal treatment was performed after reviewing CBCT images obtained in the endodontic clinic to determine the extent of the lesion and examine its anatomical relationship with the diseased tooth and surrounding tissues. At the subsequent follow-up visit, it was observed that the clinical periodontal parameters of the involved tooth corresponded to the clinical health, and apical surgery was scheduled. Following the administration of LA, a FT flap was elevated using a periosteal elevator through a submarginal incision and two vertical incisions. The defect was meticulously cleared of granulation tissue and thoroughly irrigated with sterile saline. Following a comprehensive evaluation of the crown-to-root ratio, a decision was made to proceed with an apical resection. The root surface was resected at a distance of approximately 3 mm perpendicular to the long axis of the tooth. This was achieved using piezosurgical instruments to expose the root apex. A retrograde Class 1 cavity was created, and a retrograde filling was applied with MTA. The defect was then augmented with an all-graft and closed with a PRF membrane. The flap was then reattached using 4.0 non-absorbable polypropylene sutures, with the application of minimal tension. The pathology result for the lesion revealed a dentigerous cyst. Histopathological examination reveals an inflamed, non-keratinized squamous epithelial lining taken from the fragmented cyst wall. The panoramic and periapical radiographs from the patient's 6-month follow-up are presented in Figure 5.

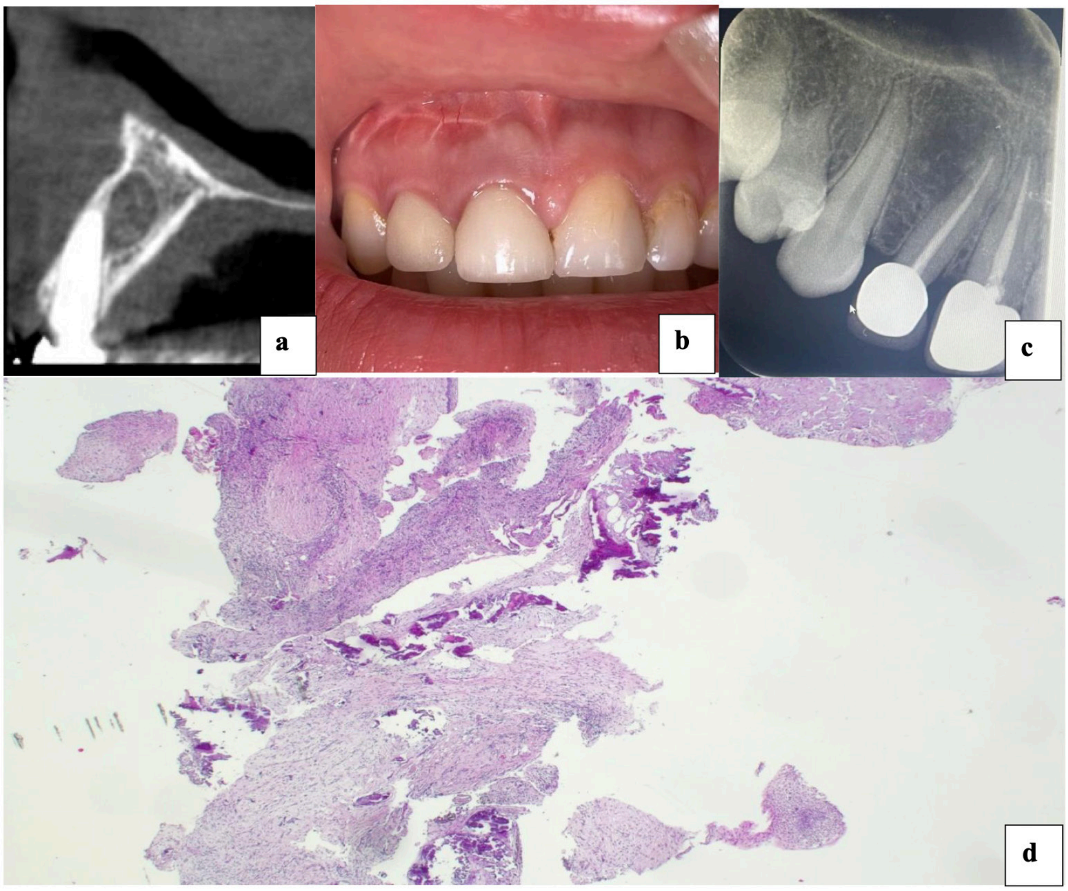

Figure 5. Preoperative CBCT image (a) shows the height and width of the lesion, postoperative clinical image (b) shows no gingival recession, postoperative periapical radiograph (c) is the 6-month periapical radiograph, and histopathological hematoxylin-eosin staining image (d) shows the lesion diagnosed as dentigerous cyst in Case 5.

Discussion

The overall performance of conventional endodontic treatment for periapical lesions is significantly higher; however, in persistent and complex cases or cyst formation, surgical treatment and regeneration are required as the last treatment option before tooth extraction.[6]

The diagnosis, treatment and post-treatment process of periapical lesions present a considerable challenge for the clinician, requiring detailed diagnosis and planning from both endodontic and periodontological perspectives. Despite their relative rarity in clinical practice, they have the capacity to compromise dental prognosis to a significant degree.[8] The prognosis is contingent upon the efficacy of periodontal repair/regeneration initiated by the treatment procedures, and the patient's response to treatment, which can vary from patient to patient.[9] An accurate diagnosis, a well-planned treatment plan incorporating a multidisciplinary approach, and the subsequent implementation of the treatment plan with the selection of appropriate techniques and materials are crucial for successful treatment.

The healing process following periapical surgical treatment is characterized by the local bone repair. This process is defined as wound healing, which involves the formation of new tissue that does not fully restore the architecture or function of the existing bone.[10] The process of complete periapical healing is characterized by the regeneration of periodontium.[6] Regenerative techniques are increasingly incorporated into periapical surgical procedures to enhance healing quality by restoring lost or damaged tissues with biologically compatible cells and to support repair in clinically challenging situations.[6,10] Although the indication for grafting periapical defects remains controversial, existing evidence suggests that bone grafting may contribute positively to periodontal healing around the affected tooth and improve overall prognosis.[11,12] Within the framework of guided tissue regeneration (GTR), various adjunctive materials—including graft substitutes, barrier membranes, and platelet-derived concentrates—are utilized to promote regenerative outcomes, all of which fall under the principles of tissue engineering.[6,10] GTR has also been advocated in endodontic surgical applications and has demonstrated favorable results in the healing of periapical lesions.[6,7,13] Long-term follow-up data have shown successful regeneration in a high proportion of teeth with advanced apical attachment loss following periodontal regenerative therapy.[14] Conversely, other investigations have reported satisfactory long-term outcomes in four-walled defects treated surgically without the use of membranes, noting that membrane application may increase treatment costs, add technical complexity, and potentially introduce postoperative complications.[7] In the present study, demineralized freeze-dried bone allografts—known to exhibit osteoinductive and osteoconductive characteristics depending on their composition and processing—were selected as grafting materials. Additionally, PRF membranes were employed to assess both clinical effectiveness and cost-efficiency.

Autologous platelet concentrates have been widely recognized as biologically active materials that support healing in intrabony defects. PRF, in particular, functions as a bioactive scaffold that facilitates periodontal regeneration. It remains within the surgical site for a limited duration, during which it promotes tissue repair and regeneration through the sustained release of platelets and a variety of growth factors.[15] The fibrin matrix, owing to its adhesive and mechanical properties, aids in flap stabilization and serves as a reservoir for growth factor release. These bioactive molecules stimulate the migration and proliferation of key regenerative cells—including osteoblasts, fibroblasts, and endothelial cells—thereby supporting angiogenesis, cellular differentiation, wound healing, and periodontal regeneration.[16] Current evidence remains inconclusive as to whether platelet concentrates are more beneficial when applied alone or in conjunction with bone substitute grafts in intrabony defects. Researchers have concluded that the combined use offers superior clinical efficacy,[17] while others have demonstrated no additional benefit.[18] Numerous studies have demonstrated that platelet concentrates combined with bone grafts offer a high success rate, support effective radiographic and clinical bone repair, accelerate lesion healing, and increase the predictability of the regenerative process.[17,19,20] Consistent with our study, a recent research also highlighted that periapical lesions treated with L-PRF showed a higher healing success rate. Additionally, it was concluded that the combination of periapical curettage and L-PRF offers a less invasive alternative, particularly in cases where the crown-root ratio is a concern.[21] Furthermore, due to the poor prognosis in lesions >5 mm, the use of regeneration materials appears necessary.[22] It is well established that regenerative outcomes positively correlate with the number of remaining bone walls, with four-walled defects demonstrating more predictable healing.[23] In our cases, all defects were >5 mm and had a four-walled morphology. For these reasons, allografts were supported with PRF as the regenerative material in the cases in this study. A clinical study compared the effectiveness of PRF and freeze-dried bone allograft in the surgical treatment of periapical lesions. PRF was found to be more effective in healing within the first 6 months, while complete healing was observed in both groups of cases by the 12th month.[24] The combined use of both materials aims to mutually benefit from the slower resorption of graft materials compared to PRF and the potential of PRF to promote regeneration and wound healing through growth factor release, thus supporting periodontal regeneration. At the 6-month follow-up, the presence of bone filling was observed in all radiographic images. Histological analysis of bone tissue is widely regarded as the most reliable technique for assessing healing. However, routine application is limited by ethical considerations.[6,22] In the present study, histopathological evaluation is necessary to determine whether the healing is complete regeneration, and its absence constitutes a limitation.

Conventional root canal obturation using gutta-percha in combination with a root canal sealer remains the primary filling method because of its favorable handling properties and biocompatibility. However, there is also evidence to suggest that gutta percha is vulnerable to bacterial/coronal microleakage.[25] The utilization of gutta percha and MTA for root canal filling has been demonstrated to facilitate the resolution of complex endo-periosteal lesions.[26] The optimal treatment strategy for such cases involves the combination of MTA filling and bone grafting.[27] Therefore, in the present study, all root canal fillings were performed using gutta-percha, while all retrograde fillings were performed using MTA.

The anatomical characteristics of teeth as well as flap design have been shown to significantly influence the outcomes of regenerative therapy. Multi-rooted teeth are generally regarded as more susceptible to infection because of limited surgical accessibility, complex root canal anatomy, and the presence of furcation areas. In addition, treatment outcomes in these teeth are typically less favorable when compared with single-rooted teeth.[28] Various flap designs—including conventional flaps, papilla-preserving techniques, and minimally invasive surgical approaches with or without papilla elevation—have been reported to minimize exposure of regenerative materials and to lower the risk of early wound-healing complications in regenerative procedures.[29,30] For anterior teeth, a rectangular flap design incorporating mesial and distal vertical releasing incisions together with a horizontal incision placed within the gingival sulcus or adjacent gingiva is commonly preferred.[2] In aesthetically demanding areas, horizontal submarginal or papilla-based incisions are recommended to reduce the likelihood of gingival recession, which may occur following horizontal sulcular incisions.[31] Previous investigations comparing single- and double-flap approaches in periodontal regenerative therapy have demonstrated no significant differences between these techniques with respect to radiographic defect fill at six months. To ensure methodological standardization, the present study included only single-rooted, single-canal teeth.[29] Given the location of all teeth in the maxillary anterior region and the presence of four-walled defects, a single buccal flap approach was employed, with a submarginal design implemented in all incisions, including those adjacent to the attached gingiva. No evidence of regenerative biomaterial exposure was observed in the postoperative period.

The majority of studies on periapical surgery evaluate radiographic criteria and bone fill as the primary criteria for success or failure.[13] The definition of success in this context is considered to be effective if there is no pain or swelling in the involved tooth, good soft tissue healing, no sinus patency, no loss of function, and imaging studies show that the lesions have disappeared or shrunk.[2] In the present study, the healing and bone fill were evaluated using periapical radiographs at follow-up. The results of the study demonstrated that bone filling and trabeculae formation were observed on radiographs in all cases during the follow-up periods. This finding supports the potential of the combined use of allograft and PRF. Furthermore, radiographic criteria for complete healing and failure have been reported to have a high degree of reliability following a 1-year period of follow-up.[13] However, the follow-up period in our study was limited to 6 months, which is shorter than the 12-month period recommended in the literature for reliable radiographic assessment of periapical healing. It is acknowledged that bone healing, particularly in the context of combined periodontal-endodontic lesions, may require a longer observation period to reach complete maturation and stability. Therefore, further studies with extended follow-up durations are recommended to confirm the long-term predictability of the treatment outcomes. It should be noted that radiographic assessment is subject to significant variability and observer bias.

Conclusion

In the surgical treatment of four-walled periapical lesions requiring a multidisciplinary treatment approach, the use of allograft and PRF provides additional benefits for promoting healing and improving prognosis and may be a potential good treatment strategy. Properly performed periapical surgery can treat endodontically derived diseases with a high success rate, thus preserving the healthy natural dentition. It is imperative that further randomized clinical studies are conducted, incorporating large sample sizes, standardized flap designs, and long-term follow-up, utilizing diverse materials, both individually and in combination, to substantiate the efficacy of bone grafting in such defects and to ascertain the effectiveness of PRF utilization.

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Ethical Approval

This study did not use human or animal-derived sources, ethics committee approval was not obtained. An informed consent form is available.

Conflict of Interest

None of the authors of this article has any relationship, connection or financial interest in the subject matter or material discussed in the article.

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Idea/Concept: Ş.A, T.Y.E Design: Ş.A, T.Y.E Control/Supervision: Ş.A, T.Y.E Resources: Ş.A, T.Y.E Materials: T.Y.E Data Collection and/or Processing: Ş.A Analysis and/or Interpretation: Ş.A Literature Review: Ş.A Writing the Article: Ş.A Critical Review: Ş.A

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