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ARAŞTIRMA MAKALELERİ - RESEARCH ARTICLES

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Effectiveness of Ascorbic Acid in Eliminating Orange-Brown Precipitate from Root Canals

Kök Kanallarından Turuncu-Kahverengi Çökeltiyi Uzaklaştırmada Askorbik Asitin Etkinliği

Beyza Tunç[1], İrem Özçelik[1], Ceren Özcan Diker[2], Kürşat Er[3*]

ABSTRACT

Objectives: To determine the effect of ascorbic acid (AA) on the removal of orange-brown precipitate (para-chloroaniline) (PCA) formed by the interaction of sodium hypochlorite (NaOCl) and chlorhexidine (CHX) during root canal treatment.

Materials and Method: PCA was obtained by mixing 1.25 mL of 2.5% NaOCl and 1.25 mL of 2% CHX in glass tubes. Different concentrations of AA ranging from 5-30% were prepared and the effect of these solutions on PCA solubility was determined by gravimetric method. In addition, a deep eutectic solvent system (DES) was obtained by mixing certain mole ratios of AA, glycerin and deionized water at 70 °C for 1 h and cooling to room temperature at the end of the time. The performance of DES on the solubility of PCA was evaluated using the same method.

Results: In control group prepared with a certain volume of physiological saline applied to PCA at constant volume at 25 °C, it was determined that PCA dissolved approximately 27%. When a certain volume of AA was applied to the PCA the same way, it was determined that this rate increased to approximately 55% with the increase in the concentration of AA. In addition, a solubility of over 80% was achieved in PCA to which a certain volume of DES was applied.

Conclusion: High concentrations of AA can be used as an irrigating solvent for the removal of PCA and it was also found that DES system has the potential to be a more effective solvent for PCA solubilization compared to AA.

Keywords: *Ascorbic acid, Precipitate, Chlorhexidine, Root canal irrigation, Para-chloroaniline, Sodium hypochlorite*

ÖZET

Amaç: Bu çalışmanın amacı, kök kanal tedavisi sırasında sodyum hipoklorit ve klorheksidin solüsyonlarının etkileşimi sonucu oluşan turuncu-kahverengi para kloroanilin çökeltisinin (PKA) uzaklaştırılmasında askorbik asitin (para-kloroailin) (AA) etkisini belirlemektir.

Gereç ve Yöntem: PKA, laboratuvar koşullarında cam tüplerde 1.25 mL %2.5'lik sodyum hipoklorit ve 1.25 mL %2'lik klorheksidin çözeltileri karıştırılarak elde edildi. %5-30 arasında değişen farklı konsantrasyonlarda AA çözeltileri hazırlandı ve bu çözeltilerin kök kanalındaki PKA çözünürlüğü üzerindeki etkisi gravimetrik yöntemle belirlendi. Ayrıca, belirli mol oranlarında AA, gliserin ve deiyonize suyun (AA: Gli: H_2O) 70 °C'de 1 saat karıştırılması ve sürenin sonunda oda sıcaklığına soğutulmasıyla derin ötektik bir çözücü sistemi (DÖÇ) elde edildi. DES'in PKA çözünürlüğü üzerindeki performansı aynı yöntem kullanılarak değerlendirildi.

Bulgular: 25 °C'de sabit hacimde sodyum hipoklorit ve klorheksidin ile hazırlanan PKA'ya belirli hacimde serum fizyolojik uygulanarak hazırlanan kontrol grubunda, PKA'nın yaklaşık %27 oranında çözündüğü belirlendi. Aynı şekilde hazırlanan PKA'ya belirli hacimde AA uygulandığında, AA konsantrasyonundaki artışla bu oranın yaklaşık %55'e çıktığı belirlendi. Ayrıca, belirli hacimde DÖÇ uygulanan PKA'da %80'in üzerinde bir çözünürlük elde edildi.

Sonuç: Kanal içerisinde oluşan PKA'nın uzaklaştırılmasında irrigasyon çözücüsü olarak yüksek konsantrasyonlu AA solüsyonunu kullanılabilir. Ayrıca, DÖÇ sisteminin AA'ya kıyasla PKA'nın çözündürülmesinde daha etkili bir çözücü olma potansiyeline sahip olduğu bulunmuştur.

Anahtar Kelimeler: *Askorbik asit, Çözelti, Klorheksidin, Kök kanal irrigasyonu, Para-kloroanilin, Sodyum hipoklorit*

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Introduction

The goal of root canal treatment (RCT) is to eliminate bacteria from infected root canals and prevent reinfection. Biomechanical cleaning and shaping of the root canal significantly reduces bacterial counts; however, due to the anatomical complexity of the root canal system, organic and inorganic debris and bacteria cannot be completely removed, and bacteria often persist in root canal systems. Therefore, various irrigants are used to help remove residual debris, necrotic tissue, microorganisms, and the smear layer. Sodium hypochlorite (NaOCl), chlorhexidine (CHX), citric acid, and phosphoric acid are some of these irrigants.[1-3]

NaOCl is the most frequently used irrigant in endodontics. Its concentration can range from 0.5% to 8.5%, with 2.5% being the most common.[4] It has both tissue-dissolving and antibacterial capabilities. While higher concentrations of NaOCl enhance its antimicrobial efficacy, they may also lead to irritation of periapical tissues.[5] CHX is a positively charged, antimicrobial irrigant. In higher concentrations, it demonstrates bactericidal effects, while at lower doses, it exhibits bacteriostatic effects.[6] Despite having similar antimicrobial properties to NaOCl with lower toxicity, CHX lacks tissue-dissolving properties.[7,8]

The combination of NaOCl and CHX has been proposed as an irrigation protocol to enhance antimicrobial properties during RCT. However, a problem with this combination is that CHX irrigation in the presence of NaOCl in the canal produces a dense orange-brown precipitate.[3,9] Clinically, this precipitate is difficult to remove from the canal walls and can cause esthetic tooth discoloration. Another concern is that this precipitate can form a chemical smear layer, obstruct dentinal tubules, and compromise the seal of root canal fillings, particularly those using resin-based sealer.[9] Furthermore, its cytotoxic and carcinogenic potential on human tissues is a major concern. To prevent or remove this precipitate, researchers have tested a range of intermediate irrigants and final rinses (including chelators (EDTA, citric acid), organic acids and phytic acid, alcohol (ethanol or isopropyl alcohol), saline/water rinses, and newer agents) with variable efficacy: chelators and alcohols generally perform better at dissolving or displacing the deposit than water alone.[9,10] Several in vitro studies[11,12] specifically report that brief intermediate irrigation with EDTA or citric acid, or a short flush with high-concentration alcohol, significantly reduces residual precipitate compared with no intermediate rinse. In addition, activation techniques such as passive ultrasonic irrigation or sonic/EDDY activation enhance the mechanical disruption and removal of the precipitate versus syringe irrigation alone, improving penetration of the irrigant into irregularities and increasing the cleanliness of canal walls.[13,14] Taken together, these studies linking these strategies to improved long-term outcomes remain limited. Therefore, the search for new solutions and techniques continues. The aim of this study was to determine the effect of ascorbic acid (AA) (C Vitamin) and AA-containing deep eutectic systems (DES) in removing orange-brown precipitate (para-chloroaniline) (PCA) formed by the interaction of NaOCl and CHX during RCT.

Materials and Methods

Chemical agents

AA, used to prepare the irrigant, was supplied from BDH (British Drug Houses, London, UK), and the glycerol required for the preparation of the deep eutectic solvent system was supplied from Riedel-de Haen (Seelze, Germany). The 2.5% NaOCl required to produce parachloroaniline (PCA) was supplied from Cerkamed Medical (Chloraxid, Stalowa Wola, Poland). The 2% CHX was supplied from Jefix Dental (Istanbul, Türkiye). The physiological saline solution used in the control group was supplied by Turkfleks (Ankara, Türkiye). Deionized water was used throughout the study.

Preparation of solutions

In this study, specific amounts of AA solid were weighed separately. These amounts were dissolved in deionized water to prepare 25 mL AA solutions of 5%, 10%, 15%, 20%, 25%, and 30% by weight/volume. To investigate the effects of these solutions on the solubility of PCA, 2.5 mL of NaOCl and 2.5 mL of CHX were added to 6 separate test tubes, and PCA formation was achieved. Then, 5 mL of AA solution at a specific

concentration was added to each test tube. The tubes containing AA were vortexed for 10 sec to ensure thorough dispersion. Photographs of the test tubes were then taken. The same process was repeated with 5 mL of AA solutions at specific concentrations added to each test tube to determine whether the AA volume affected PCA solubility. The control group of this study was prepared by adding physiological serum instead of AA solution to PCA prepared with 2.5 mL of NaOCl and 2.5 mL of CHX in a separate test tube.

Test process

The study also investigated the effects of AA-based deep eutectic solvents (DES) on the solubility of PCA. For this purpose, AA, glycerol (Gly), and H_2O were added to separate capped glass vials at molar ratios of 1:4:10 (DES-1) and 1:10:10 (DES-2). The DES-1 system was stirred at 70 °C on a magnetic stirrer for 1 h, and the DES-2 system was stirred at 60 °C on a magnetic stirrer for 2 h. After allowing the mixture to cool to room temperature, both DESs were determined to have a homogeneous, transparent, and fluid structure.[15-17] To determine whether the prepared DESs could be used to dissolve PCA, 2.5 mL of DES-1 and DES-2 were added to PCA prepared with 1.25 mL of NaOCl and 1.25 mL of CHX in separate test tubes, and photographs were taken of the test tubes.

The amounts of PCA precipitated by mixing NaOCl and CHX and dissolved by adding various solutions were determined gravimetrically. For this purpose, eight 50 mL capped centrifuge tubes were weighed empty. 1.25 mL of NaOCl and 1.25 mL of CHX were added to each tube. Centrifugation was performed for 10 min at a rotation speed of 7500 rpm to precipitate the resulting PCA. After centrifugation, the liquid remaining on the precipitated PCA was removed by decantation, and the centrifuge tubes containing PCA were reweighed. The total amount of precipitated PCA was calculated from the difference between these weighing results and the weights of the empty tubes. Then, 5%, 10%, 15%, 20%, 25%, and 30% AA solutions were added to 6 tubes separately, DES-1 was added to one tube, and 2.5 mL of physiological serum was added to the control tube. The tubes were vortexed and ultrasonicated sequentially to completely disperse the precipitated PCA in the liquid portion. They were then centrifuged again at a rotation speed of 7500 rpm for 10 min. To determine the amount of PCA precipitated by centrifugation, the liquid in the tubes was removed by decantation and reweighed. The amount of PCA remaining undissolved in the centrifuge tube was determined from the difference between the final weighing values and the weights of the empty tubes. Thus, precipitated PCA, insoluble PCA, and % solubility values were calculated.

Results

Photographs showing the effect of AA concentration and applied AA volume on the solubility of PCA and including the control group are given in Figure 1, and photographic images of test tubes to which a total of 10 mL of AA solution at certain concentrations and physiological serum were added are given in Figure 2. An examination of Figures 1 and 2 reveals that PCA dissolves better with increasing the concentration of the AA solution added to the PCA formed with NaOCl and CHX. It appears that increasing the volume of AA applied does not significantly change the solubility of PCA, but diluting the medium facilitates visual monitoring of the remaining undissolved PCA. Figure 2 compared to the control group using physiological saline, clearly demonstrates that AA can be used as a highly effective irrigating solution for PCA, regardless of the applied concentration.

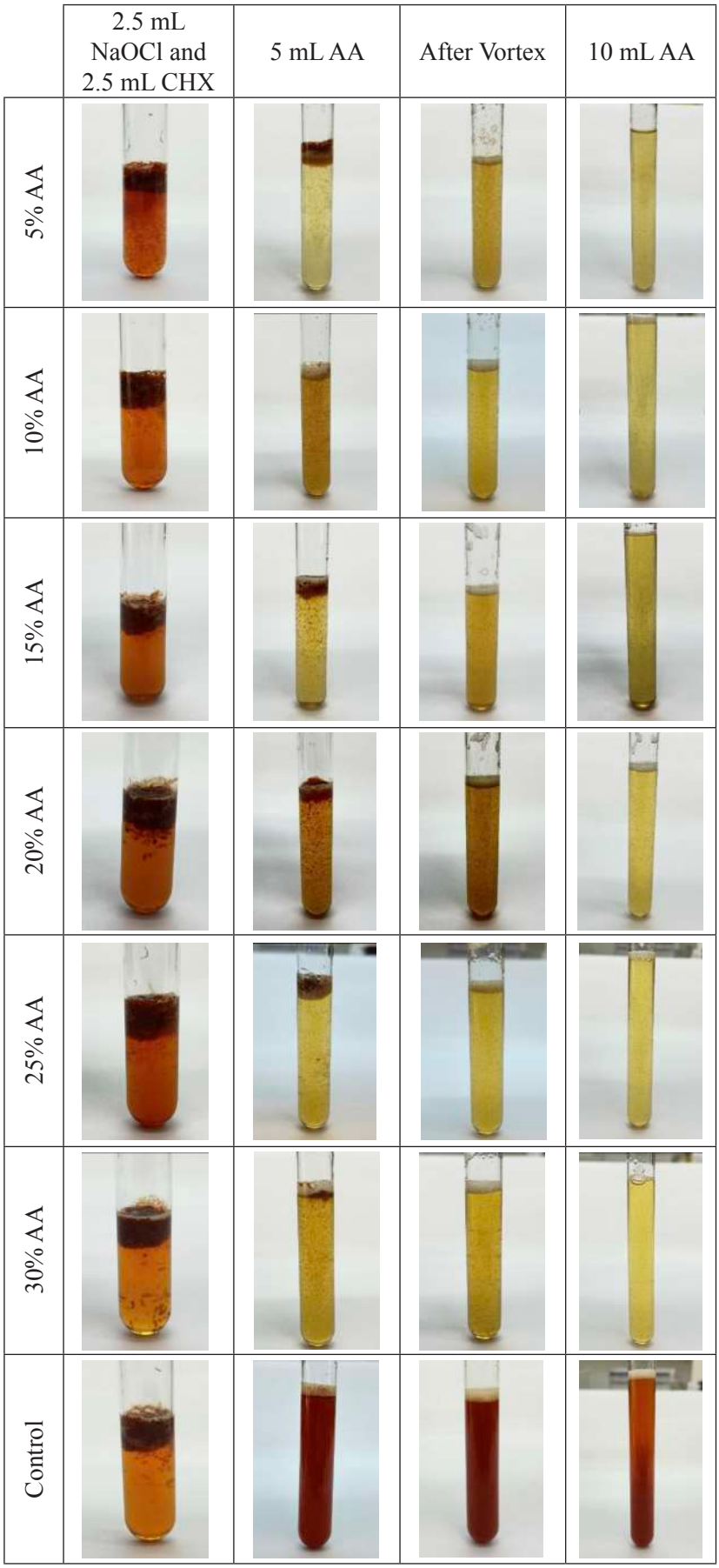

Figure 1. Photographs showing the effect of AA concentration and applied AA volume on the resolution of PCA and including the control group.

Figure 2. Photographs of test tubes to which 5 mL of AA (a) and 10 mL of AA (b) were added at specific concentrations.

The effects of deep eutectic solvents prepared using different ratios of AA, Gly, and H_2O on the dissolution of PCA were investigated. Photographs showing the effects of DES-1 and DES-2 on the solubility of PCA are given in Figure 3. The photographs in Figure 3 show that both DES-1 and DES-2 significantly dissolve PCA. It is particularly clear that DES-1 is the best dissolving PCA system among the DES systems, both compared to the AA solutions at different concentrations shown in Figure 2, and that it can be used as a highly effective irrigation solution for removing PCA formed in the canal.

Table 1. Precipitated PCA, insoluble PCA and % solubility values.

Solution	Precipitate PCA (g)	Insoluble PCA (g)	Solubility (%)
%5 AA	0.2247	0.1485	33.912
%10 AA	0.1919	0.1252	34.758
%15 AA	0.2746	0.1748	36.344
%20 AA	0.2081	0.1226	41.086
%25 AA	0.2150	0.1225	43.023
%30 AA	0.1939	0.0836	56.885
DES-1	0.1816	0.0339	81.333
Control	0.1828	0.1323	27.626

The amounts of dissolved PCA in the solvent systems applied to the precipitated PCA were determined gravimetrically. The calculated values for precipitated PCA, insoluble PCA, and % solubility are given in Table 1. When the values in Table 1 are examined, it is seen that the 27.626% solubility of PCA achieved by applying physiological saline solution increases from 33.912% to 56.885% with increasing concentrations of AA solution applied instead of physiological saline from 5% to 30%, and these numerical data confirm the results obtained

in Figures 1 and 2. From the data presented in Table 1 it is clearly seen that a high solubility of 81.333% was achieved with the deep eutectic solvent system prepared with AA:Gly:H_2O at a 1:4:10 molar ratio, coded as DES-1. However, during the studies, it was determined that the homogeneous DES-1 lost its stability after remaining at room conditions for more than 6 h. This suggests that if the reaction conditions for DES-1 prepared with AA:Gly:H_2O are optimized, it has the potential to be used as an irrigation solution providing high dissolution for PCA.

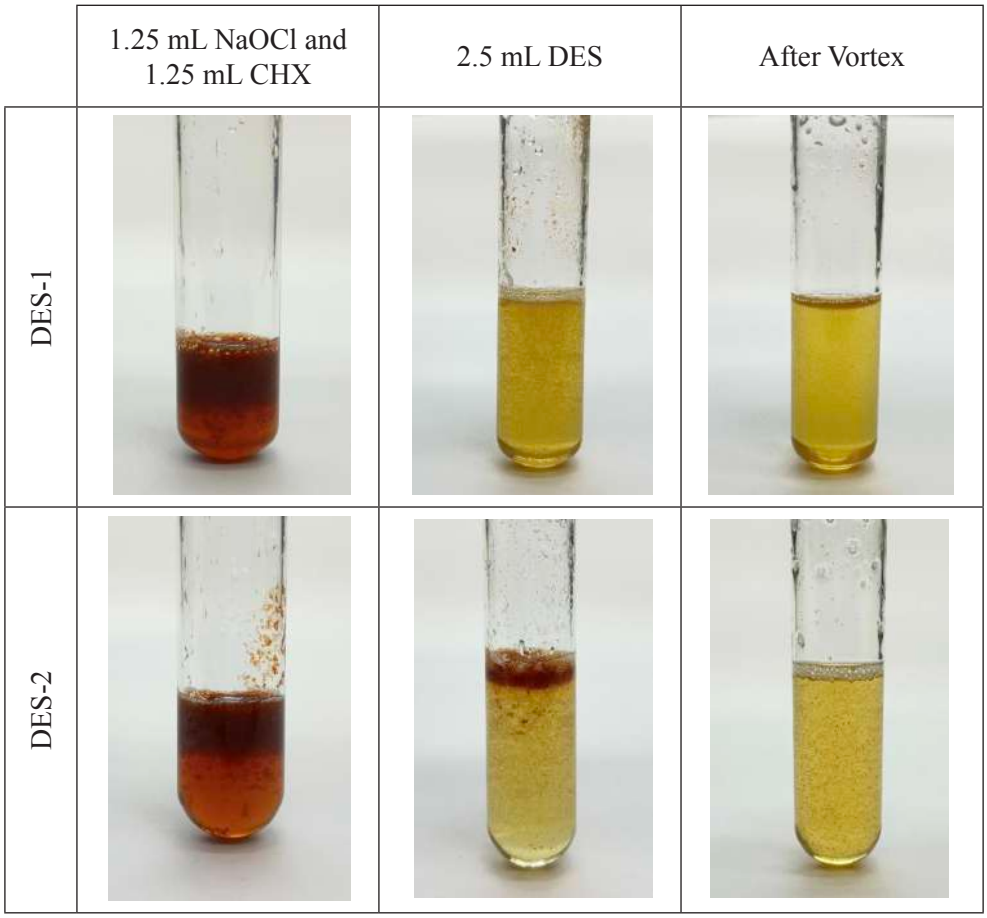

Figure 3. Photos showing the effect of DES-1 and DES-2 on the resolution of PCA.

Discussion

The interaction between NaOCl and CHX in the root canals is a well-documented clinical challenge in endodontics.[9] While both are highly effective irrigants, their combination results in the formation of an orange-brown PCA, which can obstruct dentinal tubules, compromise the seal of root canal fillings, and potentially pose cytotoxic risks.[9,18-23] The search for an effective and safe solvent to remove this precipitate is ongoing, as existing intermediate rinses like EDTA, QMix, citric acid, and alcohol show variable efficacy and additionally several activation techniques (e.g. EndoActivator, PIPS).[24-31] This study investigated the potential of AA and a DES as novel agents for PCA solubilization.

AA is a water-soluble antioxidant and an essential cofactor for collagen biosynthesis, catecholamine production and iron absorption; humans cannot synthesize it endogenously and must obtain it from the diet.[32] In the oral and dental context, AA's roles are twofold: systemically it supports connective-tissue formation and modulates inflammatory responses that are central to periodontal disease and wound healing, and locally it has been investigated as an adjunct to promote healing after tooth extraction and implant surgery.[32-35] Clinical and experimental studies suggest that perioperative or short-term oral supplementation with AA can improve extraction-socket healing and may accelerate soft-tissue repair in implant sites, likely through

enhanced collagen deposition and antioxidant effects.[33,35] At the same time, formulations of AA (especially acidic tablets or powders) may pose an erosion risk to enamel if used improperly, so its dental application requires attention to dosage form and timing relative to oral hygiene.[36] Recent narrative and systematic reviews propose that AA is a promising adjunct in periodontal therapy and oral wound management, but they emphasize that high-quality, larger randomized clinical trials are still needed to define optimal dosing, delivery methods, and long-term outcomes in dental practice.[34] Recent researchs have highlighted the multifaceted role of AA in endodontic and restorative dentistry. Diederich et al.[37] demonstrated that AA functions as a growth and differentiation factor for dental stem cells, thereby supporting its potential application in regenerative endodontic therapies. Complementing these biological findings, Grazioli et al.[38] reported that antioxidant solutions, including AA, can counteract the adverse effects of NaOCl on dentin, significantly improving the bond strength of adhesive systems. Similarly, Albashaireh et al.[39] showed that conditioning solutions such as AA and QMix enhance the adhesion of glass fiber-reinforced composite posts to root dentin, underscoring the clinical relevance of antioxidant-mediated dentin conditioning.

A DES is a mixture of two or more substances (often a hydrogen-bond donor and a hydrogen-bond acceptor) that, when mixed in a precise molar ratio, produces a liquid with a substantially lower melting point than the separate components. They function similarly to ionic liquids, but at a lower cost and with less environmental impact. They are commonly utilized in medicines, chemical synthesis, extraction, nanoparticle production, and biomaterials. AA-containing DES is a DES system in which AA is a constituent of the eutectic mixture. It can behave as a hydrogen-bond donor, acceptor, or functional additive with antioxidant activity. These are beneficial because they have significant antioxidant capabilities, are biodegradable, are considered green solvents, and may stabilize reactive molecules (for example, metal ions and nanoparticles).[40] In this study, we investigated the effects of AA-based DES on the solubility of PCA. For this purpose, AA, glycerol (Gly), and H_2O were added to separate capped glass vials at molar ratios of 1:4:10 (DES-1) and 1:10:10 (DES-2).

The results demonstrate a clear concentration-dependent effect of AA on PCA solubility. While the control group, using physiological saline, achieved a solubility of approximately 27.6%, the application of AA solutions significantly increased this rate. Specifically, the solubility increased from 33.9% to 5% AA to a maximum of 56.9% at 30% AA concentration. This finding is visually supported by photographic evidence, which shows a marked reduction in the PCA as the AA concentration increases (Fig. 1 and 2). The observation that increasing the volume of AA did not significantly alter the solubility suggests that the chemical concentration, rather than the total volume, is the primary factor driving the dissolution process. This is critical finding for clinical application, as it suggests that a higher concentration of AA, even in a standard irrigation volume, would be more effective.

The use of DES represents a novel approach in this context. DES are often considered green solvents with tunable properties.[15-17] The AA-based DES system, specifically DES-1 (AA:Gly:H2O at 1:4:10 molar ratio), demonstrated superior performance compared to all tested AA solutions. The gravimetric analysis showed that DES-1 achieved a high solubility of 81.3%, which is a substantial improvement over the 30% AA (56.9%). This high efficacy is also visually evident, with DES-1 showing the best dissolution among all tested systems (Fig. 3). This suggests that the unique solvent properties of the DES, which may include enhanced hydrogen bonding or altered polarity compared to a simple aqueous AA, are highly effective at breaking down the PCA. However, a significant limitation was identified regarding the stability of the DES-1 system, which lost its homogeneity after approximately 6 h at room temperature. This instability necessitates further research into optimizing the preparation and storage conditions of the DES-1 system to ensure its clinical viability. Future studies should focus on modifying the molar ratios or incorporating

stabilizing agents to extend the shelf life of this highly effective solvent.

In summary, this study confirms that AA is an effective solvent for PCA, with its efficacy increasing with concentration. More importantly, the DES system based on AA shows a significantly higher potential for PCA removal, although its stability requires further optimization.

Conclusion

Based on the gravimetric and visual analysis, the following conclusions can be drawn:

1. AA is an effective solvent for the orange-brown PCA formed by the interaction of NaOCl and CHX. The efficacy of AA in dissolving PCA is directly proportional to its concentration.
2. The DES system prepared with AA, glycerol, and water (DES-1) is a significantly more effective solvent for PCA.
3. The DES-1 system has the potential to be a superior irrigating solvent for PCA removal compared to aqueous AA, but its stability at room temperature must be improved before clinical application.
4. High concentrations of AA (e.g., 30%) can be considered a viable and biocompatible irrigating solvent for the removal of PCA formed in the root canal.

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Ethical Approval

Ethical approval was not required for this study as it did not involve any interventions on human participants, the use of personal data, or animal experiments. The study was conducted in accordance with relevant regulations and ethical principles.

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Authorship Contributions

Idea/Concept: K.E Design: K.E, B.T, İ.Ö Control/ Supervision: K.E Literature Review: B.T, İ.Ö Materials B.T, İ.Ö, C.Ö.D Data Collection and/ or Processing: B.T, İ.Ö, C.Ö.D Analysis and/or Interpretation: K.E Writing the Article: B.T, İ.Ö, C.Ö.D Critical Review: K.E

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Content And Cognitive-Level Analysis Of Surgery Questions In The Dental Specialty Examination (2012–2025)

Diş Hekimliğinde Uzmanlık Sınavı'nda Cerrahi Sorularının İçerik ve Bilişsel Düzey Analizi (2012–2025)

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ABSTRACT

Objectives: This study examined the content characteristics and cognitive-level demands of Oral and Maxillofacial Surgery (OMFS) questions in the Turkish Dental Specialty Examination (DUS; *Diş Hekimliğinde Uzmanlık Sınavı*), with the goal of informing candidate preparation and curriculum–assessment alignment in dental education.

Materials and Methods: A retrospective, cross-sectional, descriptive item analysis was conducted using publicly available DUS question booklets from Spring 2012 to Spring 2025. After excluding officially annulled questions (n=2), 188 OMFS items were analyzed. Items were coded by topic, item format (knowledge-based vs case-based), presence of visual material, and Bloom-based cognitive level (Level 1–3, based on the highest cognitive process required). Inter-rater reliability was assessed on a random subset of 50 questions (Cohen's κ=0.8677).

Results: Lower-order cognitive demand predominated across periods. Level 2 (Apply/Analyze) questions increased from 9.4% (2012–2022) to 20.0% (2023–2025) and were consistently case-based; however, this shift did not reach statistical significance (OR=2.40, p=0.075, 95% CI: 0.98–5.90). Visual items were rare in 2012–2022 (5/138; 3.62%) and absent in 2023–2025 (0/50). Topic coverage showed redistribution over time, indicating changing examination emphasis.

Conclusion: DUS–OMFS assessment remains heavily weighted toward remembering/understanding, with limited representation of higher-order clinical reasoning and minimal use of clinically relevant visuals. These findings suggest opportunities to strengthen assessment validity by expanding well-designed case-based and visual-supported items, which may better promote clinical reasoning and visual literacy within dental education.

Keywords: *Clinical Competence, Curriculum, Education Dental Graduate, Educational Measurement, Oral Surgery.*

ÖZET

Amaç: Bu çalışma, Türkiye'de Diş Hekimliğinde Uzmanlık Sınavı'nda (DUS) yer alan Ağız, Diş ve Çene Cerrahisi (ADÇC/OMFS) sorularının içerik özelliklerini ve bilişsel düzey gereksinimlerini inceleyerek; aday hazırlığını ve diş hekimliği eğitiminde müfredat–ölçme/değerlendirme uyumunu desteklemeyi amaçlamıştır.

Gereç ve Yöntemler: İlkbahar 2012–İlkbahar 2025 dönemine ait, kamuya açık DUS soru kitapçıkları kullanılarak retrospektif, kesitsel ve tanımlayıcı madde analizi yürütülmüştür. Resmî olarak iptal edilen sorular (n=2) dışlandıktan sonra 188 ADÇC maddesi analiz edilmiştir. Sorular; konu başlığı, madde formatı (bilgi temelli vs olgu/vaka temelli), görsel materyal varlığı ve Bloom temelli bilişsel düzey (en yüksek bilişsel süreç esas alınarak Düzey 1–3) açısından kodlanmıştır. Değerlendiriciler arası uyum, rastgele seçilen 50 soru üzerinde Cohen's κ=0,8677 olarak saptanmıştır.

Bulgular: Dönemler boyunca düşük düzey bilişsel talep baskın bulunmuştur. Düzey 2 (Uygulama/Analiz) sorularının oranı 2012–2022'de %9,4 iken 2023–2025'te %20,0'ye yükselmiş ve bu sorular tutarlı biçimde vaka temelli olmuştur; ancak bu artış istatistiksel anlamlılığa ulaşmamıştır (OR=2,40; p=0,075; %95 GA: 0,98–5,90). Görsel içeren sorular 2012–2022 döneminde nadir görülmüş (5/138; %3,62) ve 2023–2025 döneminde hiç yer almamıştır (0/50). Konu kapsamı zaman içinde yeniden dağılım göstermiş ve sınavın vurgu alanlarında değişime işaret etmiştir.

Sonuç: DUS–ADÇC değerlendirmesi, ağırlıklı olarak hatırlama/anlama düzeyinde kalmakta; daha üst düzey klinik akıl yürütmeyi sınırlı ölçüde temsil etmekte ve klinik açıdan anlamlı görselleri asgari düzeyde kullanmaktadır. Bu bulgular, iyi tasarlanmış vaka temelli ve görsel destekli maddelerin artırılmasıyla ölçme geçerliğinin güçlendirilebileceğini; bunun da diş hekimliği eğitiminde klinik akıl yürütme ve görsel okuryazarlığı daha iyi destekleyebileceğini düşündürmektedir.

Anahtar Kelimeler: *Diş hekimliği lisansüstü eğitimi, Eğitimsel ölçme ve değerlendirme, Klinik yeterlilik, Müfredat, Oral cerrahi,*

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Introduction

Societal expectations of the healthcare system are changing markedly. The public is increasingly demanding greater transparency and accountability, stronger participation in decision-making processes, and more efficient use of resources. This transformation is also shaping the future of specialization in dentistry.[1] Undergraduate dental education is a lengthy process in which intensive theoretical knowledge is delivered alongside clinical training. However, in a field where the margin for error is minimal, undergraduate training may not always provide sufficient experience to manage all complex or "special" cases. Therefore, specialty training represents a critical step for the accurate planning and effective delivery of diagnosis and treatment for rare clinical conditions and for improving patient satisfaction.[2] The advanced knowledge and clinical experience gained during specialization facilitate more accurate treatment planning under atypical circumstances, and specialists with advanced training in specific patient groups are increasingly preferred in contemporary practice.[3,4]

In Türkiye, dentists who complete the five-year undergraduate dental curriculum must pass the Dental Specialty Examination (DUS) to be eligible for specialty training in a specific field. With the amendment to Law No. 1219 published in the Official Gazette dated 26 April 2011 (No. 27916), commonly referred to as the "Omnibus Law," specialty training in dentistry was structured under eight main disciplines: Oral and Maxillofacial Surgery; Oral and Maxillofacial Radiology; Paediatric Dentistry; Endodontics; Orthodontics; Periodontology; Prosthodontics; and Restorative Dentistry[5] (Table 1).

Table 1. Distribution of dentistry specialization entrance exam questions by branch.

Clinical sciences	n	%	Basic sciences	n	%
Restorative dentistry	10	12.5	Anatomy	6	15
Prosthetic dentistry	10	12.5	Physiology	6	15
Oral and maxillofacial surgery	10	12.5	Histology and embryology	4	10
Oral and maxillofacial radiology	10	12.5	Medical biochemistry	6	15
Periodontology	10	12.5	Medical microbiology	6	15
Endodontics	10	12.5	Pathology	4	10
Pediatric dentistry	10	12.5	Pharmacology	4	10
Orthodontics	10	12.5	Medical biology and genetics	4	10
Total	80	100	Total	40	100

The Dental Specialty Examination (DUS) was first administered in the spring term of 2012. Between 2012 and 2014, the exam was generally held twice a year (in April and September); in the 2015–2022 period, it reverted to an annual administration. As of 2023, it has again been conducted twice yearly, in the first and second terms (Assessment, Selection and Placement Center).[6] Within the framework of dental specialty training regulations, the DUS is a centrally administered examination grounded in the principles of merit and competition, consisting of multiple-choice sections that cover both clinical and core professional knowledge domains.[7]

The increasing number of candidates taking the DUS, the test-taking strategies required by its multiple-choice format, and the limited number of specialty training positions have made the examination an increasingly competitive selection tool. This competitive environment encourages candidates to concentrate on content areas that are perceived as "high-yield" and has promoted study practices grounded in systematic item analysis. However, beyond identifying which content domains are emphasized, it is equally important to understand which cognitive processes the questions demand from candidates, because this may shape both learning strategies and the alignment of educational programmes with the examination.[8]

To strengthen the alignment of written examinations with intended learning outcomes, educators often design and evaluate assessment items using a learning taxonomy. One of the most widely used frameworks for this purpose is Bloom's Taxonomy of Learning.[9] Bloom's taxonomy conceptualizes cognitive processes across six levels that progress from simple to complex: remembering (recalling information), understanding (making meaning of information), applying (using information in new situations), analyzing (breaking down relationships and components), creating/synthesizing (generating a new product or solution from existing knowledge), and evaluating (making judgments based on criteria). This approach is frequently used as a reference for curriculum planning and the design of assessment tools, and it is based on the assumption that learners first develop competence at lower cognitive levels and gradually advance toward higher-order thinking skills.[10-12]

In recent years, several studies have examined topic headings and distributions of questions from different disciplines in the DUS, making it easier to identify which areas candidates prioritize during preparation and which domains are emphasized in educational content.[13-16] However, evaluating exam content solely through topic distributions may be insufficient to capture the level of thinking and cognitive demand expected from candidates. In this study, we aimed to extend the existing framework by analyzing Oral and Maxillofacial Surgery questions not only in terms of year-by-year topic distribution, but also with respect to cognitive level based on the revised Bloom's taxonomy, as well as whether items included visual material and how these characteristics changed over time. By doing so, we sought to provide a more in-depth evaluation that may inform both candidate preparation and curriculum–assessment alignment.

Materials and Methods

This study is a retrospective, cross-sectional, descriptive item analysis conducted to examine the content characteristics and cognitive-level demands of Oral and Maxillofacial Surgery (OMFS) questions included in the Turkish Dental Specialty Examination (DUS). Questions from DUS administrations between Spring 2012 and Spring 2025 were compiled from publicly released ÖSYM materials (Assessment, Selection and Placement Center)[17] and commercially available secondary sources used in DUS preparation materials. A total of 190 OMFS questions were identified and included in the analysis. For temporal comparison, the 2012–2022 period was treated as the historical baseline because OMFS questions from this interval had already been examined in the published literature, whereas the 2023–2025 period was included to provide an updated analysis of recent examinations. In addition, 2023 was considered a meaningful analytical breakpoint because DUS resumed twice-yearly administration from that year onward. Topic and subtopic classification for OMFS was structured under 25 headings based on the core reference textbooks officially listed for the examination.[18-21] These headings were analyzed by year, and the topics were tabulated to show which content areas were represented in each examination administration (Table 2).

Table 2. Distribution of oral and maxillofacial surgery questions by years.

Topics	2012/1	2012/2	2013/1	2013/2	2014/1	2014/2	2015	2016	2017	2018	2019	2020	2021	2022	2023/1	2023/2	2024/1	2024/2	2025/1	Total
Oral Pathology	1	5	2	2	1	2	2	3	1	3	2	1	3	1	1	2	3		1	36
Trauma	1	1	1	2		1	1	1	2	1	2		1				1	1		16
Anesthesia & Sedation		1	1	1	1			2	1	1	1	1		2				3	2	17
Systemic Diseases			1	1	2	2		1	1		1	1	1		1		1	1	1	15
TMJ	1		1	1		1	1	1	1		1	1		2	1	2	1		1	16
Infection			1				2			2		1	1	2	3	1	2		1	16
Surgical Techniques	1		1		1		1			1	1					1	1	1		9
Cleft Lip and Palate	1			1	1			2			1									6
Orthognathic Surgery	1			1	1	1	1		1			1								7
Complications			1						1	1				1		1		1	1	7
Neurologic Pain		1		1						1				1					1	5
Implants	1	1			1	1													1	5
Cyst/Tumor	2		1						1			1							1	6
Salivary Gland Disorders											1			1	1	1				4
Sinus		1					1								1			1		4
Preprosthetic Surgery					1								1		1					3
Head and Neck Syndromes					1								1					1		3
Head and Neck Pathology						1														1
Oncology												1	1							2
Impacted Tooth												1	1		1		1			4
Endodontic Surgery						1														1
Biopsy												1								1
ASA	1																			1
Reconstructive Surgery																1		1		2
Pharmacology																1				1
Total	10	10	10	10	10	10	9	10	9	10	10	10	10	10	10	10	10	10	10	188

Inclusion Criteria: (i) Questions included in the DUS question booklet for the specified period, and (ii) questions determined to belong to the Oral and Maxillofacial Surgery (OMFS) domain. *Exclusion criteria:* Officially annulled/cancelled questions (n = 2).

Variables and Coding

For each question, the following variables were recorded according to a pre-defined coding scheme:

1. Exam period and year: The year of the exam and the administration term (e.g., Spring/Fall) were recorded.
2. Topic: Questions were classified under a primary topic heading based on the OMFS topic list developed for this study. Even if a question related to more than one area, the primary topic was determined according to the main learning outcome the item was intended to assess.
3. Question format:

- Knowledge-based: Items primarily assessing factual knowledge/recall.
- Case-based (vignette-based): Items requiring clinical decision-making or interpretation based on a clinical scenario/case vignette.

4. Visual content: The presence of visual material (e.g., radiographs, clinical photographs, drawings/schematics) was recorded as present/absent.
5. Cognitive level (Bloom-based, 3-level classification): Cognitive demand was coded into three levels based on the revised Bloom's taxonomy:

- Level 1: Remembering + Understanding
- Level 2: Applying + Analyzing
- Level 3: Evaluating + Creating

During coding, the highest cognitive process required by the item was used as the primary determinant.

Coding Process and Inter-rater Reliability

Before coding, a coding manual was developed, including operational definitions of variables supported by examples. After the full dataset was coded, inter-rater consistency was assessed by having two independent raters, blinded to each other's classifications, re-code a randomly selected subset of 50 questions. Inter-rater agreement was evaluated using Cohen's kappa coefficient and was calculated as $\kappa = 0.8677$. This value indicates a high level of agreement between raters and supports the reliability of the classification approach. Any discrepancies were resolved through a consensus meeting, and final codes were agreed upon.

Statistical Analysis

Data were summarized using descriptive statistics. Categorical variables were reported as counts (n) and percentages (%). Distributions of topics, question format (knowledge-based vs. case-based), visual content (present/absent), and cognitive level were presented using tables and appropriate graphs. Period comparisons (2012–2022 vs. 2023–2025) were performed using Fisher's exact test or the chi-square test when appropriate. Effect sizes were reported as odds ratios (ORs) with 95% confidence intervals (CIs). Statistical significance was set at $p < 0.05$.

Results

A comparative analysis of OMFS questions in the DUS exam between the periods 2012–2022 and 2023–2025 reveals significant shifts in topic emphasis. Oral Pathology, which was the dominant subject in the earlier period with 29 questions, saw a marked reduction to 7 in the recent years. Similarly, traditional topics such as Trauma, Orthognathic Surgery, and Cleft Lip and Palate experienced noticeable declines or were completely absent in the latest exams. In contrast, the presence of topics like Reconstructive Surgery and Pharmacology, which were not previously covered, suggests an expansion of the curriculum toward emerging or clinically evolving areas. Core topics such as Anesthesia & Sedation, Infection, and TMJ maintained their relevance, with modest fluctuations, indicating their continued clinical importance. Interestingly, some subfields such as Oncology, Biopsy, and Endodontic Surgery, which appeared in earlier exams, were completely excluded in the 2023–2025 period, possibly reflecting a shift in examination priorities or a reframing of subject boundaries (Fig.1).

Overall, the data highlight a trend toward greater diversity and redistribution of question topics, emphasizing the importance of staying aligned with current exam patterns and evolving clinical priorities in oral and maxillofacial surgery education.

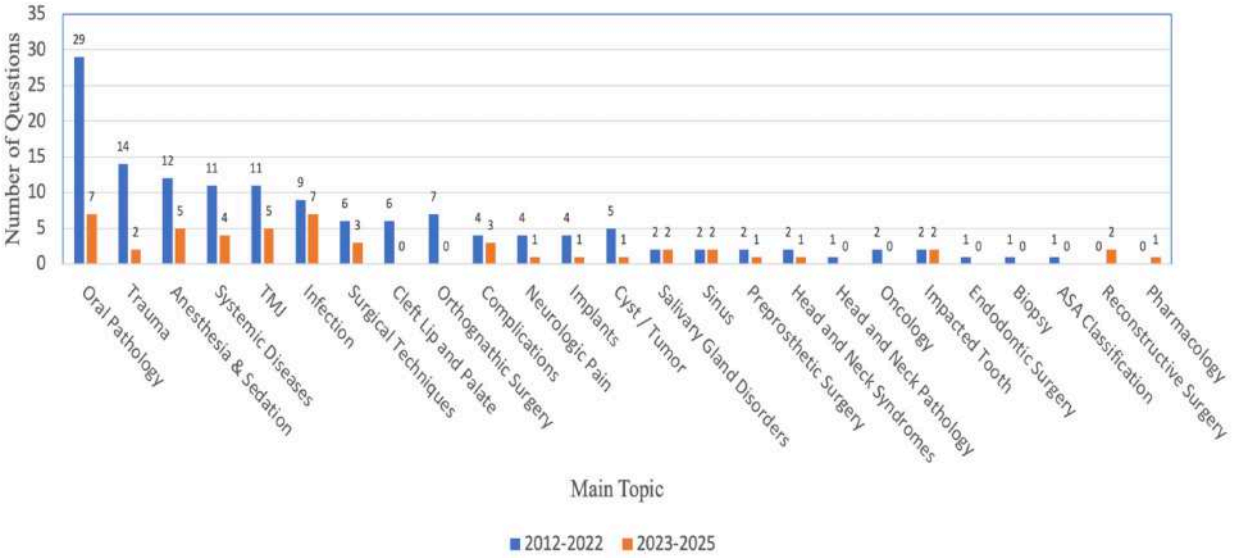

Figure 1. Distribution of OMFS questions by topic 2012-2022 vs. 2023-2025.

When the questions were classified according to Bloom's taxonomy, a predominant focus on Level 1 (Remember/Understand) items was observed in both periods. Importantly, Level 2 (Apply/Analyze) items were consistently case-based, indicating that higher cognitive demand in OMFS was primarily assessed through clinical vignette formats.

A proportional shift toward Level 2 questions became apparent in the more recent period. In 2012–2022, Level 2 questions accounted for 9.4% (13 of 138 questions), whereas Level 1 comprised 90.6% (125 questions). In contrast, during 2023–2025, the share of Level 2 questions rose to 20.0% (10 of 50), while Level 1 questions represented 80.0% (40 questions).

Overall, although lower-order cognitive questions continue to dominate, the more recent period suggests a trend toward incorporating a greater proportion of case-based, higher-order questions that emphasize clinical application and analytical reasoning in OMFS assessment.

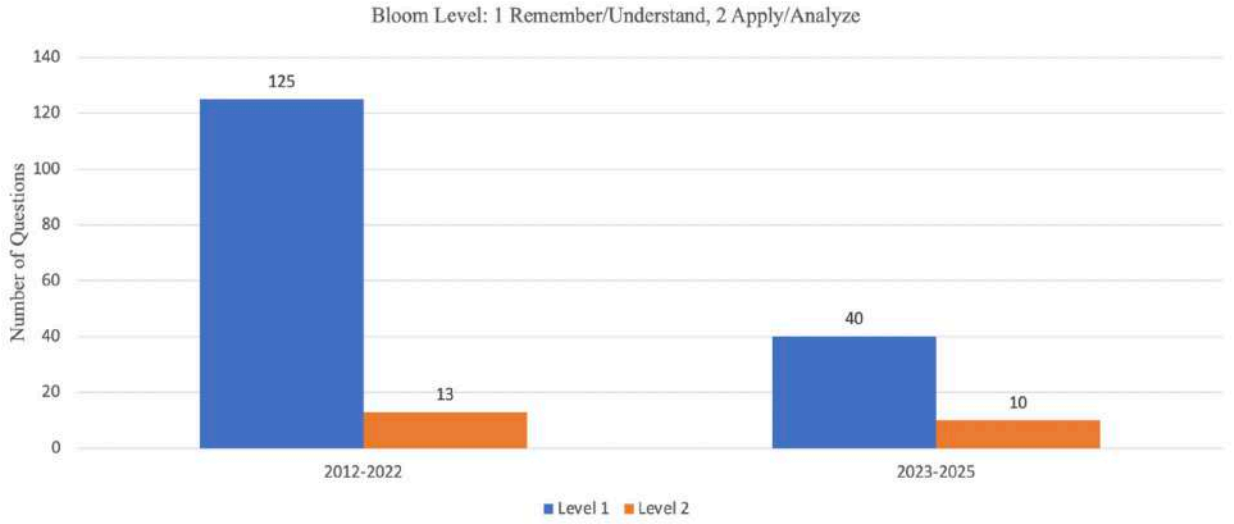

Figure 2. Distribution of questions according to Bloom's taxonomy levels between the 2012-2022 and 2023–2025 DUS examinations.

To further explore whether this shift in cognitive complexity was statistically significant, an odds ratio analysis was performed. A comparison of Bloom's taxonomy levels between the two periods (2012–2022 and 2023–2025) showed a higher proportion of Level 2 (Apply/Analyze) questions in the recent period. Although the odds of a Level 2 question were 2.40 times higher in the 2023–2025 period compared to the previous one, this difference did not reach statistical significance (p = 0.075, OR = 2.40, 95% CI: 0.98–5.90). This result may reflect a trend toward increased cognitive complexity in recent years, warranting further observation in upcoming exam cycles (Table 3).

Table 3. Comparison of Level 1 and Level 2 Bloom taxonomy questions in DUS exams by period, including odds ratio and statistical significance.

Comparison	Odds Ratio (OR)	95% Confidence Interval	p-value
Level 2 vs Level 1 (2023–2025 vs 2012–2022)	2.40	0.98 – 5.90	0.075

Statistical comparison was performed using Fisher's exact test. Effect size is reported as odds ratio (OR) with 95% confidence interval (CI).

Between 2012 and 2022, only 5 out of 138 OMFS questions included a visual component corresponding to 3.62% of all questions in that period. In contrast, no visual materials were used in any of the 50 questions administered between 2023 and 2025. This finding suggests a decrease in the proportional use of visual materials, even though clinical visual interpretation is a critical competency in OMFS.

The complete absence of visual questions in the 2023–2025 period might indicate a shift in exam design or assessment focus. In the previous period (2012–2022), the visual materials were limited and included formats such as (Fig.3):

- CT scans/(n=2),
- OPG (orthopantomogram)/(n=1)
- Clinical photographs/(n=1)
- Clinical photographs+CT scan/ (n=1).

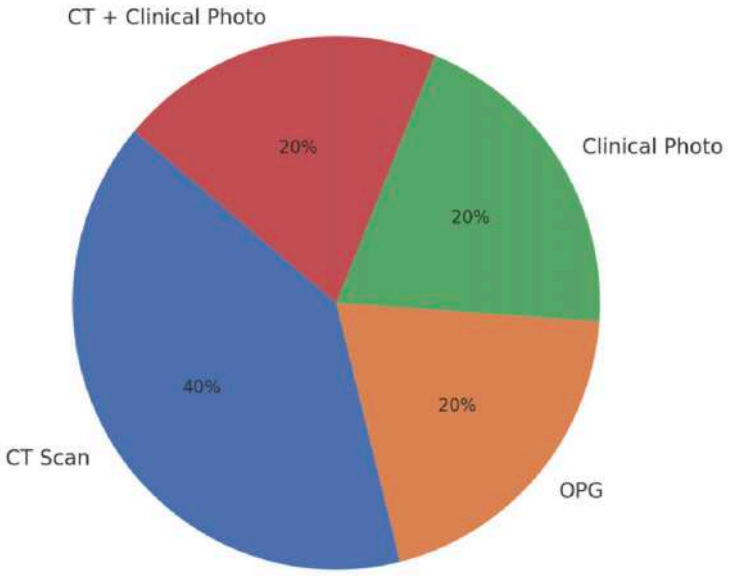

Figure 3. Types of Visual Materials Used in OMFS Questions (2012-2022).

Discussion

It is well established that assessment influences learning through multiple mechanisms, including assessment design, the pre-assessment preparation process, the test-taking experience, and post-exam reflection. For this reason, the question profile of high-stakes examinations can shape not only what is assessed, but also which topics and skills candidates perceive as "high-yield," thereby influencing their study strategies. In dental education, structuring assessment systems in a way that supports exam preparation while also encouraging clinical practice and analytical reasoning is important for long-term learning and professional development.[22]

In this study, we aimed to help DUS candidates set their study priorities more rationally and to provide OMFS educators with an objective overview of the examination's content emphasis. Accordingly, Oral and Maxillofacial Surgery questions from DUS administrations between Spring 2012 and Spring 2025 were retrospectively compiled and analyzed. By evaluating topic distribution, item format (knowledge-based vs. case-based), the presence of visual materials, and Bloom-based cognitive level, we characterized the examination representation profile of the OMFS domain.

In dental education, assessment is not merely a tool to measure student achievement; it is also a fundamental element that shapes perceptions of the academic environment by influencing whether students adopt a "performance" orientation rather than a "learning" orientation.[23-25]

An ideal dental education environment should enable students to acquire not only theoretical knowledge, but also core professional competencies—such as clinical decision-making, patient communication, and interprofessional collaboration—in a structured manner. Moreover, the curriculum should go beyond safeguarding students' psychological and physical well-being and contribute to the development of ethical values, professional culture, and social/psychosocial well-being. Because higher education inherently supports personal development as well as professional training, it also offers an important opportunity to foster values such as solidarity, volunteerism, and service to the community. Given that dental practice can sometimes evolve into a relatively "isolated" mode of work, it is particularly important for students to strengthen teamwork, effective communication, and coordination with other healthcare professionals during their training.[26]

To achieve these goals, the curriculum should not rely on a single, uniform teaching approach; rather, it should be delivered through innovative methods that accommodate diverse learning needs and provide early clinical exposure. In addition, helping students "learn how to learn" is a key outcome that shapes their post-graduation approach to knowledge acquisition and promotes lifelong learning and critical thinking.[27]

In today's rapidly evolving landscape of knowledge production and technological innovation, dental practice is increasingly grounded in a broader scientific base and more complex clinical decision-making processes. While this dynamism makes it challenging for predoctoral education alone to provide deep specialization across all areas, it also renders postgraduate specialty training a more visible necessity for attaining advanced competence in specific fields. In Türkiye, candidates who complete undergraduate dental education are required to pass the Dental Specialty Examination (DUS) to be placed into specialty programmes. Because the examination encompasses both clinical and basic sciences, it requires candidates to integrate the knowledge and skills acquired during undergraduate training.

The most striking finding of our study was the strong concentration of items at lower cognitive levels: 87.8% of questions were classified as Level 1 (remembering/understanding), whereas the proportion of Level 2 (applying/analyzing) questions remained at 12.2%, and no Level 3 (evaluating/creating) items were identified. This distribution suggests that, within the OMFS domain, the examination primarily tends to assess factual knowledge and basic comprehension, while questions representing higher-order clinical reasoning and decision-making are relatively limited.

An important additional finding was that all Level 2 questions were presented in a case-based (vignette-based) format. This indicates that higher cognitive demand in the examination is operationalized mainly through clinical scenarios. Therefore, if the goal is to increase the assessment of clinical reasoning and applying/analyzing components in OMFS, expanding the use of well-constructed case-based items may be a key strategy. However, the relatively low overall proportion of case-based questions (12.2%) suggests that candidates encounter fewer items that reflect clinical decision-making processes. This may lead "high-yield" preparation to be shaped predominantly around memorization and basic knowledge, with clinical reasoning receiving comparatively less emphasis.

The low proportion of questions containing visual materials (2.7%) is also noteworthy given the nature of Oral and Maxillofacial Surgery (OMFS). In routine OMFS practice, radiographic assessment, interpretation of clinical photographs/schematics, and image-based decision-making (e.g., trauma, infection, cystic lesions, temporomandibular joint pathologies, and surgical planning) are central to daily clinical workflow. In contrast, the limited use of visuals in the examination may suggest that the assessment tools do not sufficiently reflect real-world clinical decision-making contexts. Nevertheless, an appropriate balance is required: increasing the proportion of visual items should not merely involve "adding an image," but rather ensuring that the visual is constructed and integrated in a way that strengthens the item's cognitive objective.

In the period comparison, although an upward trend in Level 2 questions was observed in 2023–2025 (2012–2022: 9.4% vs. 2023–2025: 20.0%), this difference did not reach statistical significance ($p = 0.075$). This finding can be interpreted in two ways: (i) there may have been a recent shift toward writing more questions that require clinical reasoning; or (ii) the study may have lacked sufficient power to detect a statistically significant difference because the number of questions in the 2023–2025 subperiod was smaller. Therefore, it is more appropriate to interpret this result as an "emerging trend" rather than definitive evidence of change.

From the perspective of topic distribution, the more frequent representation of certain headings (e.g., oral pathology, anesthesia/sedation, trauma, TMJ disorders, and infection) can be considered an expected pattern within the broad scope of Oral and Maxillofacial Surgery (OMFS) (see Table 2). Nevertheless, because a wide field must inevitably be sampled with a limited number of questions, some clinically critical subtopics may be underrepresented in the examination (Assessment, Selection and Placement Center [6] [7]. From an educational planning standpoint, this finding is valuable at two levels. First, identifying high-frequency topic clusters can help candidates rationalize their preparation strategies. Second, undergraduate and specialty curricula should be structured in a balanced manner that is not driven solely by "frequently tested" areas, but also ensures adequate coverage of domains that may be less represented on the exam yet carry high clinical importance and risk.[26]

The strengths of this study include its long observation period, the clarification of the analytic dataset by excluding annulled questions, and the use of a standardized coding scheme. In addition, the high inter-rater agreement observed in a randomly selected subset of 50 questions (Cohen's $\kappa = 0.8677$) supports the reliability of the classifications for cognitive level and other variables. However, several limitations should be acknowledged. First, Bloom-based cognitive-level assignment inherently involves subjective judgment; despite the use of a coding guide and a high kappa value, the classification process is not fully "automatic." Second, psychometric indicators of item quality (e.g., discrimination, difficulty, and item analysis) could not be evaluated because such metrics require candidate performance data.

Overall, DUS–OMFS questions were predominantly concentrated at Level 1 cognitive demand, while Level 2 questions were limited in number and appeared almost exclusively in a case-based format. These findings suggest a potential area for improvement in increasing the proportion of items that assess clinical reasoning

within the OMFS domain. Future studies could provide a more comprehensive evaluation of the examination's measurement validity by expanding the use of case-based and visually supported item structures that strengthen cognitive objectives, conducting comparative analyses across different specialties, and, where feasible, incorporating psychometric indicators.

Conclusion

Across 2012–2025, DUS–Oral and Maxillofacial Surgery questions demonstrated a noticeable re-weighting of topic coverage, with declines/disappearance in some traditional subdomains and the emergence of new headings, suggesting a shift in examination priorities over time. In terms of cognitive demand, items were predominantly concentrated at lower levels (87.8% Level 1; 12.2% Level 2; no Level 3), and higher-level demand was observed exclusively in case-based items. Although there was an upward trend in Level 2 questions in 2023–2025 (OR=2.40; p=0.075), this did not reach statistical significance; moreover, the absence of any visual-material questions in the most recent period may indicate a potential gap in assessing clinically relevant visual interpretation skills. These findings imply that dental curricula and assessment strategies should not only align with evolving exam content, but also strengthen case-based teaching, clinical reasoning, and visual literacy (e.g., interpretation of radiographs and clinical images) while encouraging item-writing practices that incorporate cases and high-quality visuals to better support higher-order learning outcomes.

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Ethical Approval

No individual patient data were used; only publicly available examination questions were analyzed. Therefore, the study was considered a secondary analysis of non-human-subject data.

Conflict of Interest

The authors declare no conflicts of interest.

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Authorship Contributions

Idea/Concept: N.Ü.K, E.Ş Design: N.Ü.K Control/Supervision: N.Ü.K, E.Ş Literature Review: E.Ş Data Collection and/or Processing: N.Ü.K, E.Ş Analysis and/or Interpretation: N.Ü.K, E.Ş Writing the Article: N.Ü.K, E.Ş Critical Review: N.Ü.K, E.Ş

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RESEARCH ARTICLE

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Akrilik Bloklu ve Bloksuz Hızlı Üst Çene Genişletme Protokollerinde Molar Devrilmesinin Posteroanterior Filmler Üzerinde Karşılaştırılması

Comparison of Molar Tipping in RME Protocols with and without Acrylic Block on Posteroanterior Films

Sinem Dedeoğlu Öztürk[1*], Banu Mert[2], Ahmet Nejat Erverdi[3]

ÖZET

Amaç: Bu retrospektif çalışmanın amacı, bloklu (akrilik blok) ve bloksuz hızlı üst çene genişletme (HÜÇG) uygulamalarının üst molar dişlerin bukkale devrilmesi üzerindeki etkilerini değerlendirmektir.

Gereç ve Yöntemler: Bloklu ve bloksuz HÜÇG uygulanmış olan vakalar taranarak yaşları 12-15 arası değişen 15 erkek 15 kadın olmak üzere toplam 30 birey çalışmaya dahil edilmiştir. Genişletme öncesi ve sonrası rutin olarak alınmış PA filmler, araştırmanın gerecini oluşturmaktadır. Belirlenen doğru, düzlem, noktalar yardımıyla tedavi öncesi ve sonrası 10'ar adet ölçüm PA filmler üzerinde gerçekleştirilmiştir.

Bulgular: Bloklu HÜÇG yapılan bireylerde üst molar dişlerin uzun aksları arasındaki açı ortalama (ort.) 6,4˚ artarken, bloksuz HÜÇG yapılmış bireylerde 10˚ artmıştır ($p<0,05$). Üst sağ ve sol 1. molar dişlerin uzun akslarının, yatay referans düzlemiyle yaptığı açıların ortalaması bloklu HÜÇG yapılmış bireylerde ort. 3,2˚ artarken bloksuz HÜÇG yapılmış bireylerde 6,2˚ artmıştır ($p<0,05$).

Sonuç: Hem bloklu hem de bloksuz grupta HÜÇG sonrası molar devrilmesi görülmüştür. Bloklu grupta molar devrilmesinin bloksuz gruba göre daha az gerçekleşmiş olması istatistiksel olarak anlamlıdır. Çalışma, akrilik bloklu apareylerin üst molar dişlerdeki devrilme miktarını azaltsa da tamamen ortadan kaldırmadığını göstermektedir. Vertikal büyüme yönü olan bireylerde her iki aparey kullanımının da molar devrilmesiyle sonuçlanarak dik yön boyutlarında artışa neden olabileceği göz önünde bulundurulmalıdır.

Anahtar kelimeler: *Diş Hareketi, Ortodontik Apareyler, Üst çene genişletmesi*

ABSTRACT

Objectives: This study aimed to evaluate and compare the effects of rapid maxillary expansion (RME) with and without blocks (acrylic) on buccal tipping of maxillary molars using posteroanterior (PA) films.

Materials and Methods: This retrospective study included 30 individuals (15 males and 15 females; aged 12–15 years) who underwent RME with either block or non-block appliances. PA films obtained before (t0) and immediately after expansion (t1) were analyzed. Ten linear and angular measurements were performed using predefined landmarks, reference lines, and planes. The U6MZ angle was considered the primary outcome variable. Statistical analyses were conducted using appropriate parametric and non-parametric tests, and effect sizes were calculated, $p<0,05$ was considered statistically significant.

Results: Molar tipping was observed in both groups following RME. The increase in the angle between the long axes of the maxillary molars was greater in the non-block group (10°) compared to the block group (6,4°) ($p<0,05$). Similarly, the increase in molar inclination relative to the reference plane was higher in the non-block group (6,2°) than in the block group (3,2°) ($p<0,05$). A statistically significant difference was found between the groups for the primary outcome variable (U6MZ), with a large effect size (Cohen's d = 1,53), indicating a clinically significant difference.

Conclusion: Both block and non-block RME protocols result in molar tipping; however, block appliances significantly reduce the magnitude of this effect. Despite this reduction, molar tipping is not completely eliminated. These findings suggest that appliance selection should be carefully considered, particularly in patients with vertical growth patterns, where increased molar tipping may contribute to unfavorable vertical changes.

Keywords: *Maxillary expansion, Orthodontic appliances, Tooth movement*

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Giriş

Maksillanın yatay yöndeki genişliği, büyümesi ilk sonlanan dentofasiyal boyuttur.[1] Maksiller darlık, klinisyenler tarafından sıklıkla tespit edilen bir iskeletsel uyumsuzluktur.[2] Bu uyumsuzluğun toplumda görülme sıklığı çocuklarda %13-23 arasında değişirken, erişkinlerde %30'a kadar ulaşabilmektedir.[3] Maksiller darlığın en temel iki klinik belirtisi posterior çapraz kapanış ve çapraşıklıktır. Diğer belirtiler ise, palatinale eğimli üst posterior dişler, dar ve derin damak kubbesi, gülümsemede karanlık bukkal koridorlar ve fasiyal asimetridir. Farengeal havayollarında daralma, dil postüründe bozulma ve ağızdan solunum gibi fonksiyonel problemler de maksiller darlıkta görülebilen klinik belirtilerdir.[4] HÜÇG, maksiller arkın transversal genişliğini arttırmak, çapraz kapanışları düzeltmek, yer kazanmak ve daha geniş gülümsemeler oluşturmak için ortodontide yaygın olarak kullanılmaktadır.[5–7] Diş destekli, diş-doku destekli, kemik destekli, diş-kemik destekli olmak üzere dört şekilde uygulanmaktadır. Diş destekli HÜÇG için bloklu veya bloksuz olmak üzere iki temel aparey tasarımı kullanılmaktadır. Bloksuz HÜÇG apareyi, arka dişlere metal bantlarla tutunan Hyrax vidasından oluşmaktadır. Bu apareyin, yeterince rijit olmaması ve kuvvet kaybı nedeniyle bazı yan etkiler meydana gelmektedir. Bu yan etkilerin başında üst molar dişlerin bukkale devrilmesi gelmektedir.[8] Bu devrilme palatinal tüberküllerin sarkmasıyla birlikte bir miktar uzamayı da yanında getirerek vertikal yön boyutları artmış bireylerde kapanışın azalmasına, alt dik yön boyutlarının daha da artmasına ve profilin kötüleşmesine neden olabilmektedir. Karışık dişlenme dönemi de dahil olmak üzere, dik mandibular düzlem açısına sahip hastalarda bloklu genişletme apareyi tercih edilmektedir. Bu aparey, Hyrax vidası ile dişleri kaplayan blok ve bir tel çerçeveden oluşmaktadır.[9] Araştırmacılar, blok ile posterior dişlerin oklüzal yüzeylerinin örtülmesiyle molar dişlerdeki ekstrüzyonun azaldığını, çapraz kapanışların giderilerek maksillanın simetrik ve bütüncül şekilde genişlediğini belirtilmektedir.[8,10,11]

Ortodontik tedavi sonuçlarını değerlendirmede yaygın olarak kullanılan yöntemler posteroanterior filmler (PA), lateral sefalometrik röntgen filmler, oklüzal röntgen filmler ve ölçü modellerdir.[12,13] Günümüzde bu yöntemlere dijital tarama yöntemleri ve kayıtlar da dahil olmuştur.[14] PA filmler; iskelet, diş, yumuşak doku morfolojisini ve transversal ilişkiyi aynı anda gözlemleme olanağı tanıdığı için, yüz değerlendirmelerinde önemli bir yer tutmaktadır.[15] Bu filmler, düşük radyasyon maruziyeti ve düşük maliyet avantajı ile ön plana çıkarken, diğer iki boyutlu görüntülemelerden elde edemediğimiz tanısal bilgilere ulaşmamızı sağlamaktadır.[16,17] Maksilla ve mandibulanın genişlik ölçümleri, bazal kemikle olan açıları, transversal pozisyonları, iskeletsel ve dental yapıların bilateral vertikal ilişkilerinin tayini, asimetri teşhisi, nazal kavite genişlik ölçümleri PA filmler ile başarıyla gerçekleştirilebilmektedir.[17] Çalışmanın amacı, ortodontik tedavilerin bir parçası olarak HÜÇG uygulanmış olgulardan rutin olarak alınmış PA filmler kullanılarak, akrilik bloklu ve bloksuz apareylerin molar dişlerin bukkale devrilme miktarı üzerindeki etkilerinin karşılaştırılmasıdır. Çalışmanın null hipotezi (H_0), bloklu ve bloksuz HÜÇG protokolleri arasında PA filmler üzerinde ölçülen molar devrilme miktarı açısından istatistiksel olarak anlamlı bir fark bulunmadığıdır. Alternatif hipotez (H_1) ise iki protokol arasında molar devrilme miktarı bakımından istatistiksel olarak anlamlı bir fark bulunduğudur. Çalışmada özellikle molar devrilmesinin değerlendirilmesinde U6MZ açısı primer sonuç değişkeni olarak dikkate alınmıştır.

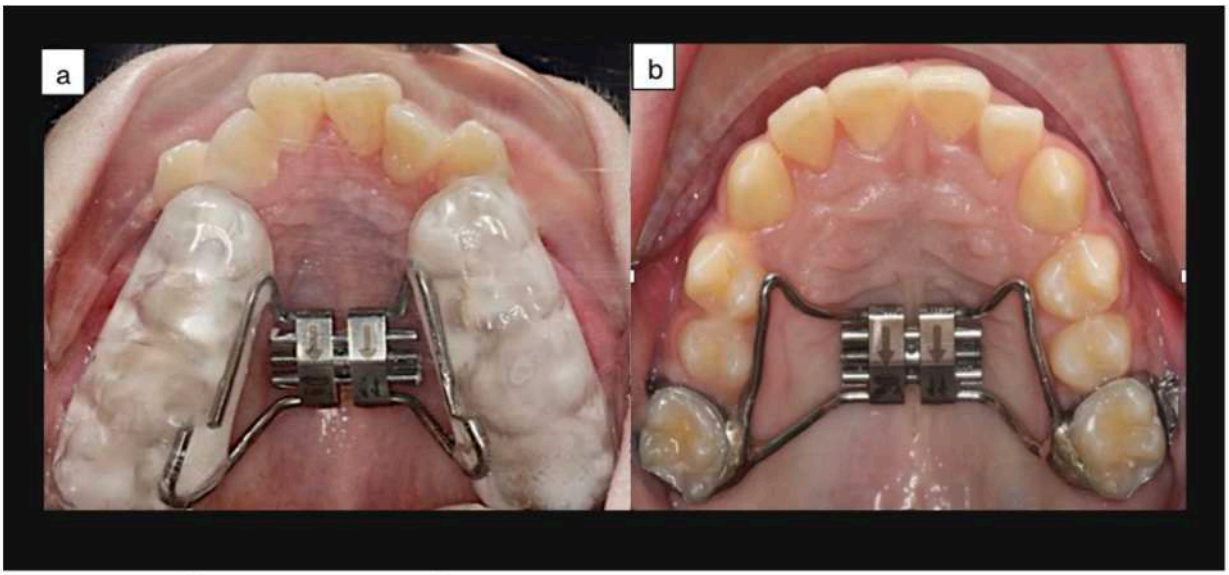
Gereç ve Yöntemler

Bu çalışma, İstanbul Okan Üniversitesi Sağlık Bilimler Enstitüsü Etik Kurulu tarafından 9.10.2024 tarihinde etik kurul onayı almıştır.

İstanbul Okan Üniversitesi Diş Hekimliği Fakültesi Ortodonti Anabilim Dalı'nda 02.01.2023-15.09.2024 tarihleri arasında bloklu ve bloksuz HÜÇG uygulanmış olan vakalar taranarak, yaşları 12-15 arası değişen 15 erkek 15 kadın olmak üzere toplam 30 birey bu retrospektif çalışmaya dahil edilmiştir. Genişletme öncesi ve sonrası rutin olarak alınmış PA filmler, araştırmanın gerecini oluşturmaktadır. Araştırmada, her bir bireyin 12-15 yaş aralığında olması, daimi dentisyona

geçmiş olması, sistemik ve periodontal olarak sağlıklı olması, genişletme öncesi iskeletsel maksiller darlık tanısı almış olması, bloklu veya bloksuz HÜÇG apareyiyle tedavi edilmiş olması, daha önce herhangi bir ortodontik/ortopedik tedavi görmemiş olması dahil edilme kriterleri olarak belirlenmiştir.

Araştırmaya dahil edilen bireylere uygulanan bloklu ve bloksuz apareylerde klinik rutinine uygun olarak Hyrax genişletme vidası kullanılmıştır (Forestadent 11 mm Snap Lock Expander, Pforzheim, Almanya). Hyrax vidası, palatinal kubbenin en derin bölgesine ve aktivasyona rahatlıkla olanak sağlayacak konumda uygulanmıştır. Metilmetakrilat esaslı akrilik bloklar, istirahat aralığı sınırı içinde kalmak şartıyla alt dişlerle dengeli ve maksimum temas edecek şekilde ağza uyumlanmış, üzerlerine siman kaçış delikleri hazırlanarak cam iyonomer siman (3M multi cure glass ionomer orthodontic band cement, St Paul, ABD) ile simante edilmiştir. Bloksuz aparey de cam iyonomer siman (3M multi cure glass ionomer orthodontic band cement, St Paul, ABD) ile simante edilmiştir. Klinik rutininde HÜÇG sırasında vida çevirme protokolü, ¼ tur sabah akşam olmak üzere günde iki defa uygulanmaktadır. Bireyler genişletme protokolü sonlanana kadar haftada bir kontrol edilerek, vida, aparey, genişleme miktarı ve çevre dokuların muayenesi yapılmaktadır. Maksiller palatal tüberküller, mandibular bukkal tüberküller ile temas ettiğinde genişletme işlemi sonlandırılmaktadır. Protokol sonlandırıldığında vida, ligatür teli ile bağlanarak akışkan kompozitle sabitlenerek aparey üç ay pasif olarak ağızda tutulmak üzere pekiştirme protokolüne geçilmektedir. Bu retrospektif çalışmaya dahil edilen bireyler aynı prosedürün uygulandığı bireyler arasından seçilmiştir.

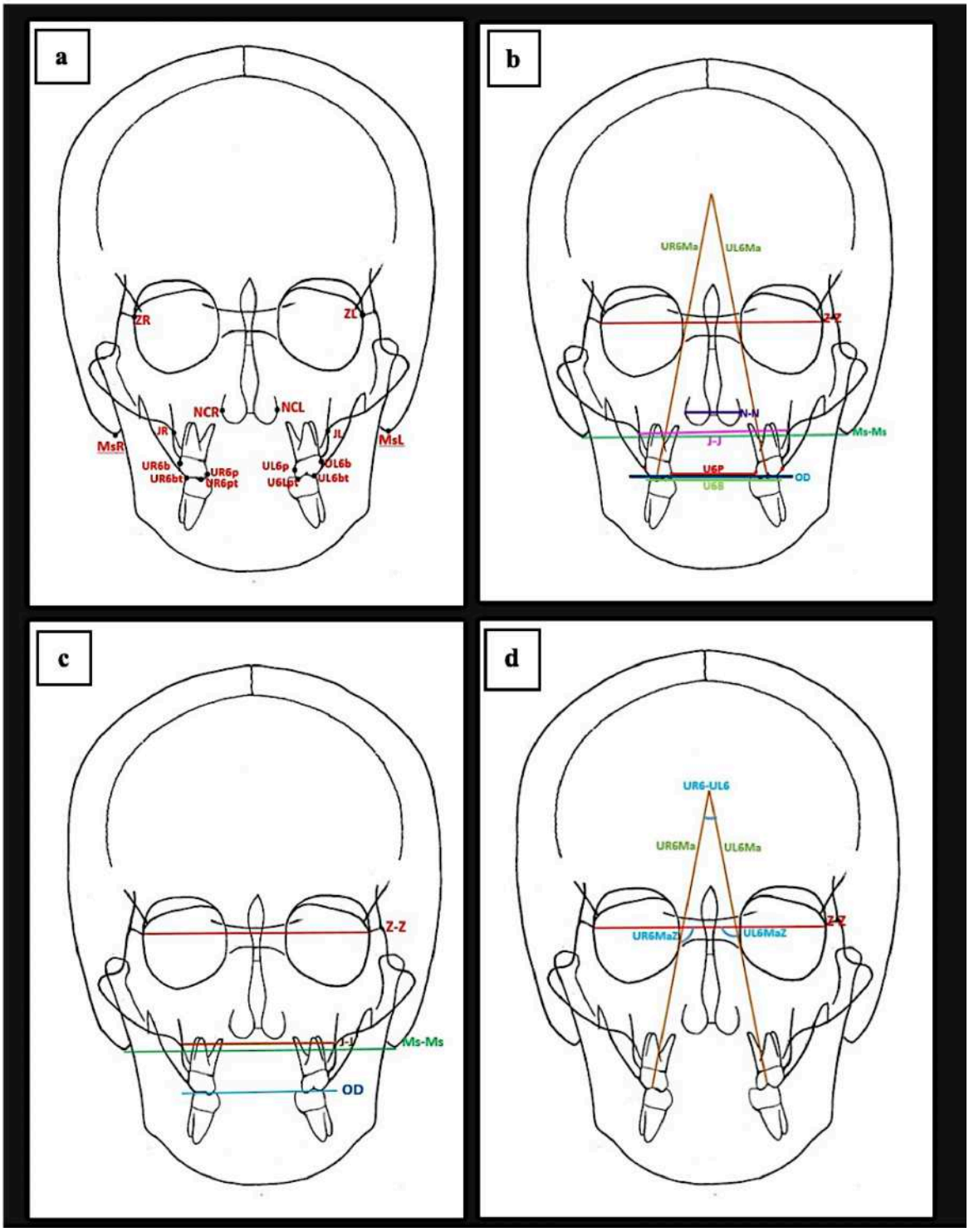


Şekil 1. (a) Bloklu HÜÇG apareyi (**b)** Bloksuz HÜÇG apareyi

Çalışmada kullanılan PA filmler, klinikteki rutin prosedüre uygun olarak elde edilmiştir. Genişletme yapılan her bireyden, genişletme protokolü başlamadan önce ve bittikten hemen sonra toplam iki adet PA film alınmaktadır. Tüm filmler, İstanbul Okan Üniversitesi Diş Hekimliği Fakültesi'nde bulunan Planmeca ProMax 3D Mid cihazı (Planmeca, Helsinki, Finlandiya) ile elde edilmiştir. PA filmler, bireyin midkoronal düzlemi ışın kaynağına dik ve film düzlemine paralel, film ile arasında 13 cm olacak şekilde, Frankfurt horizontal düzlemi yere paralel, çeneler sentrik ilişki konumunda olacak şekilde aynı operatör tarafından elde edilmiştir. Burun köprüsüne yerleştirilen burun çubuğu, hastanın baş pozisyonu sabitlenerek yerleştirilmiştir. Işınlama 74 kV (kilovolt) ve 12,5 mA (miliamper) değeriyle 10 saniye boyunca gerçekleştirilmiştir. İstanbul Okan Üniversitesi Diş Hekimliği Fakültesi Ortodonti Anabilim Dalı arşivi taranarak, dişsel nokta ve sınırların apareylerin metal uzantıları yardımıyla ayırt edilebildiği, anatomik noktaların

net görüntülenebildiği filmler çalışmaya dahil edilmiştir. Genişletme öncesi ve sonrası 30 bireyden elde edilmiş olan toplam 60 röntgen filmi incelenmiştir.

PA filmlerin analizi Nemostudio 2024 (Nemotec, A Biotech Dental Company, 28919 Leganes, Madrid, İspanya) programında bulunan Rocky mountain frontal analizi yardımıyla gerçekleştirilmiştir. Aynı zamanda bireylerden rutin olarak alınmış sefalometrik filmlerden servikal vertebra maturasyon aşamalandırma (SVMA) ile kemik yaşı tayini gerçekleştirilmiştir. Çalışmada belirlenen nokta, doğru ve düzlemler Şekil 2 ve Tablo 1' de gösterildiği gibidir;[8,18,19]



Şekil 2. (a) Posteroanterior referans noktaları, **(b)** posteroanterior referans düzlemler, **(c)** izdüşüm noktaları, **(d)** doğrusal ve açısal ölçümler.

Tablo 1. Posteroanterior analizde kullanılan referans ölçüm ve tanımlar

Posteroanterior referans noktaları	
ZL, ZR	Zigomatikofrontal süturun orbita ile kesişme noktasıdır. (ZR sağ, ZL sol)
JL, JR	Jugal proses üzerinde zigomatik arkın tüber maksillayla kesiştiği noktadır. (JR sağ, JL sol)
UR6b, UL6b	Üst 1. molar dişlerin bukkal yüzeylerinin en dış noktasıdır. (UR6b sağ, UL6b sol)
UR6p, UL6p	Üst 1. molar dişlerin palatinal yüzeylerinin en iç noktasıdır. (UR6p sağ, UL6p sol)
UR6bt, UL6bt	Üst 1. molar dişlerin bukkal tüberkül tepe noktasıdır. (UR6bt sağ, UL6bt sol)
UR6pt, UL6pt	Üst 1. molar dişlerin palatinal tüberkül tepe noktasıdır. (UR6pt sağ, UL6pt sol)
NCR, NCL	Nazal kavitenin en geniş bölgesindeki en dış noktadır. (NCR sağ, NCL sol)
MsR, MsL	Mastoid çıkıntının en alt noktasıdır. (MsR sağ, MsL sol)
Posteroanterior referans düzlemler	
ZZ Düzlemi (ZZ)	ZR ve ZL noktalarını birleştiren yatay düzlemdir.
Okluzal Düzlem (OD)	Üst 1. molar dişlerin oklüzyon çizgisini belirleyen yatay düzlemdir.
Bimastoid Düzlem (MsMs)	MsR ve MsL noktalarını birleştiren yatay düzlemdir.
JJ Düzlemi (JRJL)	JL ve JR noktalarını birleştiren düzlemdir.
İzdüşüm noktaları	
UR6P, UL6P	UR6p ve UL6p noktalarının okluzal düzlem üzerindeki izdüşümüdür. (UR6P sağ, UL6P sol)
UR6B, UL6B	UR6b ve UL6b noktalarının okluzal düzlem üzerindeki izdüşümüdür. (UR6B sağ, UL6B sol)
UR6M, UL6M	Molar dişlerin bukkal, palatinal tüberküllerinin tepe noktalarının izdüşümlerinin orta noktasıdır. (UR6M sağ, UL6M sol)
Doğrusal ölçümler	
UR6Ma, UL6Ma	U6M noktası ve bifurkasyondan geçen üst 1. molar dişin uzun aksını ifade eder. (UR6Ma sağ, UL6Ma sol)
U6B	UR6B ve UL6B arasındaki mesafenin ölçümüdür.
U6P	UR6P ve UL6P arasındaki mesafenin ölçümüdür.
JJ	JL JR arası mesafenin ölçümüdür. (efektif maksiller genişlik)
NN	NCR NCL arasındaki mesafenin ölçümüdür (nazal kavite genişliği).
MsMs	MsR-MsL arası mesafenin ölçümüdür (bimastoid genişlik).
ZZ (zigomatikofrontal genişlik)	ZR ve ZL noktaları arasındaki mesafenin ölçümüdür.

Açısal ölçümler

U6MaZ	Üst 1. molar dişlerin uzun aksının (U6Ma) ZZ ile yaptığı açıdır. (UR6Ma-Z sağ, UL6Ma-Z sol)
U6MZ	UR6Ma-Z ve UL6Ma-Z açılarının ortalamasıdır.
UR6UL6	URMa ve ULMa arasındaki açıdır.

Veriler IBM SPSS Statistics (Statistical Packages of Social Sciences) for Windows, 29,0 (IBM Corp., Armonk, NY, USA) programı kullanılarak analiz edilmiştir (Bkz. Şekil 3). Verilerin normal dağılıma uygunluğu Shapiro Wilk's testi ile değerlendirilmiştir. Açıklayıcı istatistikler sürekli değişkenler için ortalama, standart sapma, medyan, minimum ve maksimum şeklinde, kategorik değişkenler için frekans ve yüzde şeklinde gösterilmiştir. Bağımsız iki grubun normal dağılıma uyan verilerinin karşılaştırılmasında iki bağımsız örneklem t testi, normal dağılıma uymayan verilerinin karşılaştırılmasında Mann-Whitney U testi kullanılmıştır. Grup içi zaman içi değişimin değerlendirilmesinde normal dağılıma uyan veriler için eşlenik örneklem t testi, normal dağılıma uymayan veriler için Wilcoxon İşaret testi kullanılmıştır. Kategorik değişkenler arasındaki farkın analizi için Fisher-Freeman-Halton kesin olasılık testi kullanılmıştır. İki değişken arasında ilişki olup olmadığını belirlemek için Spearman korelasyon katsayısı hesaplanmıştır, $p<0,05$ olması durumunda aradaki fark istatistiksel olarak anlamlı kabul edilmiştir. Ölçüm güvenilirliğini değerlendirmek amacıyla tüm ölçümler aynı araştırmacı tarafından 15 gün arayla tekrar edilmiştir. Ölçümler arası uyum intraclass korelasyon katsayısı (ICC) ile değerlendirilmiş, rastgele ölçüm hatası ise Dahlberg formülü ($ME = \sqrt{(\sum d^2 / 2n)}$) kullanılarak hesaplanmıştır. Çalışmada molar devrilmesini değerlendirmek amacıyla U6MZ açısı primer sonuç değişkeni olarak belirlenmiştir. Örneklem büyüklüğünün yeterliliğini değerlendirmek amacıyla bu değişken üzerinden post-hoc güç analizi yapılmıştır. İki bağımsız grup karşılaştırması esas alınarak alfa hata düzeyi 0,05 ve güç 0,80 kabul edilmiştir. Yapılan analizde etki büyüklüğünün yüksek olduğu (Cohen's $d = 1,53$) ve mevcut örneklem büyüklüğü ile çalışmanın istatistiksel gücünün yaklaşık %98 olduğu belirlenmiştir. Ayrıca %80 güç için gerekli minimum örneklem büyüklüğünün grup başına yaklaşık 8 birey olduğu hesaplanmıştır.

Ayrıca, elde edilen bulguların daha kapsamlı değerlendirilmesi amacıyla %95 güven aralıkları (confidence interval) hesaplanmıştır. Bu retrospektif çalışmanın örneklem büyüklüğü, belirlenen tarihler arasında dahil edilme kriterlerini karşılayan olgular üzerinden oluşturulmuştur.

Bulgular

Ölçüm güvenilirliği denetlemek için yapılan analizlerde, intraclass korelasyon katsayılarının (ICC) 0,847 ile 0,994 arasında değiştiği ve tüm değişkenler için yüksek düzeyde güvenilirlik sağlandığı belirlenmiştir. Dahlberg formülü ile hesaplanan rastgele ölçüm hatalarının doğrusal ölçümler için 0,45–0,70 mm, açısal ölçümler için ise 0,73–0,98° aralığında olduğu saptanmıştır. Bu bulgular, ölçümlerin yüksek derecede güvenilir ve tekrarlanabilir olduğunu göstermektedir. Gruplar arasındaki farklara ait %95 güven aralıkları hesaplanmış ve sonuçların istatistiksel ve klinik anlamlılığını desteklediği görülmüştür.

Çalışmadaki bireylerin yaş ortalaması 13,29±0,88'dir. Bloksuz grupta 8 erkek 7 kadın, bloklu grupta ise 7 erkek 8 kadın birey bulunmaktadır. Bloksuz grupta yaş ortalaması 13,28, bloklu grupta ise 13,29' dur. Bloklu-bloksuz gruplar arasında cinsiyet, yaş ve SVMA dağılımı bakımından istatistiksel olarak anlamlı bir farklılık bulunmamıştır ($p>0,05$). Bloklu ve bloksuz gruplar arasında HÜÇG öncesi ve sonrası değişim ortalamaları, standart sapmalar Tablo 2' de karşılaştırmalı olarak gösterilmiştir. Grupların kendi içinde genişletme öncesi ve sonrası karşılaştırılan 10 ölçümden 9'u istatistiksel olarak anlamlıyken, 1 ölçümde anlamlı değişim bulunmamıştır. Bloklu ve bloksuz gruplar arasında ise JJ, NN, UL6MaZ, U6P, U6MZ ve U6B ölçümlerinin t0 ve t1 değişim ortalamaları arasındaki fark istatistiksel

olarak anlamlıdır (p<0,05). İstatistiksel olarak anlamlı bulunan ölçümlerin bloklu grup değişim ortalaması, bloksuz grup değişim ortalamasına göre daha azdır. Bloklu HÜÇG yapılan bireylerde UR6UL6 değeri ortalama (ort.) 6,4˚ artarken, bloksuz HÜÇG yapılmış bireylerde 10˚ artmıştır (p<0,05). HÜÇG sonrası grup ayrımı olmadan bakıldığında efektif maksiller genişlik (J-J) ort. 4,4 mm artarken, UR6UL6 değeri 8,2˚ artmıştır (p<0,05). Bu çalışmada JJ değeri, bloklu grupta genişletme sonrası ort. 3,7 mm artarken, bloksuz grupta 5,1 mm artmıştır (p<0,05). JJ artışı ile molar devrilme açılarındaki artış arasında bloklu grupta korelasyon bulunmuş, bloksuz grupta ise istatistiksel olarak anlamlı bir ilişki bulunamamıştır. JJ değeri arttıkça, bloksuz grupta ZZ değeri artışı belirgin şekilde azalmış, bloklu grupta ise belirgin şekilde artmış olması istatistiksel olarak anlamlıdır (p<0,05).

Tablo 2. Bloklu /bloksuz grup ölçümlerinin t0 ve t1 değişim ortalamalarının karşılaştırılması

	Bloklu/bloksuz	N	Ortalama	St. Sapma	Medyan	Minimum	Maksimum	P değeri
t1-t0 JJ(mm)	Bloksuz	15	5,1613	1,71472	6,0500	2,59	6,70	0,008[b]*
	Bloklu	15	3,7353	2,51908	2,7200	2,39	9,82	
	Toplam	30	4,4483	2,23804	3,0550	2,39	9,82	
t1-t0 NN(mm)	Bloksuz	15	3,2820	1,24638	3,4900	1,14	5,41	0,001[a]*
	Bloklu	15	1,8773	0,86943	1,9800	0,57	3,36	
	Toplam	30	2,5797	1,27482	2,3400	0,57	5,41	
[1]t1-t0 UR6MaZ(°)	Bloksuz	15	6,3200	2,24092	6,3000	2,40	9,20	0,074[b]
	Bloklu	15	4,3093	3,60620	1,8000	0,80	9,02	
	Toplam	30	5,3147	3,12217	6,0000	0,80	9,20	
t1-t0 UL6MaZ(°)	Bloksuz	15	6,0800	2,06612	6,9000	2,40	8,30	<0,001[a]*
	Bloklu	15	2,1000	1,82639	2,9000	-1,70	4,80	
	Toplam	30	4,0900	2,78708	3,6500	-1,70	8,30	
t1-t0 UR6UL6(°)	Bloksuz	15	10,0533	5,06344	9,8000	1,70	17,50	0,217[b]
	Bloklu	15	6,4533	3,69360	5,4000	1,90	11,00	
	Toplam	30	8,2533	4,72387	9,5500	1,70	17,50	
t1-t0 U6P(mm)	Bloksuz	15	7,3680	2,52739	7,1700	3,27	11,75	<0,001[a]*
	Bloklu	15	3,6700	2,53894	3,6100	0,52	7,66	
	Toplam	30	5,5190	3,11968	5,7150	0,52	11,75	
t1-t0 U6B(mm)	Bloksuz	15	8,9773	3,68288	10,9900	2,96	13,55	0,001[b]*
	Bloklu	15	4,6847	3,12147	5,8500	0,74	8,88	
	Toplam	30	6,8310	4,00217	6,8700	0,74	13,55	
t1-t0 ZZ(mm)	Bloksuz	15	0,3540	0,44175	0,1900	-0,19	1,04	0,389[b]
	Bloklu	15	0,9613	1,09327	0,1700	0,00	2,76	
	Toplam	30	0,6577	0,87556	0,1900	-0,19	2,76	
t1-t0 MsMs(mm)	Bloksuz	15	0,0027	0,48013	0,0000	-1,42	0,63	0,389[b]
	Bloklu	15	0,1427	0,66081	-0,0600	-0,49	1,68	
	Toplam	30	0,0727	0,57198	0,0000	-1,42	1,68	
t1-t0 U6MZ(°)	Bloksuz	15	6,2000	1,76888	6,5500	2,90	8,40	<0,001[b]*
	Bloklu	15	3,2047	2,11929	2,3500	0,60	6,40	
	Toplam	30	4,7023	2,44931	5,6000	0,60	8,40	

[a]Bağımsız örneklem t testi [b]Mann-Whitney U testi *p<0,05 istatistiksel olarak anlamlı

Tartışma

Çalışmanın null hipotezi (H_0), bloklu ve bloksuz HÜÇG protokolleri arasında PA filmler üzerinde ölçülen molar devrilme miktarı açısından istatistiksel olarak anlamlı bir fark bulunmadığıdır. Alternatif hipotez (H_1) ise iki protokol arasında molar devrilme miktarı bakımından istatistiksel olarak anlamlı bir fark olduğudur.

Çalışmanın amacı, bloklu ve bloksuz HÜÇG apareylerinin üst molar dişlerde oluşturduğu bukkal devrilme miktarını PA filmler üzerinden karşılaştırmalı olarak değerlendirmektir. Elde edilen bulgular doğrultusunda, her iki apareyin de molar devrilmesine neden olduğu; ancak bloklu apareylerin bu devrilmeyi istatistiksel olarak anlamlı düzeyde azalttığı görülmüştür. Bu nedenle çalışmanın null hipotezi reddedilmiştir.

Araştırmacılar, bloklu HÜÇG apareyinin dentoalveolar etkiden çok iskeletsel etki oluşturduğunu vurgulamaktadır.[20–25] Memikoğlu ve ark.,[21] bloklu ve bloksuz HÜÇG apareylerinin dentofasiyal etkilerini karşılaştırdıkları çalışmada, bloksuz grupta molar devrilmesinin ve kapanış azalmasının bloklu gruba göre daha fazla olduğunu belirtmişlerdir. Asanza[8] ise bloklu apareyin rijit olmasına rağmen molar dişlerde belli ölçüde devrilme hareketi gözlendiğine dikkat çekmektedir. Güncel çalışmalara bakıldığında Horn ve ark.[26] bloklu apareylerin dik yön boyutu kontrolü konusunda değişken etkileri olabileceğini, Viarani ve ark.[27] ise yaptıkları çalışmada bloksuz apareylerle vertikal kontrolün daha iyi sağlandığına dikkat çekmektedir. Alqahtani ve ark.[28] yaptıkları güncel çalışmada bloklu apareylerin vertikal boyut kontrolünde daha üstün olduğunu belirtmişlerdir. Bu bulgular, genişletme sırasında uygulanan kuvvetlerin tamamen iskeletsel yapılarla sınırlı kalmayıp dentoalveolar komponentleri de etkilediğini destekler niteliktedir.

Çalışmalar, bloklu apareylerin çapraz kapanışı gidererek maksillayı daha paralel ve bütüncül şekilde genişlettiğini belirtmektedir. Farklı vida sistemlerinin yerleşmesine olanak sağlayan tasarımları, tercih edilme nedenleri arasındadır. Bu apareylerin yeterince hijyenik olmaması, hasta konforunu azaltmasının yanında gingivitis ve diğer periodontal hastalıklar için zemin hazırlayıcı faktör olarak kabul edilmektedir.[29] Literatürde HÜÇG'nin dentoalveolar ve iskeletsel etkileri farklı görüntüleme yöntemleri ile geniş ölçüde incelenmiştir. Bazı çalışmalar, bloklu HÜÇG apareyleri ile daha fazla iskeletsel genişleme ve daha az molar devrilmesi elde edildiğini bildirirken, diğer çalışmalar iki aparey arasında önemli bir fark bulunmadığını vurgulamaktadır.[8,21,30,31] Bununla birlikte, bloklu ve bloksuz apareylerin molar devrilme üzerindeki etkilerinin standartlaştırılmış PA analiz ile ve aynı klinik protokol altında doğrudan karşılaştırıldığı çalışmalar sınırlıdır. Bu açıdan değerlendirildiğinde, mevcut çalışma özellikle klinik pratikte yaygın olarak kullanılan PA filmler üzerinden elde edilen verilerle literatüre özgün ve uygulanabilir katkı sunmaktadır.

PA filmlerin kullanımı çalışmanın güçlü yönlerinden biri olmakla birlikte, bu görüntüleme yönteminin doğasından kaynaklanan bazı sınırlılıklar da göz önünde bulundurulmalıdır. Anatomik yapıların üst üste binmesi, referans noktalarının belirlenmesinde ortaya çıkabilen hatalar ve projeksiyon distorsiyonları ölçümlerin doğruluğunu etkileyebilmektedir.[32] Bu dezavantajlar üç boyutlu görüntülüme yöntemi olan tomografinin önünü açmaktadır.[33,34] PA filmler ile karşılaştırıldığında daha net bir görüntü spektrumu sağlasa da konik ışınlı bilgisayarlı tomografi (KIBT), daha fazla radyasyon dozu gerektiren, ekonomik olmayan bir yöntemdir.[35] KIBT, Amerika ve Kanada'da ortodonti uzmanlık programlarının sadece %18' inde her hastada kullanılan bir teşhis aracıdır.[36] İngiliz ve Amerikan Ortodonti Birliği, tomografinin her hastadan rutin olarak alınmasını onaylamamaktadır.[35] PA filmler, çalışmayı sınırlandırıcı etkileri bulunsa da avantajları nedeniyle klinik rutininde önemli yer tutan efektif bir görüntüleme yöntemidir.

Çalışmanın sınırlılıkları arasında bulunan retrospektif tasarımı hasta seçiminde olası bias riskini tamamen ortadan kaldıramamaktadır. Gruplar arasında elde edilen genişleme miktarlarının farklılık göstermesi, sonuçların yorumlanmasını etkileyebilecek bir diğer sınırlandırıcı faktördür.

Bloklu grupta UR6-UL6 değeri ort. 6,4˚ artarken, bloksuz grupta ort. 10˚ artış göstermiştir. Tüm bireylerde ise ort. 4,4 mm J-J artışı için UR6UL6 değerinin ort. 8,2˚ arttığı kaydedilmiştir. Ramoğlu[37] HÜÇG sonrası J-J değeri ort. 2,3 mm artarken, UR6UL6 değerinin 9,3˚ arttığını belirtmiş, değerlerin artışında paralellik bulunduğunu ifade etmiştir.

J-J ölçümlerinde bloklu grupta genişletme sonrası artış ort. 3,7 mm iken, bloksuz grupta ort. 5,1 mm olmuştur. Farklı miktarda genişlemeler elde edilmiş olması çalışmayı sınırlandırıcı bir faktördür. Bloklu ve bloksuz gruplarda JJ ile U6MZ, UR6UL6 değişkenleri arasındaki ilişkiler Spearman sıra farkları korelasyon katsayısı ile analiz edilmiştir. Bloksuz grupta J-J artışıyla U6MZ˚, UR6UL6˚artışı arasında istatistiksel olarak anlamlı bir ilişki bulunmamıştır ($p>0,05$). Bloklu grupta ise JJ artışı ile U6MZ ve UR6UL6 artışları paralellik göstermektedir ($p<0,05$). Kanomi ve ark.[31], bloklu ve bloksuz HÜÇG etkilerini karşılaştırdıkları çalışmada, bloklu grupta ort. 4

mm, bloksuz grupta ort. 4,3 mm genişlik artışı elde edildiğini belirtmişlerdir. Bloklu grupta daha az iskeletsel genişletme elde edilmiş olması, çalışmayla örtüşür niteliktedir.

U6MZ˚ değeri bloklu grupta ort. 3,2˚ artarken bloksuz grupta 6,2˚ artmıştır. Phatouros,[38] KIBT ile bloklu HÜÇG etkilerini araştırdığı çalışmada molar dişlerde ort. 3,6˚ açı artışı olduğunu belirtmiştir. Ciambotti ve ark.[39] ise HÜÇG sonrası molar dişlerde 6,08±6,25˚ açı artışı kaydetmiştir. Bu bulgular, Ciambotti ve ark.[39] ile Phatouros ve Goonewardene'nin[38] çalışmalarıyla paralellik göstermektedir.

J-J değişimi ile hem SVMA hem de kronolojik yaş arasında bloklu ve bloksuz gruplarda istatistiksel olarak bir korelasyon bulunmamıştır (p>0,05). Bu bulgu Grünheid'ın[40] 2017 yılında SVMA ile iskeletsel genişlik artışı arasındaki ilişkiyi araştırdığı çalışmanın bulgularıyla örtüşmektedir. Sonlu elemanlar analizi temelli güncel çalışmalar, genişletme sırasında tekrarlayan vida aktivasyonlarının kafa kaidesine komşu yapılar üzerinde stres birikimine neden olduğunu belirtmektedir.[41,42] Gautam,[42] HÜÇG sonrası kraniyofasiyal iskeletin stres ve yer değiştirmesini incelediği çalışmada, zigomatikofrontal, zigomatikotemporal, zigomatikomaksiller süturlarda hem basınç hem de diferansiyel gerilme kuvvetlerinin oluştuğunu, bu kuvvetlerin diferansiyel kemik yapımına neden olabileceğini belirtmiştir. Çalışmada JJ değeri arttıkça, bloksuz grupta ZZ değeri artışının belirgin şekilde azalmış, bloklu grupta ise belirgin şekilde artmış olması istatistiksel olarak anlamlıdır (p<0,05). Bu bulgu zygomatikofrontal genişliğin maksiller genişlikle paralel artmayabileceğini, belli bir artıştan sonra sınırlanabileceğini düşündürür niteliktedir.

Sonuç

Çalışma, bloklu ve bloksuz HÜÇG apareylerinin molar devrilmesi üzerindeki etkilerini doğrudan karşılaştıran ve bu değişimleri PA filmler üzerinde karşılaştıran sınırlı sayıdaki çalışmalardan biridir. Elde edilen bulgular sonucunda bloklu HÜÇG apareylerinin üst molar dişlerdeki devrilme miktarını azaltsa da tamamen ortadan kaldırmadığını göstermektedir. Dik yön boyutları artmış bireylerde her iki aparey kullanımının da molar devrilmesiyle sonuçlanarak bu boyutlarda artışa neden olabileceği göz önünde bulundurulmalıdır.

Bloklu ve bloksuz HÜÇG protokollerinde molar devrilmesinin karşılaştırılması konusunda daha fazla araştırmaya ihtiyaç vardır. Gelecekte yapılacak, daha geniş örneklemli ve uzun dönem takip içeren prospektif çalışmaların bu konudaki bilgi birikimini artıracağı düşünülmektedir. Klinik pratikte, HÜÇG sırasında molar devrilmesini en aza indirmek için dikkatli planlama, uygun aparey seçimi ve özenli izlem önem kazanmaktadır.

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Pull-out Retentive Strength of Different Fiber Post Systems after Retreatment with Guttasolv

GuttaSolv Kullanılarak Retreatment Yapılan Dişlere Uygulanan Fiber Postların Bağlanma Dayanımlarının Pull-out Testi ile Değerlendirilmesi

Seda Aydemir[1*], Büşra Karakaş[2], Ayşe Koçak Büyükdere[3]

ABSTRACT

Objectives: This study evaluated whether the use of the gutta-percha solvent Guttasolv during retreatment procedures influences the retention of two fiber post systems: D.T. Light-Post used with Duolink dual-cured luting resin cement and RelyX posts used with RelyX Unicem self-adhesive resin cement.

Materials and Methods: Forty extracted human mandibular premolars were included in the study. After the preparation and obturation of the root canals, the specimens were randomly assigned to four groups (n=10) according to the retreatment protocol. In Groups 1 and 3, the filling material was removed using only the ProTaper Retreatment system, whereas in Groups 2 and 4 the solvent GuttaSolv was additionally applied during the removal procedure. Afterward, the canals were re-obturated. RelyX fiber posts were placed in Groups 1 and 2 using the RelyX U200 Automix self-adhesive resin cement system. In Groups 3 and 4, D.T. Light fiber posts were cemented with All-Bond Universal and Duo-Link resin cement. The roots were mounted in a pull-out testing device connected to a universal testing machine. The maximum force recorded at the moment the post was dislodged from the root was defined as the bond failure value.

Results: The pull-out test demonstrated statistically significant differences among the groups ($p=0.001$, $p<0.01$). Group 1 exhibited significantly greater pull-out strength compared with Groups 2 and 4 ($p<0.001$).

Conclusion: The use of solvent during retreatment procedures adversely affected the bonding performance of RelyX posts. However, the bond strength of D.T. Light posts was not significantly influenced by solvent use.

Key words: *Endodontics, Retreatment, Solvents.*

ÖZET

Amaç: Bu çalışmada, retreatment sırasında GuttaSolv kullanımının, iki farklı fiber post sisteminin (D.T. Light-Post/ Duolink dual-cure rezin siman ve RelyX post/ RelyX Unicem self-adheziv rezin siman) bağlanma dayanımlarına etkisini pull-out testi ile analiz edilmesi amaçlanmıştır.

Gereç ve Yöntemler: Çalışmaya 40 adet çekilmiş insan alt çene küçük azı dişi dahil edildi. Kök kanallarının şekillendirilmesi ve doldurulmasının ardından, örnekler retreatment protokolüne göre rastgele dört gruba (n=10) ayrıldı. 1. ve 3. gruplarda dolgu materyali sadece ProTaper Retreatment sistemi kullanılarak çıkarılırken, 2. ve 4. gruplarda çıkarma işlemi sırasında ek olarak GuttaSolv çözücüsü uygulandı. Daha sonra kanallar yeniden dolduruldu. 1. ve 2. gruplarda RelyX U200 Automix self-adeziv rezin siman sistemi kullanılarak RelyX fiber postlar yerleştirildi. 3. ve 4. gruplarda ise D.T. Light fiber postlar All-Bond Universal ve Duo-Link rezin siman ile simante edildi. Kökler, üniversal test makinesine bağlı bir çekme test cihazına monte edildi. Postun kökten ayrıldığı anda kaydedilen maksimum kuvvet, bağ kopma değeri olarak tanımlandı.

Bulgular: Çekme testi, gruplar arasında istatistiksel olarak anlamlı farklılıklar olduğunu gösterdi ($p=0.001$, $p<0.01$). Grup 1, Grup 2 ve 4'e kıyasla anlamlı derecede daha yüksek çekme kuvveti sergiledi ($p<0.001$).

Sonuç: Retreatment işlemlerinde çözücü kullanımı, RelyX postlarının yapışma performansını olumsuz etkilemiştir. Bununla birlikte, D.T. Light postlarının yapışma gücü çözücü kullanımından önemli ölçüde etkilenmemiştir.

Anahtar Kelimeler: *Çözücüler, Endodonti, Yeniden tedavi.*

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Introduction

Successful outcomes in endodontic therapy depend on adequate chemomechanical disinfection of the root canal system in combination with proper biomechanical preparation and hermetic obturation. Following these procedures, timely placement of a permanent coronal restoration is essential to maintain the integrity of the tooth and protect the remaining structure.[1]

Despite advances in endodontic treatment, failures may still occur, requiring further intervention. In such situations, nonsurgical retreatment is commonly performed with the objective of eliminating infection by removing previously placed obturation materials, debris, and microorganisms from the root canal system. Compared with surgical approaches, retreatment is generally considered the preferred option because it is less traumatic and allows removal of the intracanal infection source.[2,3] Gutta-percha used together with an endodontic sealer is the most frequently employed root canal filling material.[4] Consequently, effective elimination of these materials is a critical step in retreatment procedures.[5] Numerous mechanical techniques have been described for this purpose, including stainless steel hand instrumentation, nickel–titanium rotary systems, ultrasonic instruments, reciprocating devices, and laser-assisted methods.[6–12] In addition to these approaches, organic solvents have been used to facilitate the softening and removal of gutta-percha and associated sealers.[13–15] One such material is Guttasolv, a solvent based on eucalyptol that has been recommended for softening gutta-percha core material.[16,17]

Teeth that have undergone endodontic retreatment often present with significant loss of coronal tooth structure, which may necessitate restoration with a post-and-core system.[18,19] The aesthetic characteristics of these restorative materials have gained considerable importance due to the increasing use of all-ceramic crowns, particularly in anterior teeth. For this reason, translucent and tooth-colored post materials are widely preferred.[20] Nonmetallic prefabricated post systems include carbon fiber-reinforced epoxy resin posts, glass fiber-reinforced epoxy resin posts, polyethylene fiber-reinforced posts, and zircon posts[21] Fiber-reinforced posts are reported to decrease the likelihood of root fracture because their elastic modulus closely resembles that of dentin.[22] In addition, these posts provide several advantages, including good biocompatibility, favorable aesthetics, and reliable bonding to dentin walls.[23–25] Long-term clinical investigations have also reported high success rates associated with the use of fiber post systems.[26,27]

To secure fiber posts within the root canal, adhesive resin cements are commonly used as luting agents. Their bonding mechanism involves a chemical interaction between phosphate methacrylate monomers and hydroxyapatite in dental tissues.[28,29] The integrity of the interface formed between the fiber post and the adhesive resin cement is crucial for maintaining restoration retention. However, the most frequently reported cause of failure in these restorations is debonding occurring at the adhesive resin–dentin interface.[30] This study aimed to assess the influence of a eucalyptol-based solvent on the pull-out bond strength of two different fiber post systems.

Materials and Methods

Forty extracted human mandibular premolar teeth with single roots, single canal and comparable root length and diameter were selected for this study. Ethical approval was obtained from the institutional review board of the Kocaeli University Ethics Committee No. GOKAEK-2018/1.19 2018/11 in accordance with the World Medical Association Declaration of Helsinki. Until the experimental procedures were performed, the teeth were stored in a 0.12% chloramine solution. The crowns were removed to standardize the root length to 15 mm. Root canal instrumentation was carried out using ProTaper Next rotary files (Dentsply Maillefer, Ballaigues, Switzerland) up to size X3. During the preparation process, irrigation was performed with 2 mL of 2.5% sodium hypochlorite after each instrument change. After completion of instrumentation, the canals were dried using paper points. Obturation of the root canals was performed using gutta-percha (Diadent, ChoongchongBuk Do, Korea) together with AH Plus root canal sealer

(Dentsply-DeTrey, Konstanz, Germany) by applying the cold lateral compaction technique. The specimens were then randomly distributed into four experimental groups (n=10) based on the retreatment procedure. Randomization was performed using a coin-toss method.

In Groups 1 and 3, removal of the root canal filling material was performed using only the ProTaper Retreatment system (Dentsply Maillefer, Ballaigues, Switzerland). In Groups 2 and 4, the same system was used in combination with the gutta-percha solvent GuttaSolv (Septodont, Cedex, France). Following the manufacturer's instructions, few drops of Guttasolv solution were instilled into the pulp chamber and waited a few seconds to soften the gutta-percha. Fresh solvent was added periodically, and the canals were irrigated with sodium hypochlorite. Final canal preparation was completed with ProTaper Next X4, after which the canals were obturated again as described previously. For the preparation of post spaces, gutta-percha was first removed using #2 and #3 Gates Glidden drills (Dentsply Maillefer, Ballaigues, Switzerland). A D.T. Preshaping Drill (Bisco Dental Products, Schaumburg, IL, USA) was subsequently used, followed by a size #1 Drill (Bisco Dental Products, Schaumburg, IL, USA). Post spaces were prepared to a depth of 9 mm from the coronal direction.

In Groups 1 and 2, RelyX fiber posts (St. Paul, MN, USA) were luted using the RelyX U200 Automix self-adhesive cement system (St. Paul, MN, USA). In Groups 3 and 4, the required overall post length was determined using a quartz fiber D.T. Light-Post (Bisco Dental Products, Schaumburg, IL, USA). The root canals were etched with 37% phosphoric acid for 15 seconds and then rinsed with water. Residual moisture was removed using a paper point. One-Step Plus (Bisco Dental Products, Schaumburg, IL, USA) was applied twice and light cured for at least 10 seconds. Duo-Link (Bisco Dental Products, Schaumburg, IL, USA) dual-cured resin composite luting cement was mixed and delivered into the root canal. Excess cement was removed and light curing was performed for 40 seconds.

To perform the pull-out test, the roots were embedded in acrylic resin blocks in order to stabilize and properly position the specimens in the pull-out testing device connected to a universal testing machine (Instron, model 4411; Universal Testing System; Instron Corp). A constant loading rate of 0.5 mm/min was applied until failure of the cement occurred (Figure 1). The maximum force value recorded at the moment the post was extracted from the tooth was defined as the bond failure value. The obtained data were statistically analyzed using Kruskal–Wallis and Mann–Whitney U tests, and statistical significance was accepted at $p<0.05$.

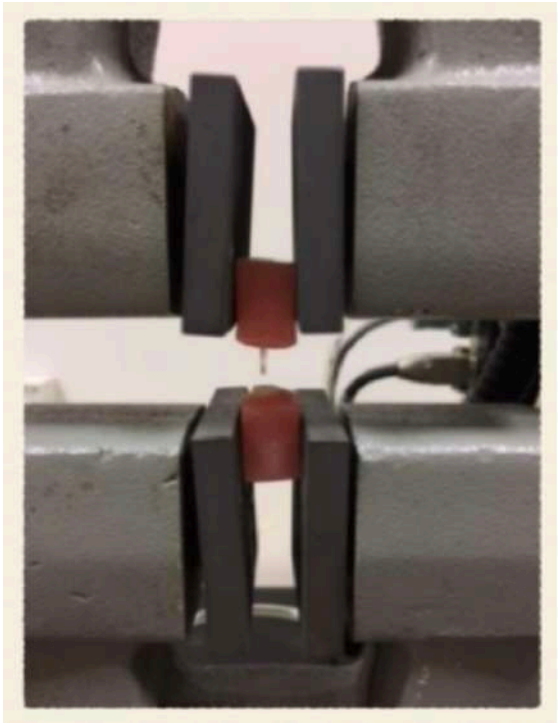

Figure 1. A specimen in the pull-out testing device connected to a universal testing machine

Results

Pull-out retentive strength values (N) of groups are shown in Table 1. Statistical analysis indicated significant differences among the groups ($p<0.01$). The highest bond strength values were recorded in the Rely X post group. When Guttasolv was not applied, the bond strength values of the Rely X and D.T. Light groups were not significantly different ($p>0.05$). In comparison, the use of Guttasolv resulted in a significantly lower pull-out retentive strength in the Rely X with Guttasolv group than in the Rely X group ($p<0.01$).

Table 1. Pull-out retentive strength values (N) of groups

	Pull-out strength (N)	
Groups	**Min-Max (Median)**	**(Mean±SD)**
Rely X	181.70-316.60 (239.50)	239.08±43.59
Rely X with Guttasolv	96.51-171.40 (126.45)	139.03±27.69
D.T.Light	109.73-270,30 (167.85)	176.46±42.81
D.T.Light with Guttasolv	115.40-283.10 (167.75)	170.31±52.93
	[a]p	0.001**
Rely X- Rely X with Guttasolv	[b]p	0.001**
Rely X- D.T.Light	[b]p	0.106
Rely X- D.T.Light with Guttasolv	[b]p	0.048*
Rely X with Guttasolv- D.T.Light	[b]p	0.202
Rely X with Guttasolv- D.T.Light with Guttasolv	[b]p	0.365
D.T.Light- D.T.Light with Guttasolv	[b]p	1.000

*[a]Kruskall Wallis Test [b]Mann Whitney U Test * p<0.05 ** p<0.01*

Discussion

Prefabricated fiber post systems used in restorative dentistry include carbon fiber, quartz fiber, and glass fiber posts.[21] D.T. Light posts belong to the quartz fiber category and are composed of crystallized pure silica. In the present study, these posts were cemented using Duo-Link dual-cured resin in accordance with the manufacturer's instructions. In contrast, the RelyX fiber post used in this study consists of glass fibers incorporated into a composite resin matrix. During the manufacturing process, resin wets the prestretched fibers and subsequently polymerizes. This mechanism enables the glass fibers to absorb tensile stresses when they are subjected to bending forces.[31] The use of glass fiber-reinforced composite posts has increased considerably in recent years.[32]

For successful restoration of endodontically treated teeth, a stable connection between the fiber post, adhesive cement, and intracanal dentin is required in order to simulate the structure of a natural tooth.[33] To achieve this, various adhesive systems and luting materials have been proposed for bonding fiber-reinforced composite posts to dentin. These materials are generally categorized as etch-and-rinse adhesive systems and self-etch adhesives.[34] More recently, self-adhesive dual-polymerizing resin cements have been introduced.[35] According to the manufacturer, these cements can bond directly to both dentin and posts without requiring the application of primer or bonding agents.[36,37] Bitter et al.[34] reported that RelyX Unicem self-adhesive dual-cured resin cement demonstrated greater bond strength than chemically cured resin cements when used with fiber-reinforced composite posts. This result was attributed to the presence of phosphoric acid methacrylate, simple fillers, and hydroxyapatite in RelyX Unicem cement. The interaction of these components allows moisture tolerance due to water formation during the neutralization reaction. Furthermore, the manufacturer recommends the use of RelyX fiber posts together with RelyX Unicem self-adhesive resin cement.

The present study investigated the pull-out bond strength between fiber posts and root canal dentin using self-adhesive and separate etch adhesive resin cements, both with and without the use of Guttasolv. Several testing methods have been proposed to evaluate the retention and bond strength of intracanal posts to dentin, including microtensile, shear, push-out, and pull-out bond strength tests.[34-36,38]

Erdemir et al.[38] evaluated the influence of chloroform and halothane as gutta-percha solvents on the microtensile bond strength to root canal dentin. Their findings suggested that the use of gutta-percha solvents may negatively affect the bond strength between adhesive resin cements and root canal dentin.

Similarly, Guedes et al.[39] examined the effects of xylene, eucalyptol, and orange oil on bond strength. The results showed that the use of xylene

and orange oil as solvents during root canal retreatment did not significantly affect the bond strength of fiberglass posts bonded to radicular dentin. However, eucalyptol significantly decreased the bond strength of fiberglass posts in the cervical and middle thirds of the root. In addition, higher bond strength values were observed in the cervical third compared with the apical third.

The present study is subject to limitations typical of in vitro research. In the oral environment, teeth and restorative materials are continuously influenced by multiple factors and subjected to various forces. Consequently, these findings should be interpreted with careful consideration of clinical conditions.

Conclusion

Within the limitations of this in vitro study, the findings indicate that the use of Guttasolv during root canal retreatment may negatively influence the retention of fiber posts in the Rely X post system. However, no significant effect was observed for the D.T. Light post system.

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Ethical Approval

The ethical approval for this study was obtained from the Ethical Committee of Kocaeli University (GOKAEK-2018/1.19 2018/11).

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Conflict of Interest

None of the authors of this article have any affiliation, connection or financial interest regarding the subject or material mentioned in the article.

Authorship Contributions

Idea/Concept: S.A, B.K, A.K.B Design: S.A, B.K, A.K.B Supervision: S.A, B.K, A.K.B Resources: S.A Materials: S.A, B.K Data Collection and/or Processing: B.K Analysis and/or Interpretation: S.A, B.K Literature Review: B.K Writing/Manuscript Preparation: S.A, B.K Critical Review: S.A, A.K.B.

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REVIEW

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Isolation Techniques in Pediatric Dentistry and Recent Studies on the Topic

Çocuk Diş Hekimliği'nde İzolasyon Yöntemleri ve Konu Üzerine Yapılan Güncel Çalışmalar

Merve Mısır[1*], Ali Fırat Tatlı[2], Mine Koruyucu[1]

ABSTRACT

Pediatric dentistry involves a wide range of restorative, endodontic, surgical, and preventive treatments aimed at maintaining the oral health of individuals aged 0–15 years. The long-term success of these procedures is strongly associated with maintaining a dry, clean, and uncontaminated working field during dental interventions. For this reason, the choice of isolation technique plays a critical role in achieving optimal clinical outcomes. The effectiveness and patient compatibility of the selected isolation method directly influence the success of the treatment, especially in pediatric patients who often present unique challenges in terms of both anatomy and behavior. This narrative review focuses on evaluating commonly used traditional methods such as cotton rolls, saliva ejectors, and rubber dams, as well as modern isolation systems like Isolite and DryShield. These newer systems combine suction, lighting, and bite block functions, offering a more integrated and efficient approach. They have been shown to significantly improve clinical workflow and enhance the comfort and cooperation of pediatric patients during treatment. Furthermore, behavioral traits like short attention span, increased salivation, and limited mouth opening must be considered when selecting an isolation strategy. A personalized and patient-centered approach should be prioritized. Incorporating advanced systems can contribute to more effective, time-efficient, and stress-free pediatric dental procedures, ultimately leading to improved patient compliance and satisfaction.

Keywords: *Pediatric dentistry, Rubber dam, Saliva*

ÖZET

Pedodonti, 0–15 yaş arası bireylerin ağız ve diş sağlığını korumaya yönelik restoratif, endodontik, cerrahi ve koruyucu birçok tedaviyi kapsamaktadır. Bu tedavi işlemlerinin uzun vadeli başarısı, işlem sırasında kuru, temiz ve kontaminasyondan uzak bir çalışma alanının sağlanmasıyla doğrudan ilişkilidir. Bu nedenle, kullanılan izolasyon tekniğinin seçimi klinik başarı açısından kritik bir rol oynamaktadır. Özellikle pediatrik hastalarda seçilecek yöntemin etkinliği ve hastaya uygunluğu, tedavi sürecini doğrudan etkilemektedir. Bu anlatı derlemesi, pamuk rulolar, tükürük emiciler ve rubber dam gibi geleneksel izolasyon yöntemlerinin yanı sıra Isolite ve DryShield gibi modern sistemlerin etkinliğini değerlendirmektedir. Bu yeni nesil sistemler, entegre emme, aydınlatma ve ısırma desteği gibi fonksiyonları bir araya getirerek daha verimli ve entegre bir yaklaşım sunmaktadır. Klinik süreci hızlandırmakta, hasta konforunu artırmakta ve çocuk hastaların tedaviye uyumunu kolaylaştırmaktadır. Ayrıca, kısa dikkat süresi, artmış salivasyon ve sınırlı ağız açıklığı gibi çocuklara özgü davranışsal ve anatomik özellikler izolasyon tekniği seçiminde mutlaka dikkate alınmalıdır. Bireyselleştirilmiş ve hasta merkezli bir yaklaşım ön planda tutulmalıdır. Modern sistemlerin klinik uygulamalara entegrasyonu, pedodontik tedavilerin etkinliğini ve hasta memnuniyetini artırmada önemli katkılar sağlayabilir.

Anahtar Kelimeler: *Çocuk diş hekimliği, Rubber dam, Tükürük*

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1. Introduction

For restorative procedures to be successful, it is crucial to effectively manage moisture and microbial contamination in the treatment area.[1] Isolation techniques are employed to prevent the operative field from being exposed to saliva, bacteria, or blood. These methods help control challenges such as excessive salivation and frequent tongue movement, thereby reducing treatment time and minimizing the risk of foreign body aspiration. Additionally, isolation improves visibility for the clinician and enhances the performance of restorative materials by maintaining optimal working conditions.[1] The American Academy of Pediatric Dentistry highlights the importance of providing safe pediatric dental treatment and emphasizes that patient airway protection should be ensured through appropriate isolation techniques.[2]

2. Isolation Tecniques in Pediatric Dentistry

2.1. What is Isolation and Why is it Necessary?

In dentistry, isolation refers to the practice of maintaining the operative field clean and dry by protecting it from saliva, blood, and other oral fluids during treatment. Effective isolation significantly influences the success of dental procedures. Moisture control is especially critical for composite resin restorations, as proper bonding to dentin and enamel requires a dry surface. The presence of moisture can compromise bond strength and negatively affect the long-term durability of the restoration. Furthermore, in endodontic treatments, successful outcomes depend on keeping the root canal system dry and free from moisture, which is made possible through proper isolation techniques. Effective isolation also plays a crucial role in infection control. By preventing microbial contamination during dental procedures, it ensures a safer treatment environment for both the patient and the clinician. In summary, the proper and efficient application of isolation techniques in dentistry not only enhances the overall quality of treatment but also significantly reduces the risk of infection.[3-5]

2.2. Isolation Techniques

2.2.1. Cotton Rolls

Cotton rolls are among the fundamental isolation tools used to maintain a clean and dry operative field by protecting the working area from saliva, blood, and other oral fluids during dental procedures. These simple yet effective devices play a direct role in the success of restorative treatments.[3] By slightly retracting soft tissues, cotton rolls help enhance the clinician's visibility and improve patient comfort. When placed correctly, they contribute positively to the progression and outcome of the treatment. Selecting the appropriate size and quantity of cotton rolls not only increases patient comfort but also enables the dentist to perform with greater precision and control.[3]

Despite their usefulness, cotton rolls have certain limitations, particularly in achieving complete isolation and consistent moisture control. Unlike rubber dam systems, they are not capable of fully isolating the operative field from contaminants such as saliva and blood. Therefore, relying solely on cotton rolls in adhesive restorative procedures—which require strict isolation—may increase the risk of clinical failure. Additionally, since cotton rolls absorb intraoral fluids, they need to be replaced frequently throughout the procedure to maintain effectiveness.[3]

2.2.2. Saliva Ejectors

The primary function of saliva ejectors is to maintain a consistently dry working field by preventing the accumulation of oral fluids, thereby enhancing treatment efficiency and patient comfort. They are especially useful during restorative procedures, endodontic treatments, and surgical interventions, as they assist in removing saliva and blood from the oral cavity. Typically made of plastic and designed for single use, saliva ejectors operate at low suction pressure. Positioned on the floor of the mouth, they effectively remove fluids before accumulation occurs. By continuously evacuating moisture from the oral environment, saliva ejectors improve visibility for the clinician and support a more controlled and precise treatment process.[6]

Since saliva ejectors are connected to automated suction systems, they function without requiring active intervention from the clinician. However, in cases where saliva ejectors alone are insufficient, they may need to be combined

with high-volume evacuators or other isolation techniques. Proper positioning of the suction tip is crucial for both effectiveness and patient safety. Incorrect placement can cause discomfort by adhering to the mucosa or lead to fluid accumulation in the operative field due to inadequate suction. While saliva ejectors provide a convenient solution for short dental procedures, longer or more complex treatments often require supplementary isolation methods. Saliva ejectors designed to match the patient's oral anatomy enhance treatment outcomes and improve overall patient experience. Additionally, the tips attached to the ejectors should be made of non-irritating materials and shaped to prevent obstruction by soft tissues or intraoral debris.[7]

In surgical procedures, high-speed surgical suction systems are utilized. This is typically achieved using Fraser suction tips, which are available in various sizes and are essential components of surgical instrument sets. The hole located on the handle of the Fraser tip allows the operator to control the suction power. For maximum suction, the operator covers this hole with the thumb, enabling full vacuum strength. Conversely, when aspirating delicate soft tissues, the hole is left open to reduce the suction intensity. Additionally, it is recommended to have a Yankauer or tonsil suction tip available in the clinical setting. These tips are suitable for removing large volumes of tissue and debris. Their blunt-ended design allows for safe advancement toward the posterior oral cavity and pharynx, even without direct visual guidance.[8]

2.2.3 Retraction Cords

Retraction cords are commonly used in restorative and prosthodontic procedures to temporarily displace the gingival tissues, allowing better access and visibility of the cervical margins of the tooth. By gently pushing the gingiva away from the tooth surface, retraction cords help to create a dry, clear working area and prevent bleeding or fluid seepage during impression-taking or adhesive procedures. These cords are typically made from cotton or synthetic fibers and may be impregnated with hemostatic agents to control bleeding. Proper placement of retraction cords is crucial, as excessive pressure or incorrect technique may lead to tissue trauma or postoperative discomfort.[3] The size of the retraction cord selected should be appropriate to avoid causing trauma to the gingival tissues. Additionally, care must be taken to avoid applying excessive force during placement, as undue pressure can lead to gingival injury or postoperative discomfort.[3]

2.2.4 Rubber Dam

Rubber dam, made from either latex or latex-free materials, not only provide clinicians with a cleaner and more controlled operating field, but also protect patients from exposure to toxic substances and prevent inhalation of potentially harmful agents. By effectively isolating the treatment area, rubber dams reduce the spread of saliva, blood, and dental aerosols, thereby minimizing the risk of cross-contamination and infection for both the patient and the dental professional. Additionally, they help prevent the ingestion or aspiration of small instruments and restorative materials during treatment.[9,10]

Invented in 1864 by Dr. Sanford Barnum, the rubber dam initially consisted of a rubber sheet and a simple frame, and was used to isolate one or more teeth from contaminants such as saliva, blood, and harmful microorganisms within the oral cavity. By the late 19th century, its use had become widespread in endodontic and restorative dentistry. During the mid-20th century, advancements were made in the design of clamps and frames, leading to the development of more modern and efficient rubber dam systems.[11] By the mid-20th century, the development of composite resins and the need to perform procedures in dry, moisture-free environments made the use of rubber dams increasingly important. Today, organizations such as the American Association of Endodontists consider rubber dam application an essential component of endodontic treatment protocols.[12]

In pediatric patients, elevated salivary flow increases the risk of failure in adhesive restorations. The use of a rubber dam is therefore essential, as it helps maintain optimal bonding conditions by preventing contamination from saliva, blood, and other oral fluids, thereby enhancing the effectiveness of adhesive materials. In pediatric patients, the use of a rubber

dam aids in maintaining mouth opening during longer procedures and significantly reduces the risk of accidental ingestion of foreign materials. Since children often present challenges in terms of salivary and moisture control, rubber dam isolation becomes essential for achieving successful outcomes in both endodontic and restorative treatments.[13]

2.2.4.1.Components of the Rubber Dam System

2.2.4.1.1. Rubber Dam Sheet

They can be produced from either latex or latex-free materials and are available in various thicknesses.[7] Rubber dams are typically available in pre-cut, pre-shaped sheets measuring 150 mm square. Although less common, they are also sold in roll form. For pediatric patients, scented versions are available to minimize discomfort caused by unpleasant odors. In terms of thickness, rubber dams come in thin, medium, heavy, and extra heavy options. Medium thickness is generally recommended for endodontic procedures, as it provides a suitable balance between flexibility and tear resistance. Dark-colored sheets—such as green, black, or purple—enhance visual contrast, improve operator comfort, and help reduce eye strain. Most rubber dam sheets are designed with one glossy and one matte side; the matte side is typically positioned facing the clinician. To preserve their elasticity and durability, rubber dams should be stored in a cool and dry environment.[14]

2.2.4.1.2 Rubber Dam Punch and Forceps

The rubber dam punch is used to create holes in the dam sheet that correspond to the teeth in the operative field, allowing isolation of the targeted area. There are two main types of punches: single-hole punches and rotary disc punches. Single-hole punches typically produce holes with a standard diameter of 1.63 mm or 1.93 mm. Rotary models, such as the Ainsworth and Ivory punches, feature adjustable rotating plates that can produce holes ranging from 0.5 mm to 2.5 mm in diameter. Larger holes are often preferred for molar teeth or when using winged clamps. Rubber dam forceps are instruments designed to transport, place, and remove clamps onto the tooth. While various designs exist, some are specific to certain clamp systems. Commonly used models include the University of Washington/Stoke, Brewer (Ash), and Ivory (Heraeus Kulzer). In certain forceps models, overly retentive jaws may hinder clamp release; in such cases, the tips of the forceps can be modified to reduce grip strength and improve usability.[14]

2.2.4.1.3 Frames

The rubber dam frame functions to stretch the edges of the dam sheet, ensuring stability and enhancing visibility of the operative field. Frames are available in both metal and plastic versions. Plastic frames—such as the Starlight Visi-Frame and Nygaard-Ostby are often preferred due to their lighter weight and, in some cases, their radiolucent properties. This allows them to be used during radiographic procedures without the need for removal. Additionally, hinged or foldable frame designs, such as the Ash model, offer added convenience when radiographs are required during treatment.[14]

2.2.4.1.4 Clamps

The need to stabilize the rubber dam sheet securely on the tooth led to the inevitable use of clamps. First introduced by Samuel Stockton White in 1882, rubber dam clamps have since undergone significant advancements and have been adapted for safe and effective use in pediatric patients.[14]

Clamps are specifically designed for different groups of teeth, and proper clamp selection depends on both the type of tooth being treated and its anatomical characteristics. It is essential to choose a clamp that fits the tooth morphology accurately while minimizing trauma to the surrounding soft tissues. Once placed, the clamp must be fully stabilized and should not exhibit any mobility. An appropriate clamp should provide four-point contact around the cervical region of the tooth to ensure secure retention.[14] Over time, clinicians often develop personal preferences for specific rubber dam clamps based on the region of the mouth requiring isolation. However, if the clamp is not properly secured to the tooth, the tension from the stretched dam sheet may easily dislodge it. Therefore, it is recommended to trial-fit the clamp on the

tooth before rubber dam application to ensure its stability. As an additional safety precaution, approximately 45 cm of dental floss should be tightly tied to the clamp; this allows for easy retrieval in case the clamp becomes dislodged and poses a risk of aspiration into the pharynx. In clinical practice, the clamp is typically placed over the dam and delivered to the tooth using rubber dam forceps. Any excess dam material protruding from the clamp can be gently tucked away with a plastic instrument or explorer to achieve full marginal adaptation. If necessary, light finger pressure can be applied to seat the clamp more securely in the cervical direction.[8]
It is recommended to limit the number of isolated teeth to only those necessary for the operative field. For instance, if the first or second molar has a carious lesion limited to the occlusal surface, isolating only that tooth with a single hole punched in the rubber dam may be sufficient. This approach can be applied within seconds and contributes to a more time-efficient procedure overall.[8]

There are more than 50 different clamp designs available. These clamps may be identified by numerical, alphabetical, or color-coded systems, such as the Hygenic Fiesta system. Each clamp consists of two jaws connected by a bow. In some models, the jaws are asymmetrical and serrated, enhancing their grip on the tooth surface. Most clamps are made of stainless steel; however, variants manufactured from coated steel or plastic (e.g., SoftClamp) are also available. Coated steel clamps may be more susceptible to corrosion, particularly when exposed to agents like sodium hypochlorite. Plastic clamps, on the other hand, are radiolucent and are preferred in certain clinical situations where radiographic imaging is required.[14]

2.2.5 InstiDam

InstiDam **(**Zirc Dental Products, Minnesota, USA) is a single-use rubber dam system made from semi-transparent natural latex, designed to provide fast and easy isolation. It comes with an integrated, flexible, radiolucent nylon frame and features a pre-punched hole, which minimizes the risk of tearing. The hole is positioned half an inch off-center to facilitate easier placement. Thanks to its bendable structure, radiographs can be taken without removing the dam. As it does not require sterilization, InstiDam offers time and procedural efficiency in clinical settings.[15]

2.2.6 HandiDam

HandiDam (Aseptico Inc., Washington, USA) offers a more practical alternative to traditional rubber dam systems. It is pre-assembled with an integrated frame, eliminating the need for a separate external frame. This design allows for a quicker and simpler placement process. HandiDam provides effective access during endodontic procedures, saving time for the clinician while also enhancing patient comfort.[16]

2.2.7 OptraDam

Developed by Ivoclar Vivadent in 2005, OptraDam (Ivoclar AG, Schaan, Liechtenstein) is a modern isolation system that does not require the use of a frame or clamp (Figure 1).[17] Thanks to its anatomical shape, flexible inner ring, and soft material, OptraDam functions both as a lip and cheek retractor and as a full isolation system. It adapts to the patient's jaw movements, offering a comfortable experience during treatment. By providing a broader working field, it allows for simultaneous isolation of both the maxillary and mandibular arches. Additionally, due to its structural properties, it can be used during radiographic procedures without needing to be removed.[18]

Figure 1. OptraDam

2.2.8 Liquid Dam

Liquid dam materials such as HySolate Liquid Dam (Coltène/Whaledent, Altstätten, Switzerland) are resin-based barrier material primarily used in procedures requiring intraoral protection, such as tooth whitening. Applied directly to the gingiva, this liquid material retains its flexibility after curing, providing effective protection. It does not generate heat during application and poses no risk to sensitive tissues in the treated area. As a localized protective solution, it serves as an alternative to conventional rubber dam systems.[17]

2.2.9 MiniDam

MiniDam (VOCO GmbH, Cuxhaven, Germany) is a latex-free isolation system designed for use primarily in procedures involving proximal surfaces, offering a comfortable experience for the patient. Its design forms a protective barrier that prevents acidic chemicals from coming into contact with the gingiva. MiniDam does not require a clamp; the pre-punched silicone material can be easily stretched over the teeth. However, its use is limited to proximal and resin-based procedures. Studies have shown that pediatric patients report less discomfort

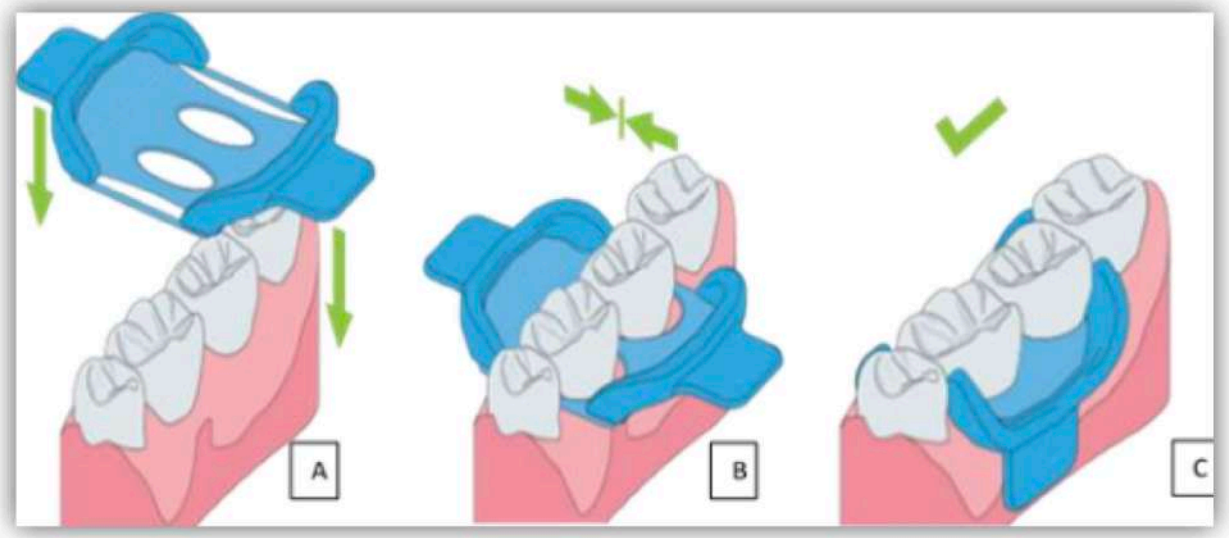

Figure 2. MiniDam

2.2.10 OptiDam

OptiDam (Kerr Corporation, Orange, CA, USA) is an isolation system distinguished by its three-dimensional (3D) anatomical shape and contoured design (Figure 3).[17] This structure conforms to the intraoral anatomy, improving access and visibility within the operative field. The system is available in models specifically designed for anterior and posterior regions. It allows patients to breathe comfortably without applying pressure to the nasal area. Clamp tension is minimized, making placement easier and reducing preparation time. Additionally, OptiDam is latex-free, powder-free, and autoclavable at 134 °C for 3 minutes.[15] During application, the nipple-like projections on the

rubber dam are first trimmed according to the position of the target tooth. The clamp is then placed on the corresponding tooth in a single step. Following this, the rubber dam material is positioned behind the wings of the clamp. In the final step, the dam is carefully stretched over the intended posterior teeth and secured in place.[17]

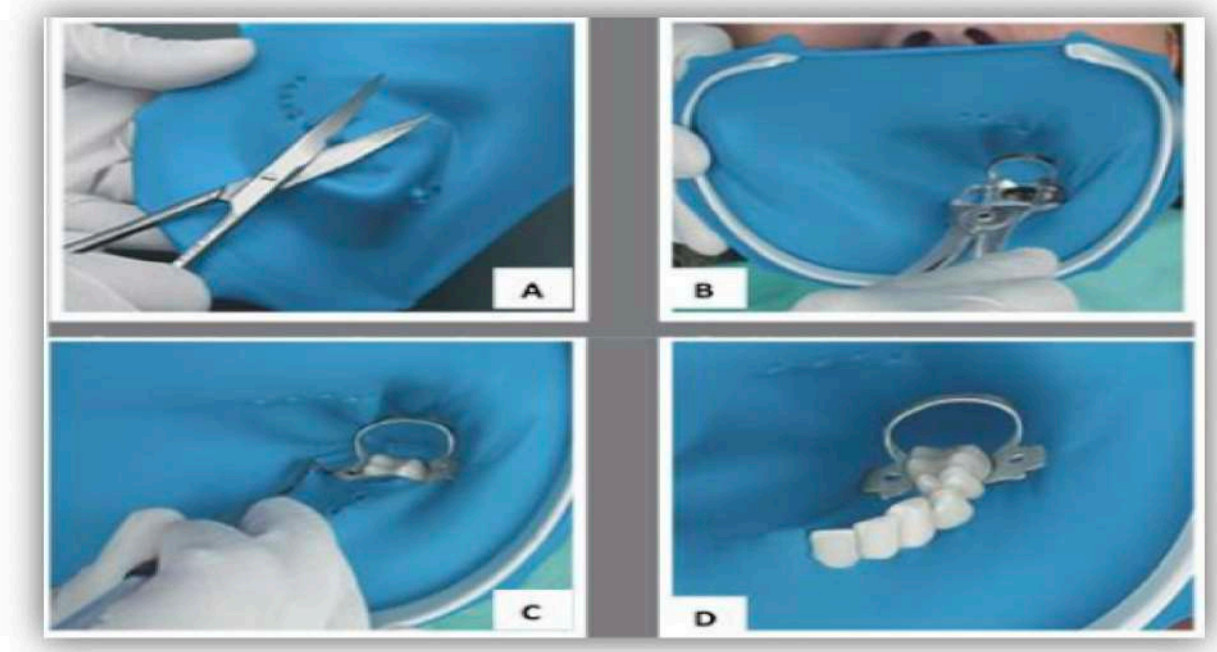

Figure 3. OptiDam

2.2.11. Framed Flexi Dam

Framed Flexi Dam (Coltène/Whaledent, Altstätten, Switzerland), is a latex-free isolation system with an integrated frame (Figure 4).[17] It provides a working area of 100 mm x 105 mm and features a soft frame that enhances patient comfort, along with a tear-resistant material for improved durability. The system is odor-free and extremely easy to place. Due to its non-irritating nature when in contact with the skin, it is also suitable for use in pediatric patients.[17]

Figure 4. Framed Flexi Dam

2.2.12 Dry Dam

The Dry Dam system (Directa AB, Stockholm County, Sweden) is an innovative solution designed to provide isolation without the need for a frame. It features a central rubber section surrounded by absorbent paper and is secured in place using elastic bands that wrap around the ears. Resembling a face mask in structure, it is particularly suitable for isolating anterior teeth. Its absorbent properties help control intraoral moisture; however, due to this characteristic, it is not recommended for use during whitening procedures (Figure 5).[16]

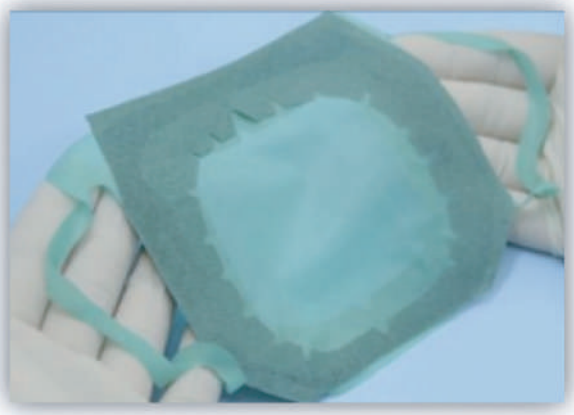

Figure 5: Dry Dam

2.2.13 Isolite and DryShield Systems

The Isolite (ISI) (Zyris Inc., Marietta, GA, USA) and DryShield Systems (DryShield LLC, Auburn, WA, USA) are multifunctional isolation solutions commonly used in modern dentistry. These integrated intraoral devices combine high-volume suction, a bite block, protective barriers for the tongue and cheeks, illumination, and soft tissue retraction into a single unit. They offer significant advantages in pediatric patients, particularly in cases where partially erupted teeth make traditional rubber dam clamp placement difficult. The Isolite system includes intraoral components made of soft, flexible polymer material that conforms to the oral anatomy, helping to prevent soft tissue injury. Additionally, it enables simultaneous treatment of both maxillary and mandibular quadrants (Figure 6).[15, 19] DryShield is a system with features similar to Isolite, but it differs in that some of its components are autoclavable and reusable, whereas the Isolite system is primarily single-use. Both systems are notable for their ability to reduce treatment time, enhance patient comfort, and optimize clinical efficiency. Integration into the dental unit requires specific adapters tailored to each system.[15, 19]

Figure 6. The Isolite system

4. Recent Studies Related to The Topic

In a systematic review and meta-analysis conducted by Shukla et al.[20] in 2024, the effectiveness of cotton rolls and rubber dam isolation techniques in fissure sealant application was compared. Following a comprehensive search in accordance with PRISMA guidelines, a total of 1,361 articles were screened. Of these, seven were randomized controlled trials (RCTs) and one was a non-randomized study, resulting in the inclusion of eight studies in total. The findings revealed that there was no statistically significant difference in the retention rates of fissure sealants between rubber dam and cotton roll isolation techniques during the first 6 months. However, by the 12-month follow-up, a statistically significant difference was observed, favoring rubber dam use. Sealants placed under rubber dam isolation demonstrated higher retention rates compared to those placed using cotton rolls. In terms of marginal integrity, no significant differences were found between the two isolation methods at either 6 or 12 months. In another study published in 2024 by Sharma et al.[21], fissure sealants were applied to the mandibular permanent molars of 30 patients aged between 7 and 10 years. The study followed a split-mouth design, with a total of 60 sites divided into two groups for comparison. In the control group, fissure sealants were applied to the lower right first permanent molars using cotton rolls and saliva ejectors for isolation. In contrast, in the experimental group, the same procedure was

performed on the contralateral left molars under rubber dam isolation. Additionally, physiological stress indicators such as pulse rate, systolic and diastolic blood pressure, and respiratory rate were evaluated. The results indicated that the use of a rubber dam was associated with a reduction in these stress-related parameters, suggesting that rubber dam isolation may contribute to decreased patient anxiety during dental procedures. In a study conducted by Saha et al.[22] in 2016, a survey was administered to 360 patients aged between 2 and 16 years who had no prior dental treatment experience. The participants were divided into three groups based on age: Group 1 (2–7 years), Group 2 (8–11 years), and Group 3 (12 years and older). Each participant watched three instructional videos demonstrating cotton roll, saliva ejector, and rubber dam isolation techniques, after which they completed a questionnaire evaluating their preferences. The results showed that across all age groups, the most preferred method was the saliva ejector, followed by the cotton roll, and lastly the rubber dam. Interestingly, while the youngest group (2–7 years) showed a preference for the rubber dam, the older groups favored the saliva ejector. The authors suggested that this outcome could be attributed to the development of logical thinking skills, which typically begin to emerge after the age of seven, influencing perception and preference.

In a clinical study, 52 children aged between 9 and 12 years were randomly divided into two groups to compare rubber dam and MiniDam isolation techniques during the application of pit and fissure sealants. The participants' anxiety levels were evaluated using the modified Venham scale and heart rate, while pain intensity was assessed via the Memojis Pain Scale. Data were analyzed using SPSS software. Statistically significant differences were observed between the two groups in terms of heart rate, pain, and anxiety levels both before and after the procedure ($p< 0.05$). It was concluded that the MiniDam technique offers an effective alternative for pit and fissure sealant procedures due to its ease of application, shorter clinical time, and positive impact on behavior management in pediatric patients.[23]

In a 2023 study conducted by Bagher and Sabbagh,[24] the clinical effectiveness, patient satisfaction, and future preference rates of the Isolite and DryShield systems were evaluated. According to findings from five clinical studies included in the review, both systems demonstrated shorter procedure times and higher patient satisfaction compared to traditional isolation methods such as the rubber dam and cotton roll. Notably, the Isolite system was reported to cause.

In a study conducted by Lyman et al.[25] in 2013, the retention of fissure sealants was evaluated using two different isolation techniques: cotton rolls and the Isolite System (ISI). The study included 29 patients with a mean age of 9.8 years. Fissure sealants were applied to the opposing first and second permanent molars within the same arch—one side using cotton rolls and the other side using ISI—in a split-mouth design. The results indicated no statistically significant difference in sealant retention between the ISI and cotton roll isolation methods. Additionally, it was observed that the maxillary arch exhibited lower retention rates compared to the mandibular arch.[25] In a study conducted by Collette et al.[26] in 2010, the time required to apply the Isolite System (ISI) was reported to be 5.7 minutes. In contrast, a previous study by Alhareky et al.[27] in 2014 found the application time to be approximately 10 minutes. More recent studies by Bagher et al.[28] (2021) and Mattar et al.[29] (2021) reported shorter durations of 3.6 and 4.1 minutes, respectively. These variations in reported application times are attributed to differences in the timing criteria and measurement methods used across the studies.

In a systematic review and randomized controlled trial conducted in 2025 to evaluate the effectiveness of the Isolite System (ISI) and its impact on patient comfort, five randomized controlled trials were identified through searches in Scopus, Embase, Medline, and Web of Science databases. Data from a total of 170 patients were analyzed. The majority of included studies reported that the Isolite System was as effective as cotton rolls and rubber dam in terms of moisture control and isolation, while also contributing

to a reduction in overall clinical procedure time. Furthermore, patient-reported outcomes indicated that the Isolite System was associated with less gag reflex and a reduced perception of taste, suggesting improved comfort compared to traditional isolation methods. However, due to the high risk of bias in the included studies and the relatively small sample sizes, the overall level of evidence was considered low.[30]

In a study conducted by Mahima et al.[31] in 2023, the effects of Optradam and rubber dam isolation techniques on dental anxiety in children were investigated. A total of 27 patients aged between 6 and 12 years were divided into two groups. In the first group, the rubber dam procedure was explained to the children using audiovisual materials (via video), after which the rubber dam was applied to a lower molar. In the second group, the Optradam system was similarly introduced through video explanation, followed by clinical application. After a 7-day washout period, the groups switched isolation techniques and the same procedures were repeated. Anxiety levels were assessed using the Venham Anxiety Scale. The results showed that anxiety scores associated with the Optradam technique were significantly lower than those recorded for the rubber dam, indicating a statistically significant difference in favor of Optradam in terms of reducing dental anxiety.

5. Conclusion

One of the most critical determinants of treatment success in pediatric dentistry is the proper selection and effective implementation of isolation techniques. Pediatric-specific factors such as increased salivary flow, limited oral opening, developing tooth morphology, and variability in patient cooperation necessitate the use of isolation systems that not only provide mechanical protection but also adapt to the individual's anatomical and behavioral characteristics.

Studies in the literature have shown that traditional methods such as cotton rolls and saliva ejectors offer advantages in terms of ease of use and speed. However, they may fall short in controlling contamination and ensuring the long-term success of restorative materials. While rubber dam provides superior isolation, it may negatively affect patient comfort in certain age groups. Interestingly, children under the age of seven have shown greater acceptance of rubber dam, possibly due to their underdeveloped logical reasoning skills. Modern systems like Isolite and DryShield, with their integrated illumination and suction capabilities, reduce treatment time, improve patient comfort, and minimize gag reflex, particularly in pediatric patients. Studies have demonstrated that these systems offer significant advantages in terms of stress reduction, anxiety control, treatment efficiency, and clinical success. However, given the limited sample sizes and high risk of bias reported in current systematic reviews, these findings should be interpreted with caution. In conclusion, the selection of isolation technique should be individualized, taking into account patient age, cooperation level, procedure duration, and comfort. Next-generation isolation systems represent a promising alternative in pediatric dental practice, offering both clinical effectiveness and improved patient satisfaction.

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Dental İmplant Cerrahisinde Osteotomi Bölgelerinde Isı Oluşumunun Nedenleri ve Kemiğe Etkileri. Anlatısal Derleme

Osteotomy Sites Heat Generation in Dental Implant Surgery, Causes and Effects on Bone. Narrative Review

Emin Celalettin Ün*

ÖZET

Dental implantlar, kaybedilen dişlerin rehabilitasyonunda, fonksiyon ve estetiği ideal karşılayabildikleri için ilk tercih olarak karşımıza çıkar. İmplant osteotomisi sırasında oluşan ısı, osseointegrasyon sürecini etkileyebilen kritik biyomekanik faktörlerden biridir. Meydana gelen sıcaklık artışı kemiğin tolere edebileceği seviyeden fazla olursa termal nekroza neden olur ve dokuda geri dönüşümsüz hücresel hasara yol açar. Bu durum, post operatif iyileşmeyi bozacağı için implantta primer stabilite kaybına ve sonuç olarak implant kaybına neden olabilir. Bu anlatısal derlemenin amacı, implant osteotomisi sırasında kemikte oluşan ısıyı etkileyen faktörleri ve bu faktörlerin biyolojik sonuçlarını mevcut literatür doğrultusunda eleştirel biçimde değerlendirmektir. Bu amaçla PubMed, ScienceDirect ve Google Scholar veri tabanlarında 2000–2025 yılları arasında yayımlanan çalışmalar incelenmiş ve osteotomi sırasında ısı oluşumu ile ilişkili biyolojik, mekanik ve teknik faktörler kavramsal olarak sınıflandırılmıştır. İncelenen çalışmalar, kemik yapısı, dril tasarımı, osteotomi teknikleri ve soğutma yöntemlerinin, termal değişimleri önemli ölçüde etkileyebileceğini göstermektedir. Bununla birlikte literatürde çalışma tasarımlarındaki heterojenlik nedeniyle kesin bir klinik protokol önerisi oluşturmanın güç olduğu görülmektedir. Sonuç olarak osteotomi sırasında termal hasarın önlenmesi için cerrahi tekniklerin biyomekanik prensipler doğrultusunda optimize edilmesi gerekir. Ayrıca bu alanda standardize klinik çalışmalara ihtiyaç olduğu görülmektedir.

Anahtar Kelimeler: *Diş implantı, Isı üretimi, Osteotomi.*

ABSTRACT

Dental implants are the preferred choice for the rehabilitation of missing teeth because they ideally meet both function and aesthetic requirements. The heat generated during implant osteotomy is one of the critical biomechanical factors that can affect the osseointegration process. If the temperature increase exceeds the level that the bone can tolerate, it causes thermal necrosis and leads to irreversible cellular damage in the tissue. This situation can impair postoperative healing, leading to primary loss of implant stability and ultimately implant failure. The aim of this narrative review is to critically evaluate the factors affecting the heat generated in the bone during implant osteotomy and the biological consequences of these factors considering the current literature. For this purpose, studies published between 2000 and 2025 in PubMed, ScienceDirect, and Google Scholar databases were examined, and the biological, mechanical, and technical factors associated with heat generation during osteotomy were conceptually classified. The studies examined show that bone structure, drill design, osteotomy techniques and cooling methods can significantly affect the thermal changes occurring during osteotomy. However, due to the heterogeneity in study designs in literature, it is difficult to establish a definitive clinical protocol recommendation. Consequently, it is necessary to optimize surgical techniques in accordance with biomechanical principles to prevent thermal damage during osteotomy. Furthermore, there appears to be a need for standardized clinical trials in this field.

Keywords: *Dental implant, Heat production, Osteotomy*

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Giriş

Dental implantlar 1965 yılında Dr. Brånemark'ın canlı bir hastaya ilk başarılı titanyum implantı yerleştirmesiyle hayatımıza girmiş oldu. Bu keşiften sonra implantın kemikle bağlantısını ifade eden "osseointegrasyon" kavramı doğdu. Osseointegrasyon; implant yüzeyi ve konak kemik doku arasında herhangi bir fibröz doku olmaksızın oluşan direkt bağlantı olarak tanımlanır.[1] Osseointegrasyon sürecinin başarısı birçok faktöre bağlıdır. Ancak bu faktörlerin en önemlisi, implant bölgesindeki kemiğin farklılaşmış ve farklılaşmamış hücrelerinin canlılığını korumasıdır.[2-4] İmplant soketindeki termal hasar, kemik rejenerasyonunu inhibe ederek hiperemiye, fibrozise, osteosit dejenerasyonuna, artmış osteoklastik aktiviteye ve sonuç olarak nekroza yol açar.[5-8] Bu durum erken dönem implant kayıplarının önemli bir nedenidir.

İmplant cerrahilerinde implantın yerleşeceği soketin hazırlığında kullanılan döner cihaz uçlarına "dril", yapılan işleme de "osteotomi" denir. Osteotomi işlemi sırasında kemikte bir miktar ısı oluşur. Bunun ana nedeni kemik dokunun düşük termal iletkenliğidir.[9] Yapılan bir araştırmaya göre 44 ^{0}C'nin üzerindeki sıcaklıklar, kemikte geri dönüşü olmayan hasara neden olmaktadır.[10] Ayrıca Eriksson,[11] 40 ^{0}C sıcaklığın 7 dakika boyunca veya 47 ^{0}C sıcaklığın 1 dakika boyunca uygulanması durumunda kemik hücresi ölümünün meydana geldiğini bildirmiştir.
İmplant bölgelerinde osteotomi sırasında ısı oluşumunu azaltmak için dril materyalleri ve tasarımları, osteotomi teknikleri ve soğutma yöntemlerindeki farklılıklar da dahil olmak üzere çeşitli stratejiler bildirilmiştir. Bununla birlikte ısı oluşumunu etkileyen faktörler konusunda fikir birliği bulunamamış ve literatürde sonuçları birbiriyle çelişen çalışmalara rastlanmıştır. Çalışma tasarımındaki standardizasyon ve tekdüzelik eksikliği, çalışma metodolojisindeki potansiyel yanlılıkla birlikte sonuçların heterojenliğinin nedeni olabilir.

Bu çalışma anlatısal derleme (narrative review) olarak tasarlanmıştır ve implant osteotomisi sırasında kemikte oluşan sıcaklık artışını etkileyen faktörleri, biyomekanik ve biyolojik açıdan eleştirel biçimde değerlendirmeyi ve mevcut literatür doğrultusunda klinik çıkarımlar ortaya koymayı amaçlamaktadır. Derleme, daha anlaşılır olması için;

1-Osteotomi yapılan kemiğin özellikleri

2-Osteotomi teknikleri (hız, kuvvet ve derinlik)

3-Drillerin mekanik özellikleri

4-Soğutma yöntemleri

şeklinde 4 başlık olarak sunulacaktır.

Çalışma için PubMed, ScienceDirect ve Google Scholar'da Ocak 2000 ila Aralık 2025 tarihleri arasında yayımlanan makaleler arasından kapsamlı bir literatür taraması yapıldı. Taramada "implant site preparation", "implant osteotomy", "bone drilling", "implant drill material", "heat generation", "thermal osteonecrosis", "intrabony temperature" anahtar kelimeleri kullanıldı.

Taranan makaleler 3 aşamalı bir seçim sürecinden geçirilmiştir:

1. Başlık ve özet taraması
2. Uygun çalışmaların tam metin değerlendirilmesi
3. Dahil edilen çalışmalarının kaynakçalarının değerlendirilmesi

Dahil etme kriterleri:

- İmplant bölgesi kemik yapısı; kompakt kemik, süngerimsi kemik
- Dril özellikleri; dril tasarımı, dril malzemesi/kaplaması, dril aşınması
- Osteotomi yöntemleri; tek dril/sıralı dril protokolü, sürekli/aralıklı osteotomi, yüksek hızda/düşük hızda osteotomi, dril ilerleme hızı, drile uygulanan eksenel kuvvet
- Soğutma yöntemi; soğutma sıvısı akış hızı, iç/dış soğutma konularını içeren kontrollü deneysel *in vitro* ve *in vivo* çalışmalar, rastgele kontrollü çalışmalar ve derleme çalışmaları olarak belirlenmiştir.

Hariç tutma kriterleri;

- Eksik ve/veya çelişkili veri içeren çalışmalar
- Vaka raporu çalışmaları/vaka serileri
- Dahil edilme kriterlerinden hiçbirini karşılamayan çalışmalar olarak belirlenmiştir.

Karşımıza çıkan makalelerin başlıkları taranarak birbirine benzer çalışmalardan en kapsamlı ve metodolojik olarak en güçlü olanlar dâhil edilerek diğerleri elendi. Kalan makalelerin de özetleri incelenerek makaleler tam metin okuma için seçildi. Tam metin makaleler ve bunların kaynakçalarından çalışmamıza toplam 56 makale dahil edilmiş oldu. Bu anlatısal derlemede çalışmalar metodolojik kalite açısından sistematik olarak puanlanmamış olup, bulgular kavramsal çerçevede sınıflandırılarak yorumlanmıştır.

Tartışma

Osseointegrasyon, dental implant yüzeyi ile canlı kemik doku arasında doğrudan oluşan fonksiyonel ve yapısal bir bağlantıdır.[12] İmplant yatağını hazırlamak için yapılan osteotomi sırasında oluşan ısı, osseointegrasyonun başarısı üzerinde önemli bir etkiye sahiptir.[13] Kemik dokusu ısı iletkenliğindeki düşük kapasitesi nedeniyle ısıyı dağıtamaz. Buna bağlı oluşan kemik hasarı, implantın primer stabilitesini azaltarak implant başarısızlığına yol açabilir.[9,14] Kemikteki sıcaklığın termal eşik seviyesinin üzerine çıkmasının nekroza neden olabileceği uzun zamandır bilinmektedir. Kemik nekrozu, kemik mimarisinin çökmesine yol açan geri dönüşümsüz bir hücre ölümüdür. Histolojik görüntülerde, implantı çevreleyen kemiğin osteojenik potansiyelini ciddi derecede etkileyebilen bir dizi boş osteositik lakuna ile kendini gösterir.[9] Kemik dokunun ısıya maruz kalma süresine bağlı olarak, bildirilen sıcaklık değerlerinin 47 ^{0}C ila 70 ^{0}C aralığında kemikte geri dönüşümsüz termal hasara neden olduğu bildirilmiştir.[9,15,16] Bununla birlikte literatürde belirtilen termal eşik değerler arasında önemli farklılıklar bulunması, osteotomi sırasında oluşan termal hasarın tek bir kritik sıcaklık değeri ile açıklanamayacağını göstermektedir.

İmplant osteotomisi sırasında oluşan ısıyı etkileyen faktörler üzerine yapılan çalışmaların sonuçları arasında belirgin tutarsızlıklar bulunmaktadır. Bu durum çalışma tasarımlarındaki farklılıklar, kullanılan deneysel modeller, kemik yoğunluğu varyasyonları ve ölçüm tekniklerindeki heterojenlik ile açıklanabilir. Özellikle *in vitro* ve *in vivo* çalışmaların sonuçlarının doğrudan karşılaştırılabilir olmaması, klinik çıkarımların genellenebilirliğini sınırlandırmaktadır.[9,16,17] Bu nedenle implant cerrahisinde termal hasarın önlenmesi, tek bir ideal parametrenin belirlenmesinden ziyade cerrahi tekniklerin çok faktörlü optimizasyonunu gerektirmektedir. Bu bağlamda mevcut literatür, osteotomi sırasında termal hasarın tamamen önlenmesine yönelik kesin bir protokol sunmaktan ziyade klinisyenlere risk azaltıcı stratejiler önermektedir.

İmplant osteotomilerinde kemikteki sıcaklık artışını etkileyen faktörleri şöyle sıralayabiliriz;

Kemik Özellikleri

İnsan kemiği, kortikal kemik ve trabeküler kemik şeklinde iki tabakadan oluşan ve homojen olmayan bir dokudur. Makro olarak gözenekli bir trabeküler iç kısmı çevreleyen yoğun bir kortikal tabakadan oluşur. Kortikal kemik osteonlardan oluşur ve her osteon, konsantrik katmanlar şeklinde sarılmış lameller oluşturan silindirik kollajen liflerden oluşur. Öte yandan trabeküler kemik ise trabekül olarak bilinen rastgele şekillendirilmiş çubuklar ve plakalar sistemidir. Trabeküler kemik genellikle içi kemik iliğiyle dolu büyük boşluklar içerir ve bu da gözenekliliğe neden olur. Genel olarak insan kemiğinin homojen olmaması ve bahsedilen yapısından ötürü implant cerrahisinde osteotomi işlemini oldukça karmaşık hale getirir.[17] Trabeküler kemik, kan damarlarıyla daha iyi beslendiği için ısıyı hızlı dağıtabilir ve bu nedenle kanlanması zayıf olan kortikal kemiğe göre daha iyi bir rejenerasyon kapasitesine sahiptir. Ayrıca kortikal kemik için osteotomi süresi trabeküler kemiğe göre daha uzun olduğundan sıcaklığın fazla olmasını anlamlı kılar. Bu durum implant cerrahisinden sonra implantın boyun bölgesindeki kemik rezorbsiyonunun nedenlerinden biri olarak gösterilebilir.[18] Erikson ve ark.[19] insan femur kemiğinde yapılan osteotominin tavşan ve köpek kemiklerinde yapılan osteotomilere kıyasla daha yüksek sıcaklıklara (89 ^{0}C) ulaştığını gözlemlemiştir. Aynı şekilde Toews ve ark.[20] at metakarpal kemiklerinde osteotomi sırasında kortikal kalınlığın artmasının kemikte oluşan sıcaklığı önemli ölçüde artırdığını bildirmiştir. Bunun nedeni olarak da kortikal kalınlığın artmasının osteotomi süresini uzatması ve

böylece sürtünme ısısının birikmesi olduğunu belirtmiştir. Yacker ve Klein[21] soğutmasız şekilde yapılan osteotomi sırasında drilin yoğun kortikal kemikle temas halindeyken dril sıcaklığının saniyeler içinde 100 ^{0}C'yi aştığını, buna karşın yumuşak trabeküler kemiğe girdiğinde sıcaklığın 39 ^{0}C'ye kadar düştüğünü bildirmiştir. Çeşitli çalışmalarda aynı canlı türü üzerinde, aynı çalışma koşullarında osteotomi yapılmasına rağmen osteotomi sırasında termal geçişlerde önemli farklılıklar gözlemlenmiştir.[22-25] Mevcut farklılıkların beslenme, yaş ve fiziksel aktivite gibi çok sayıda parametreye bağlı olarak aynı türdeki canlılar arasında doku özelliklerindeki doğal farklılıklardan kaynaklandığı düşünülmektedir. Bu durum implant osteotomisi sırasında elde edilen deneysel verilerin klinik ortama genellenmesini güçleştiren önemli bir metodolojik sınırlılık olarak değerlendirilebilir.

Osteotomi Teknikleri

Osteotomi sırasında dril hızına ilişkin incelemeler tutarlı bir eğilim göstermemektedir. Bazı çalışmalar hızdaki artışla kemikteki sıcaklığın arttığını ileri sürüp düşük osteotomi hızı önerirken diğerleri hızdaki artışla sıcaklığın azaldığını öne sürmektedir. Thompson[26], in vivo olarak iskelet pimi yerleştirdiği bir çalışmasında dril hızının 125 rpm'den 2000 rpm'e çıkarılmasıyla osteotomi giriş noktasından 2,5 mm ve 5 mm uzaklıktaki sıcaklığın arttığını bulmuştur. Buna karşılık Mathews ve Hirsch[27], insan kadavra femurlarında osteotomide dönme hızının 345 rpm'den 2900 rpm'e yükseltilmesinin kemik sıcaklığında önemli bir değişikliğe neden olmadığını bildirmiştir. Hillary ve Shuaib[28], 3,2 mm'lik dril ile osteotomi sırasında 400 rpm'den 2000 rpm'e kadar hızın artmasıyla kemikte oluşan sıcaklıkta önemli bir azalma olduğunu bildirmişlerdir. Boyne[29], Mos[30] ve Sportz[31] tarafından ortopedik cerrahi işlemler sırasında yüksek hızlı döner aletlerin kemik üzerindeki etkisi histolojik olarak incelenmiş ve yüksek hızlı osteotominin düşük hıza göre kemik üzerine daha az zararlı olduğu ileri sürülmüştür. Iyer ve ark.[32] tavşan tibiasında in vivo yaptıkları implant osteotomisinde düşük (2000 rpm), orta (30.000 rpm) ve yüksek (400.000 rpm) hızlarda üretilen ısıyı ölçmüş ve dril hızı ile üretilen ısı arasında ters bir ilişki olduğunu gözlemlemişlerdir. Aynı çalışmada yaptıkları histolojik incelemeye göre ilk 6 hafta içerisinde implant bölgesinde yüksek hızdaki osteotomide iyileşme oranının ve oluşan yeni kemik kalitesinin düşük veya orta hıza kıyasla daha yüksek olduğunu göstermişlerdir. Reingewirtz[33], sığır femur kortikal kemiğinde yaptığı in vitro çalışma sonucunda sıcaklığın; 400 rpm-700 rpm arasında hızla pozitif, 700 rpm-24.000 rpm arasındaki hızlarda negatif korelasyon gösterdiğini ve daha sonra 40.000 rpm'e kadar sabit kaldığını öne sürmüştür.

Dril hızları üzerine yapılan çalışmalara ek olarak Augustin ve ark[16]. ve Brisman[34], yaptıkları benzer çalışmalarda aynı dril hızında kemiğe doğru itme kuvvetinin artmasının hem maksimum sıcaklıkta hem de sürelerde azalmaya neden olduğunu ve kemik hasarını en aza indirdiğini bildirmişlerdir. Abouzgia ve James[35], 1,5 Newton (N) ila 9 N arasında değişen kuvvetler ve 49.000 rpm dril hızıyla soğutucu olmadan sığır femur kemikleri üzerinde osteotomi deneyleri yapmışlardır. Sıcaklığın, 4 N'ye kadar kuvvetle arttığını ve daha sonra 4 N'den büyük kuvvetlerde azaldığını bulmuşlardır. Kuvvet artışıyla ısı üretim hızının arttığı ancak osteotomi süresinin azaldığı, dolayısıyla daha az ısı üretildiği sonucuna varmışlar ve bu nedenle osteotomi sırasında daha yüksek kuvvetlerin önerildiğini belirtmişlerdir. Ancak uygulanan eksenel kuvvet aşırı yüksek olursa kemikte mikro çatlaklara neden olabilir. Bu nedenle osteotomi kuvvetinin kemik hasarına neden olacak kadar aşırı olmaması ve sürenin mümkün olduğunca kısa tutulması için en uygun ilerleme hızının bulunması gereklidir. Yukarıda bahsedilen çalışma sonuçlarından da anlaşılacağı gibi optimum dril hızı ve eksenel itme kuvveti hakkında net bir gösterge bulunmamaktadır. Bu çelişkili bulgular, osteotomi sırasında oluşan ısının tek bir cerrahi parametre ile açıklanamayacağını ve çok faktörlü bir biyomekanik süreç olarak değerlendirilmesi gerektiğini göstermektedir. Ancak deneysel çalışmaların çoğu, kemik osteotomisi sırasında minimum sıcaklık oluşumu için daha yüksek dril hızı, daha yüksek itme kuvveti ve daha yüksek ilerleme hızı önermektedir.

Osteotomilerde derinlik açısından yapılan karşılaştırmalarda etkinin doğrusal olup

olmadığı yönünde literatürde çelişkili ifadeler mevcuttur. Bazı çalışmalar osteotomi derinliği ile kemikteki sıcaklığın pozitif korelasyon gösterdiğini bildirmiştir.[28,36-42] Cardioli ve Majzoub[40], sığır femur kemiklerinde 2 mm ve 3 mm çapında, 1500 rpm hızda osteotomide 4 mm derinliğe kıyasla 8 mm'lik derinlikte kemikte daha yüksek ısı oluştuğunu gözlemlemişlerdir. Kalindindi[39], kemikteki sıcaklığın derinlikle artan davranışını, kemikle dril arasındaki temas süresinin artmasına, bunun da genel sürtünmeyi artırmasına bağlamıştır. Bu çalışmalara karşılık Moshiri ve ark.[43] tarafından yapılan çalışma sonucunda diğer parametreler standardize edildiğinde kemik osteotomisinde 6 mm derinlikte kemikteki sıcaklığın 3 mm ve 9 mm'ye kıyasla daha yüksek olduğu söylenmiştir. Yazarlar bu sonucu, osteotomi bölgesinin yüzeysel kısmının hazırlanması sırasında 3 mm'de soğutma etkisi olmasına rağmen 6 mm'de kortikal kemikteki sürtünme ısınmasına harici soğutmanın yeterince etki edememesine bağlamışlardır. Ancak 6 mm'deki sıcaklığın 9 mm'dekine nazaran daha yüksek çıkması, osteotominin daha derin kısımlarında daha yüksek sıcaklık oluştuğunu bildiren çalışmalarla çelişmektedir.

Drillerin Mekanik Özellikleri

İmplant cerrahisinde kullanılan drillerin çoğunluğu; paslanmaz çelik, tungsten karbür karbon, titanyum nitrür gibi kaplamalı metalik malzemelerden veya seramik malzemeden üretilmektedir. Literatürde metal ve seramik driller arasında yapılan karşılaştırmalarda kemikte oluşturdukları ısı açısından çelişkili sonuçlar bildirilmiştir. Bazı çalışmalar paslanmaz çelik drillerin, seramik drillerden daha fazla ısı ürettiğini bulmuştur.[42-45] Buna karşın iki materyal arasında fark olmadığını söyleyen çalışmalar da mevcuttur.[46-48] Bir çalışmada ise seramik drillerin, metal drillere nazaran daha fazla ısı ürettiği bildirilmiştir.[49]

Üretildikleri malzeme ne olursa olsun drillerde belli bir süre kullanımdan sonra aşınma kaçınılmazdır. Aşınmış dril kullanımı daha fazla sürtünme temasına, kesme verimliliğinin azalmasına ve ısı üretiminin artmasına neden olur.[12] Ancak bu durumun drilin kaç kez kullanıldıktan sonra olabileceğini kestirmek olanaksızdır. Çünkü; dril materyali, kullanılan hastaların kemik yapısı, soğutma tekniği, osteotomi tekniği ve derinliği gibi parametrelerin hepsini birden standardize etmek mümkün değildir. Oliveira ve ark.[42] hem paslanmaz çelik hem de zirkonyum drillerin 50 kez kullanımından sonraki aşınmalarını taramalı elektron mikroskobu (SEM) ile değerlendirmiştir. Buna göre drillerin hiçbirinde ciddi deformasyon görülmemesine rağmen zirkonyum drillerin paslanmaz çelik drillerden daha az aşınma gösterdiğini bildirmiştir. Başka bir çalışmada Scarano ve ark.[45] zirkonyum drillerin 120 osteotomiden sonra bile implant yatağını iyi seviyede hazırlayabildiğini belirtmiştir. Koo ve ark.[47] tarafından yapılan çalışmada ise sadece ilk (pilot) drillerin 50 kez kullanımından sonra daha fazla ısı ürettiğini bildirmesi ilginç bir sonuç olarak karşımıza çıkmaktadır. Dril kullanım sayısının termal hasar açısından kritik eşik değerinin belirlenememesi, klinik uygulamalarda standardizasyonu güçleştiren önemli bir faktördür.

İmplant piyasasında çok çeşitli sistemler olmasına bağlı olarak dril geometrisinde de çeşitlilik söz konusudur. Ancak bunlar içerisinde en belirgin olarak karşımıza çıkan iki geometri, burgulu driller ve üç kanallı drillerdir. Cardioli ve Majzoub[40], yaptıkları bir çalışmada 2 mm ve 3 mm çapında burgulu drillerle 3,3 mm ve 4 mm çapında üç kanallı drilleri 4 mm ve 8 mm derinliklerdeki osteotomilerde kemikte oluşturdukları ısı açısından karşılaştırmışlardır. Araştırma sonuçlarına göre, kalan tüm parametreler eşitlendiğinde 2 mm çapındaki burgulu drilin hem 4 mm hem de 8 mm derinlikte en fazla ısıyı oluşturduğunu bildirmişlerdir. Her iki osteotomi derinliğinde de üç kanallı drillerle daha düşük sıcaklık artışı olduğunu söylemişlerdir. Ayrıca üç kanallı drillerin sürtünme ısısını azaltmadaki etkinliğinin osteotomi derinliğiyle azalmadığını belirtmişlerdir. Literatüre göre drillerin geometrik özelliklerinin belli standartları karşılaması gerekir. Bu standartlar; dril ucu kendiliğinden merkezlenmeli ve sapmadan doğru bir şekilde osteotomiye başlamalıdır, oluşan kavite doğru çap ve derinliğe sahip olacak şekilde hazırlanabilmelidir, kemikte

sıkışmamalı ve aşırı tork üretmemelidir, dril ucu kemik talaşlarının uzaklaşmasına müsaade etmelidir, kolay soğutulabilen malzemeden üretilmiş olmalıdır.[50-52]

Soğutma Yöntemleri

İmplant cerrahisinde drillerde ve dolayısıyla kemikte soğutma yapılması termal nekrozu engelleyen önemli bir faktör olacağından soğutma yöntemleri birçok araştırıcı tarafından incelenmiştir.[16,39,53-55] Osteotomilerde soğutucu olarak genellikle içten ve dıştan olarak iki sistem kullanılır. İçten soğutma, soğutma sıvısının anguldurva şaftındaki borular aracılığıyla drile yönlendirilmesidir. Dıştan soğutma ise anguldurva ucundaki ek aparat ile soğutma sıvısının dril ucuna püskürtülmesi şeklindedir.[15] Matthews ve Hirsch[27], yaptıkları bir çalışmada oda sıcaklığındaki izotonik sıvı ile dakikada 300 ml, 500 ml, 1000 ml akış hızlarında soğutmayla osteotomi gerçekleştirmiştir. Buna göre soğutma sıvısının akış hızı ne kadar yüksekse osteotomi sırasında kemikte oluşan sıcaklığın o kadar düşük olduğunu ve 500 ml/dakika veya üzeri akış hızlarında, kemikteki sıcaklığın asla 50 ^{0}C'nin üzerine çıkmadığını bildirmişlerdir. Kirschmer ve Mayer[56], iç ve dış soğutmayı karşılaştırdıkları çalışmalarının sonucunda içten soğutma sisteminin kemik sıcaklığını düşürmede daha etkili olduğunu tespit etmişlerdir. Lavelle ve Wedgwod[53], 19 N kuvvet ve 350 rpm sabit dönüş hızında in vitro olarak kemik osteotomisi yapmışlar ve diğer çalışmalarla paralel olarak içten soğutma sisteminin daha etkili olduğunu söylemişlerdir. Horider ve ark.[54] koyunlar üzerinde yaptıkları histografik çalışmada dış soğutmanın yüzeyde, iç soğutmanın ise derinde daha etkili olduğunu göstermişlerdir. Ancak tüm bu çalışmalarla çelişkili olarak Benington ve ark.[55] yaptıkları deneysel çalışmalarında iç ve dış soğutma teknikleri arasında implant bölgesindeki termal değişimlerde kayda değer bir fark bulamamışlardır. Sener ve ark.[8] ise bu çalışmalara ek olarak farklı sıcaklıktaki soğutma sıvılarını karşılaştırmışlardır. Buna göre 25 ^{0}C ve 10 ^{0}C izotonik sıvı kullanarak yapılan dıştan soğutmada düşük sıcaklıktaki soğutma sıvısının kemikteki sıcaklığı daha fazla düşürebildiğini tespit etmişlerdir.

Genel olarak değerlendirildiğinde implant osteotomisi sırasında oluşan termal değişimlerin biyomekanik, biyolojik ve cerrahi parametrelerin kompleks etkileşimi sonucu ortaya çıktığı anlaşılmaktadır. Literatürdeki metodolojik heterojenlik, bu alanda evrensel bir klinik protokol oluşturulmasını güçleştirmektedir. Bu nedenle implant cerrahisinde termal hasarın önlenmesi, tek bir ideal parametrenin belirlenmesinden ziyade cerrahi tekniklerin çok faktörlü optimizasyonunu gerektirmektedir.

Bu anlatısal derlemenin sınırları dahilinde şu klinik çıkarımlar yapılabilir:

1. Kemik doku ısı iletkenliği düşük bir yapı olduğundan 47 ^{0}C'nin üzerindeki sıcaklıklar, kemikte termal nekroza sebep olabilir. Bu nedenle implant osteotomilerinde en az ısı oluşturacak atravmatik teknikler kullanılmalıdır.
2. Özellikle yoğun kortikal kemik varlığında aralıklı osteotomi ve etkin soğutma stratejilerinin tercih edilmesi faydalı olabilir.
3. Aşınmış veya deformasyona uğramış drillerin ısı artışına katkıda bulunabileceği göz önünde bulundurulmalıdır.
4. Dril hızı ve uygulanan kuvvetin kemik sıcaklığı üzerindeki etkisi literatürde çelişkili olduğundan, bu parametreler klinik koşullara göre dikkatle optimize edilmelidir.
5. Osteotomi derinliği ile sıcaklık ilişkisi net olmamakla birlikte, derin osteotomilerde soğutma etkinliğinin azabileceği hatırda tutulmalıdır.
6. Optimum akış hızında kesin bir görüş birliği olmamasına rağmen implant osteotomilerinde 500 ml/dakika veya daha yüksek akış hızında, oda sıcaklığında veya daha düşük sıcaklıkta soğutma sıvısı kullanmanın termal kontrol açısından yararlı olabileceği düşünülebilir.

Bu çalışmanın bazı sınırlılıkları bulunmaktadır. Öncelikle, derleme anlatısal nitelikte olup sistematik bir metodoloji veya meta-analiz içermemektedir. Dahil edilen çalışmaların önemli bir kısmının in vitro olması, elde edilen bulguların doğrudan klinik ortama genellenmesini sınırlamaktadır. Ayrıca

literatürde kullanılan deneysel modeller, ölçüm teknikleri ve parametreler arasında belirgin heterojenlik bulunmaktadır. Bu durum, farklı çalışmaların sonuçlarının karşılaştırılmasını ve standart bir klinik protokol oluşturulmasını güçleştirmektedir. Yayın yanlılığı ve veri seçimine bağlı olası yanlılıklar da göz ardı edilmemelidir.

Sonuç

Bu anlatısal derlemenin bulguları, dental implant osteotomisi sırasında oluşan sıcaklık artışının multifaktöriyel bir biyomekanik süreç olduğunu göstermektedir. İmplant cerrahisinde termal hasarın önlenmesine yönelik yaklaşımlar, tek bir cerrahi parametrenin optimizasyonundan ziyade cerrahi sürecin bütüncül olarak değerlendirilmesini gerektirmektedir. Bu nedenle implant osteotomisi sırasında oluşan termal değişimlerin klinik etkilerini daha net ortaya koyabilmek için standardize metodolojiye sahip ileri deneysel ve klinik çalışmalara ihtiyaç duyulmaktadır.

Etik Kurul Onayı

Makalemiz derleme türünde olduğundan etik kurul onayı gerekmemiştir.

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Yazarın makalede bahsi geçen konu ve malzemelerle ilgili çıkar çatışması oluşturabilecek bir ilişkisi veya parasal çıkar oluşturabilecek bir bağlantısı bulunmamaktadır.

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CASE REPORT

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Endodontic Management of a Periapical Lesion Induced by an Orthodontic Mini-Screw: A Case Report

Ortodontik Mini Vida Tedavisi Sebebiyle Gelişen Periapikal Lezyon: Vaka Sunumu

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ABSTRACT

Introduction: Orthodontic mini-screws are commonly used materials in orthodontic treatment because they can provide stable anchorage. Nevertheless, if placed close to the root apex, they can cause complications including pulpal injury, perforation, root resorption, and periapical irritation.

Case Report: This case study presents the non-surgical endodontic treatment of a periapical lesion that developed as a result of mini-screw placement near the root apex of a mandibular right canine during orthodontic therapy. Thorough anamnesis, clinical, and radiological examinations revealed a sinus tract and a radiolucent area in the periapical region. A routine root canal treatment was planned after all treatment modalities were explained to the patient. The sinus tract healed during follow-up, and complete radiographic healing of the lesion was apparent at 48 months.

Conclusion: This case report demonstrates that mini-screws placed near the root apex during orthodontic treatment can cause complications, but these issues can be resolved effectively with conservative endodontic techniques.

Keywords: *Root canal therapy, Orthodontic anchorage procedure, Orthodontic tooth movement, Periapical disease,*

ÖZET

Giriş: Ortodontik mini vidalar, stabil ankraj sağlayabilmeleri nedeniyle ortodontik tedavilerde yaygın olarak kullanılan materyallerdir. Bununla birlikte, kök apeksine yakın yerleştirildiklerinde pulpal hasar, perforasyon, kök rezorpsiyonu ve periapikal irritasyon gibi komplikasyonlara neden olabilirler.

Olgu Sunumu: Bu olgu sunumu, ortodontik tedavi sırasında mandibular sağ kanin dişin kök apeksine yakın yerleştirilen mini vida sonucu gelişen periapikal lezyonun cerrahi olmayan endodontik tedavisini sunmaktadır. Ayrıntılı anamnez, klinik ve radyolojik muayenede periapikal bölgede bir sinüs traktı ve radyolusent bir alan saptanmıştır. Tüm tedavi seçenekleri hastaya açıklandıktan sonra rutin bir kök kanal tedavisi planlanmıştır. Takip sürecinde sinüs traktı iyileşmiş ve lezyonun radyografik iyileşmesi 48. ayda tamamen belirgin hale gelmiştir.

Sonuç: Bu olgu sunumu, ortodontik tedavi sırasında kök apeksine yakın yerleştirilen mini vidaların komplikasyonlara yol açabileceğini, ancak bu problemlerin konservatif endodontik tekniklerle etkili bir şekilde çözülebileceğini göstermektedir.

Anahtar Kelimeler: *Kök Kanal Tedavisi,Ortodontik ankraj teknikleri, Ortodontik diş hareketi, Periapikal hastalık,*

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Introduction

Selecting optimal anchorage techniques is crucial for the success of orthodontic treatments. Due to the limitations of conventional methods, such as fixed appliances, orthodontic mini-screws—which are widely recognized for their ability to provide stable anchorage—have become increasingly common in modern orthodontics.[1,2] Because these screws are relatively simple to insert, do not require invasive surgery, and can be removed when required, they are especially preferred in interradicular cortical bone regions. However, anatomical and clinical factors, such as screw length, patient age, oral hygiene status, insertion angle, and—most importantly—the distance from the dental roots, all affect their success rate.[1,3]

The root surfaces may sustain mechanical trauma when mini-screws are positioned excessively close to the root structure. Inflammatory reactions triggered by this trauma may ultimately lead to complications such as pulp necrosis, external root resorption, root perforation, and periapical inflammation.[4,5] Younger patients are particularly susceptible to faster progression of root resorption due to their active bone remodeling processes. The literature reports that after an observation period of approximately three to six months, iatrogenic root damage caused by orthodontic mini-screws has occasionally been observed to heal spontaneously without the need for any intervention.[6,7] However, endodontic or surgical intervention may be required for the affected tooth if symptoms persist during the follow-up period or if no signs of radiographic healing are observed.[4,8,9] One of the more technically advanced imaging methods, cone-beam computed tomography (CBCT), offers useful diagnostic data for the early identification of such issues,[8] however, these complications typically only become noticeable after the emergence of clinical symptoms like sinus tract formation, pain, or radiolucency.[10]

Non-surgical root canal treatment protocols remain the primary option for managing periapical lesions from an endodontic approach. In this situation, calcium hydroxide's [$Ca(OH)_2$] high pH (~12.5) effectively eradicates anaerobic bacteria and encourages the formation of hard tissue in apical tissues, which prevents the resorption process from progressing.[11,12] Furthermore, it has been proven to suppress any remaining microorganisms within the root canal system and stimulate the healing of the surrounding periapical tissues when used as an interappointment medicament.[13,14]

This case report presents the non-surgical endodontic management of a chronic periapical lesion associated with the placement of an orthodontic mini-screw in close proximity to the root apex of a mandibular right canine during orthodontic treatment. Clinically, a sinus tract and a well-defined periapical radiolucency were noted. Differential diagnoses such as periodontal lesions and vertical root fractures were ruled out based on clinical examinations and radiographic findings, leading to a final diagnosis of chronic apical periodontitis. Given the lesion's size, the severity of clinical symptoms, and the extent of infection; a conservative approach involving non-surgical root canal treatment was deemed the most appropriate course of action.

Case Report

An 18-year-old systemically healthy male patient presented to Department of Endodontics, Faculty of Dentistry, Başkent University, in 2021. His complaint was a sinus tract in the right mandibular canine's buccal mucosa (Figure 1). Patient's dental history revealed that his fixed orthodontic treatment was completed in 2020, which performed with orthodontic mini-screws in the area of the mandibular canines (Figure 2).

Figure 1. Intraoral sinus tract

During clinical examination, a sinus tract was observed on the vestibular mucosa in the right mandibular canine area. The tooth exhibited no coronal restoration. The tooth revealed no signs of pain to percussion or palpation. Pulp vitality assessments, including both cold (Endo-Frost, Roeko, Langenau, Germany) and electric pulp tests (Parkell Inc, Edgewood, NY), showed negative responses. Periodontal examination of the affected canine and adjacent teeth revealed normal findings, including physiological probing depths, with no signs of mobility or attachment loss.

A panoramic radiograph obtained during orthodontic treatment and the initial periapical radiograph at presentation showed that the orthodontic mini-screws had been placed in close proximity to the root apex of the right mandibular canine (Figure 2).

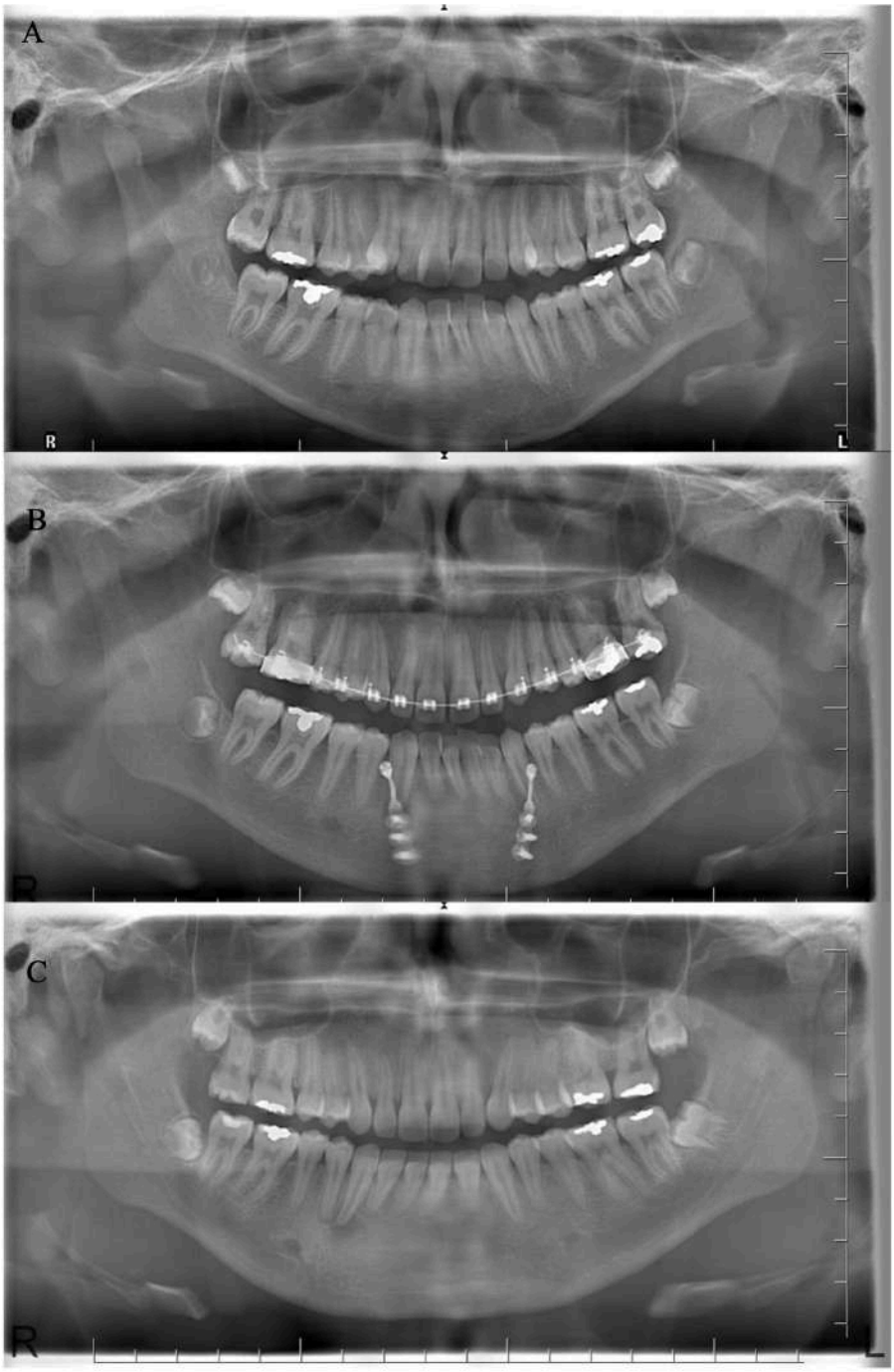

Figure 2. Panoramic Radiographs A. Initial (02/2016) B. During orthodontic treatment (06/2018) C. After orthodontic treatment (12/2020)

On the initial periapical radiograph, a well-defined periapical radiolucency surrounding the apex was detected (Figure 3). The lesion was assigned a Periapical Index (PAI) score of 4, indicating a well-defined radiolucent area. Additionally, radiopaque lines were observed (Figure 3). The structural integrity of the lamina dura was obviously affected. Clinical and radiographic assessments of the adjacent teeth, supported by pulp sensibility testing and periodontal examination, confirmed that they were vital and not involved in the pathological process. Written informed consent was obtained from the patient for the endodontic treatment and the publication of this case report with an assurance of anonymity.

Figure 3. Post-orthodontic periapical radiograph (03/2021)

A routine root canal treatment was planned for the tooth with necrotic pulp. Following a local anesthetic (articaine HCl with epinephrine 1:100,000), an access cavity was prepared under rubber dam isolation. The working length was determined with an electronic apex locator and then confirmed with periapical radiography (Figure 4). The canal was prepared using the ProTaper Next rotary file system (X1–X3; Dentsply Maillefer, Switzerland) and nickel-titanium hand files (#70).

Figure 4. Working length determination (03/2021)

A syringe was used to irrigate the canal with 2 mL of a 2.5% sodium hypochlorite (NaOCl) solution (Microvem, Istanbul, Turkey) between each file. For the final irrigation, 5 mL of 17% EDTA (Microvem, Istanbul, Turkey) was used for one minute, followed by distilled water. Manual dynamic activation was performed using a well-fitting master gutta-percha cone to enhance the efficacy of the irrigants. $Ca(OH)_2$ (Calsin, Merkez Kimya, Turkey) was placed into the canal as an intracanal medicament to suppress residual microorganisms and prevent the progression of root resorption. Then, the access cavity was sealed with a temporary restorative material (Cavit, Meta Biomed, Cheongju, Korea).

At the two-week follow-up visit, the sinus tract on the vestibular mucosa was reported to have successfully healed; no edema or pain was observed in the affected area. The intracanal medication was removed by irrigating with 5 mL of 2.5% NaOCl and 5 mL of 17% EDTA,

accompanied by manual dynamic activation. The root canal was dried with sterile paper points and was obturated with gutta-percha (70.02) (Sure Dent Corporation, Gyeonggi-do, Korea) and AH Plus sealer (Dentsply Maillefer, Switzerland) via the cold lateral compaction technique (Figure 5).

Figure 5. Root canal obturation (03/2021)

Finally, the tooth was restored with composite resin (Filtek Z250, 3M ESPE, St Paul, MN) (Figure 6). During the patient's regular follow-up appointments, no symptoms were mentioned. At the 48-month follow-up examination of the patient, the tooth was healthy and the periapical radiograph showed healing of the periapical lesion (Figure 7).

Figure 6. A post-operative radiograph (03/2021)

Figure 7. 48 months follow up (03/2025)

A notable radiographic finding in this case was the presence of two thin, ring-like radiopacities adjacent to the root apex. These findings persisted with the same morphology after obturation and throughout the 48-month follow-up period. Neither the radiographic healing process nor the clinical course was impacted by these findings.

Conclusion

The use of mini-screws during orthodontic treatment provides control over tooth movement by providing stable anchorage; nevertheless, proximity to or contact with tooth roots during placement may lead to complications.

Incorrect angulation or placement of mini-screws too close to the root surface could damage the cementum and dentin, leading to various types of root resorption. Brudvik and Rygh[5] state that when cementum surfaces exposed to such damage experience osteoclastic activity, inflammatory root resorption occurs. According to the literature, inflammation damages the pulp tissue and causes internal root resorption which is a progressive process. However, after cementum damage, external inflammatory root resorption appears in the periodontal ligament and typically takes place in the apical or lateral regions of the root.[15,16] This mechanism is frequently observed in cases involving external damage, particularly those caused by orthodontic mini-screws.[17]

Additionally, external surface resorption caused by damage to the cementum and periodontal ligament is typically a temporary, superficial form that resolves spontaneously following trauma.[15] If the inflammation process persists, a progressive variant known as replacement resorption may develop, in which bone tissue gradually replaces the cementum. This reparative process causes ankylosis, since the root structure is replaced by bone.[17,18]

The growth of periapical inflammation, particularly after pulp vitality has been lost, might result in the development of sinus tracts and apical lesions[3,4] In this case, the patient's asymptomatic clinical condition at referral supported the diagnosis of chronic apical periodontitis. One of the report's limitations was the absence of CBCT imaging. Despite this limitation, the proximity of the mini-screw to the root apex was apparent on periapical radiographs. According to standard radiography findings, external inflammatory root resorption was considered as the most likely diagnosis.[8]

The removal of pulp tissue, elimination of bacterial contamination, and complete disinfection of the root canal system provide the primary therapeutic approach for periapical lesions associated with root resorption.[9,19] For this purpose, it has been shown that an irrigation protocol combining 2.5% sodium hypochlorite (NaOCl) with 17% ethylenediaminetetraacetic acid (EDTA) is exceptionally efficient in getting eliminating both organic and inorganic debris.[20] The use of EDTA as a final irrigant has been shown to improve the sealer's adaptation to the dentinal walls by effectively clearing the smear layer.[21]

As an intracanal medication, $Ca(OH)_2$ is regarded for its antibacterial characteristics as well as its ability to promote periapical healing and slow down the resorption process.[22] In this case, the application of $Ca(OH)_2$ at the first visit contributed to the complete closure of the sinus tract and a quick clinical improvement. Similar clinical findings have been reported in other cases, where symptoms such as sinus tract, pain, and tenderness resolved within as little as 1 to 4 weeks. For instance, a 2022 systematic review by Alghamdi and Alkhatib demonstrated a significant reduction in these symptoms following the use of $Ca(OH)_2$ in periapical lesions.[23] Furthermore, another review that was published in 2024 confirmed that intracanal calcium hydroxide is useful for accelerating symptomatic healing, particularly when there are large periapical lesions.[24]

Epoxy resin-based root canal sealers are commonly preferred by endodontists due to their ability to establish an optimal interface with dentin, exhibit low solubility, and effectively prevent apical microleakage.[25,26] Especially, AH Plus Sealer is considered a reliable material for root canal obturation, and is commonly used by many endodontists in clinical practice. Due to its effective apical sealing ability, limiting the penetration of irritants into the periapical area, it is deemed as the gold standard for epoxy resin-based root canal sealers.[20]

AH Plus root canal sealer and gutta-percha cones were used to complete the root canal obturation, and long-term follow-up revealed complete healing of the periapical lesion. Based on its high dimensional stability, strong

dentin adhesion, and low solubility, AH Plus, an epoxy resin-based sealer, is accepted as a consistent material in endodontics. Because of these qualities, it has been regarded as the "gold standard" in many research studies.[27] Additionally, AH Plus promotes the formation of a three-dimensional, hermetic seal by decreasing microleakage, which significantly improves the long-term success of the treatment.[28]

According to all the available data, AH Plus remains an effective root canal sealer in clinical practice due to its long-term dependability and physical durability. However, bioceramic sealers have shown significant advantages, particularly in moist environments, due to their increased biocompatibility and ability to promote the formation of hard tissue.[29,30]

In recent years, bioceramic-based root canal sealers have received a lot of attention due to their remarkable hydrophilic nature, ability to stimulate hard tissue growth, and exceptional biocompatibility.[31] For instance, in retrospective clinical studies, bioceramic (calcium silicate-based) sealers demonstrated a 100% success rate after 11.9 months of follow-up, whereas epoxy resin-based sealers reported a 93.8% success rate under the same conditions.[32] Furthermore, *in vitro* studies demonstrate no statistically significant differences between AH Plus and bioceramic sealers in terms of their apical sealing performance.[29]

A significant feature of this case is the successful non-surgical endodontic treatment of a pathology caused by an orthodontic mini-screw, with demonstrated long-term healing over a 48-month follow-up period. Research studies analyzing the prevalence of mini-screw complications have revealed that when the screw is placed less than 1 mm from the root, the risk of root resorption increases significantly.[2,33] Therefore, before placement, orthodontists must carry out detailed radiographic planning and carefully determine the distance between the mini-screw and nearby tooth roots.[34]

A notable radiographic finding in this case was the presence of two thin, ring-like radiopacities adjacent to the root apex. Orthodontic mini-screws placed close to tooth roots have been associated with tooth-related complications, including iatrogenic root injury and subsequent periradicular pathology.[2,35] These radiopacities may represent metallic micro-fragments related to mini-screw insertion/removal, as mechanical complications (including screw fracture) are reported more frequently in situations of high bone density and root proximity.[35] However, because periapical radiographs depict three-dimensional structures in two dimensions, they may be insufficient to determine the exact nature of radiopaque findings or the full extent of iatrogenic root damage.[36] In the present case, the stability of these radiopacities on serial radiographs, the absence of symptoms, and the favorable radiographic healing suggested that they were clinically inert; therefore, no additional invasive confirmation was pursued.

In conclusion, the overall result of orthodontic therapy is significantly affected by the contact between orthodontic mini-screws and surrounding structures. This case demonstrates how non-surgical endodontic treatment can effectively manage a periapical lesion brought on by the placement of a mini-screw near the root apex. Long-term follow-up increases this approach's effectiveness and endurance. In this case, the thin apical radiopacities remained with consistent morphology throughout the follow-up period; they were asymptomatic and did not affect the healing process, thus no further intervention was necessary. In particular circumstances, a conservative treatment approach combined with an early diagnosis may produce desirable outcomes without surgical intervention.

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Ethical Approval and Informed Consent
For this case report, institutional ethical approval was not required as per the national guidelines for case reports. However, written informed consent was obtained from the patient for the endodontic treatment and the publication of this case report, including any associated images, with an assurance of anonymity.

Conflict of Interest
The authors declare that they have no conflict of interest related to this study.

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Authorship Contributions
Idea/Concept: D.I Design: D.I, C.G.C Control/ Supervision: D.I, C.G.C Literature Review: D.I. Data Collection and/or Processing: D.I Analysis and/or Interpretation: K.G, C.G.C Writing the Article: D.I Critical Review:K.G.

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CASE REPORT

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Interdental Papilla Adaptation Following Anterior Diastema Closure with Direct Composite Restorations: A Case Report

Direkt Kompozit Restorasyonlarla Anterior Diastema Kapatımı Sonrası İnterdental Papilla Adaptasyonu: Olgu Sunumu

Salman Barış[1*], Baseren Nurdan Meserret[2]

ABSTRACT

Objectives: Anterior diastemas are common esthetic problems that may negatively affect smile appearance and patient self-perception. Although various treatment options exist, direct composite restorations are increasingly preferred for diastema closure due to their conservative and minimally invasive nature. This case report presents the clinical relevance of biologically guided restorative design in preventing black triangle formation and supporting interdental papilla adaptation following anterior diastema closure.

Case report: A 35-year-old systemically healthy woman presented with esthetic concerns related to a midline diastema between the maxillary central incisors. Clinical examination revealed an approximately 4.0 mm diastema, while radiographic evaluation showed physiologic alveolar bone levels without periodontal or periapical pathology. Based on the patient's esthetic expectations and preference for a conservative, single-visit approach, diastema closure was performed using direct resin composite restorations. Particular attention was paid to contact point positioning, proximal surface contouring, and emergence profile design, aided by a transparent Mylar strip for controlled formation of the proximal contact area. At the one-month follow-up, complete interdental papilla fill was observed with healthy gingival tissues and satisfactory marginal adaptation. At six months, the restorations maintained esthetic and functional integrity, with stable gingival tissues and no evidence of discoloration, proximal contact loss, black triangle formation, or complications.

Conclusion: With appropriate case selection and biologically guided restorative design, direct resin composite restorations represent an effective and conservative option for anterior diastema closure. Proper contact point positioning and anatomically driven proximal contouring play a critical role in preventing black triangle formation and promoting stable interdental papilla adaptation.

Keywords: *Composite resins, Dental esthetics, Dental papilla, Diastema*

ÖZET

Amaç: Anterior diastemalar, gülüş estetiğini ve hastaların öz algısını olumsuz etkileyebilen yaygın estetik problemlerdir. Farklı tedavi seçenekleri tanımlanmış olmakla birlikte, direkt kompozit restorasyonlarla diastema kapatılması konservatif yaklaşımı nedeniyle giderek daha fazla tercih edilmektedir. Bu olgu raporu, anterior diastema kapatımı sonrası siyah üçgen oluşumunun önlenmesi ve interdental papillanın adaptasyonunun desteklenmesinde biyolojik temelli restoratif tasarımın rolünü klinik olarak değerlendirmektedir.

Olgu sunumu: Sistemik olarak sağlıklı 35 yaşında kadın hasta, maksiller santral kesici dişler arasındaki orta hat diastemasına bağlı estetik şikâyet ile başvurmuştur. Klinik muayenede yaklaşık 4,0 mm genişliğinde diastema saptanmış, radyografik değerlendirmede periodontal veya periapikal patoloji olmaksızın fizyolojik alveolar kemik seviyeleri izlenmiştir. Hastanın estetik beklentileri ve konservatif, tek seanslık tedavi tercihi doğrultusunda direkt rezin kompozit restorasyonlarla diastema kapatımı planlanmıştır. Restorasyon sırasında kontak noktası konumlandırmasına, proksimal yüzey konturlarına ve çıkış profilinin biyolojik prensiplere uygun tasarlanmasına özel önem verilmiş; proksimal kontak alanının kontrollü oluşturulabilmesi için şeffaf Mylar strip kullanılmıştır. Bir aylık kontrolde diastema bölgesinin interdental papilla ile dolduğu, gingival dokuların sağlıklı olduğu ve marjinal adaptasyonun yeterli olduğu gözlenmiştir. Altı aylık takipte restorasyonların estetik ve fonksiyonel bütünlüğünü koruduğu, gingival dokuların stabil olduğu ve kontak kaybı, renklenme, siyah üçgen oluşumu veya başka bir komplikasyon izlenmediği belirlenmiştir.

Sonuç: Uygun olgu seçimi ve biyolojik olarak yönlendirilmiş restoratif tasarım ile direkt rezin kompozit restorasyonlar, anterior diastema kapatımında etkili ve konservatif bir tedavi seçeneği sunmaktadır. Doğru kontak noktası konumlandırması ve anatomik olarak yönlendirilmiş proksimal konturlama, siyah üçgen oluşumunun önlenmesi ve interdental papillanın adaptasyonunun stabil şekilde sağlanmasında kritik rol oynamaktadır.

Anahtar Kelimeler: *Dental estetik, Dental papilla, Diastema, Kompozit rezinler*

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Introduction

Anterior diastemas, particularly the spaces between the maxillary incisors, represent a significant esthetic concern that directly affects smile esthetics and patients' self-perception.[1] Diastemas may lead to disturbances in facial symmetry, resulting in a smile appearance that may be perceived as less attractive by both patients and clinicians.[2] Consequently, the demand for diastema closure treatments has increased in recent years, with patients frequently favoring conservative approaches such as direct restorative procedures.

In the management of diastemas, direct composite resins offer a minimally invasive and cost-effective treatment alternative.[3] Direct composite restorations can be performed in a single clinical session, thereby preserving tooth structure to a great extent while reducing both treatment time and cost.[4] Moreover, with the use of contemporary composite materials exhibiting high esthetic properties, it is possible to closely mimic the natural tooth form and color during diastema closure.[3] From this perspective, direct composite restorations allow the achievement of a natural smile esthetics within a short treatment time and stand out as a less invasive treatment option compared with orthodontic therapy or porcelain restorations.[4]

During diastema closure using resin composites, one of the most common clinical challenges is the occurrence of gingival level black triangles or open embrasure spaces.[5] These black triangles not only compromise smile esthetics but may also predispose to periodontal problems by facilitating food impaction.[6]

The vertical distance from the contact point to the alveolar bone crest is considered the key determinant of interdental papilla presence.[7] In a previous study, it was reported that when the distance between the contact point and the alveolar crest was 5.0 mm or less, the interdental papilla was preserved in 98% of cases; however, this rate decreased to 56% at a distance of 6.0 mm and to 27% at 7.0 mm.[8] Increased interproximal spacing and root divergence compromise papillary support, making complete papilla fill difficult in excessively wide interproximal spaces.[9] When these factors are considered collectively, it becomes evident that effective diastema closure and favorables interdental papilla adaptation require careful consideration of contact point positioning, tooth morphology, and periodontal health.[10] This case report presents a restorative approach demonstrating that satisfactory interdental papilla adaptation can be achieved following diastema closure.

Case Report

A 35-year-old systemically healthy woman presented with esthetic concerns associated with a diastema between the maxillary anterior teeth. On clinical examination, an approximately 4.0 mm midline diastema was identified between the maxillary central incisors (Figure 1). Clinical evaluation revealed no pathological labial frenulum attachment, and the maxillary central incisors exhibited favorable axial inclinations without signs of root divergence. The diastema was therefore considered primarily esthetic rather than related to frenal or orthodontic factors. Interdental papilla fill was clinically assessed using the Papilla Presence Index (PPI) proposed by Cardaropoli, Re, and Corrente (2004), which evaluates the presence of the interdental papilla based on embrasure fill.[11] At baseline, prior to restorative intervention, the interdental papilla between the maxillary central incisors was absent, corresponding to a PPI score of 3.

Figure 1. Preoperative intraoral view showing the midline diastema between the maxillary central incisors.

Radiographs showed physiologic alveolar bone levels in the affected region, with no signs of periapical or periodontal pathology. Periodontal examination revealed healthy gingival tissues, with probing depths ≤2 mm, absence of bleeding

on probing, and no clinical signs of periodontal disease. Plaque control was assessed as adequate. Horizontal measurement of the diastema width was performed using a periodontal probe (UNC-15, Hu-Friedy, USA). According to the patient's history, a direct resin composite restoration had previously been placed in the same region; however, this restoration subsequently fractured (Figure 2).

Figure 2. Intraoral view demonstrating the fractured direct resin composite restoration previously placed in the diastema region.

Considering the patient's esthetic expectations, desire for a short treatment duration, and preference for a conservative approach, diastema closure with a direct resin composite restoration was planned. Written informed consent was obtained from the patient, and permission was granted for the use of clinical and photographic data for scientific purposes. To ensure adequate moisture control throughout the restorative procedures, the treatment area was isolated using a rubber dam (Sanctuary® Dental Dam, Sanctuary Health, Malaysia) (Figure 3a). The fractured existing composite restoration was carefully removed using low-speed diamond burs without causing damage to the surrounding tissues (Figure 3b).

Figure 3. a. Isolation of the operative field using a rubber dam prior to restorative procedures **b**. Careful removal of the fractured composite restoration using low-speed diamond burs without damaging the surrounding tooth structure

Prior to the restoration, a 37% orthophosphoric acid etching gel (Etch-Rite, Pulpdent Corporation, USA) was applied to the relevant tooth surfaces for 30 seconds (Figure 4a).

Following the acid-etching procedure, the surfaces were rinsed with water for 20 seconds and gently air-dried. Subsequently, the Prime&Bond Universal adhesive system (Dentsply Sirona, USA) was applied to the enamel surfaces using a micro-applicator (Figure 4b) and was light-cured for 20 seconds using an LED curing unit (Bluephase G2, Ivoclar Vivadent, Liechtenstein). Polymerization was performed using a light intensity of 1200 mW/cm².

Figure 4. a. Application of 37% orthophosphoric acid etching gel to the enamel surfaces of the maxillary central incisors **b.** Application of the universal adhesive system to the etched enamel surfaces prior to light polymerization.

Following completion of the adhesion protocol, the restorative phase was initiated. For diastema closure, a nanohybrid resin composite material (Estelite Asteria, Tokuyama Dental, Japan) in shade A1B was selected. To enhance surface adaptation of the composite material and allow controlled formation of the anatomical contours, a sable brush lightly moistened with GC Modeling Liquid (GC Corp., Tokyo, Japan) was used.

To allow proper shaping of the proximal contact area and the interdental papilla region, a proximal wall was established using a transparent Mylar strip (Hawe Transparent Matrix Strip, Hawe Neos Dental, Switzerland). The composite material was applied using an incremental technique, and each layer was light-cured with an LED curing unit. Initially, the proximal contact area was established in the gingival region, followed by shaping of the labial surface morphology and tooth contours in accordance with natural tooth anatomy. The same restorative

protocol was applied to the contralateral maxillary central incisor to achieve symmetry. After completion of the restorations, the rubber dam was removed and occlusal contacts were checked using articulating paper. Following the necessary occlusal adjustments, finishing and polishing procedures were performed. Finishing procedures were carried out using fine-grit Sof-Lex™ discs (3M ESPE, St. Paul, MN, USA). Final polishing was completed with Diacomp Plus Twist polishing rubbers (EVE Ernst Vetter GmbH, Germany) to reduce surface roughness and achieve a high surface gloss.

At the end of the treatment, the diastema between the maxillary central incisors was successfully closed, achieving satisfactory esthetic and functional emergence profile (Figure 5). Immediate postoperative evaluation of the restorations according to modified USPHS criteria revealed Alpha ratings for color match, marginal adaptation, and anatomic form. The clinical evaluation was performed using selected core criteria of the modified United States Public Health Service (USPHS) system, including color match, marginal adaptation, anatomic form, and secondary caries. The original USPHS framework described by Cvar and Ryge has been widely adopted and selectively modified in clinical restorative research.12,13 The selective use of these core criteria reflects the short-term follow-up period and the clinical nature of the present case report.

Figure 5. Immediate postoperative intraoral view demonstrating successful closure of the anterior diastema with satisfactory esthetic and functional outcome.

The proximal contact areas and labial contours of the restorations were found to be harmonious with natural tooth morphology. At the one-month clinical follow-up, the diastema region was observed to be filled by the interdental papilla, with healthy gingival tissues and maintained marginal adaptation of the restorations (Figure 6). This finding corresponded to a Papilla Presence Index (PPI) score of 1, indicating complete papilla presence with full embrasure fill and favorable soft tissue adaptation. At the one-month follow-up, the restorations were reassessed using modified USPHS criteria, and all evaluated parameters were rated as Alpha.

Figure 6. One-month follow-up intraoral view showing favorable interdental papilla fill and healthy gingival tissues in the diastema region.

At the six-month follow-up examination, the restorations maintained their esthetic and functional integrity, the gingival tissues remained stable, and no proximal contact loss or other complications were observed (Figures 7, 8). According to modified USPHS criteria, all assessed parameters remained at Alpha scores at the six-month follow-up. No secondary caries was observed during the 6-month follow-up period; however, this finding represents early clinical outcomes and should be interpreted accordingly. USPHS evaluation results at different follow-up periods are presented in Table 1.

Table 1. Clinical evaluation of the restorations at different follow-up periods according to modified USPHS criteria.

USPHS criterion	Immediate	1 month	6 months
Color match	Alpha	Alpha	Alpha
Marginal adaptation	Alpha	Alpha	Alpha
Anatomic form	Alpha	Alpha	Alpha
Secondary caries	Alpha	Alpha	Alpha

USPHS: United States Public Health Service criteria. Alpha indicates ideal clinical performance

At this time point, the interdental papilla remained stable with complete embrasure fill, corresponding to a Papilla Presence Index (PPI) score of 1 according to Cardaropoli et al.[11], demonstrating maintained favorable papilla adaptation over time. The Papilla Presence Index scores at baseline and follow-up time points are summarized in Table 2.

Table 2. Interdental papilla evaluation using the Papilla Presence Index (PPI) proposed by Cardaropoli et al.[11]

Time point	PPI score
Baseline	3
Immediate	3
1 month	1
6 months	1

PPI: Papilla Presence Index according to Cardaropoli et al.[11]

Figure 7. Six-month follow-up intraoral view illustrating stable proximal contact areas and maintained gingival health without black triangle formation

Figure 8. Six-month follow-up close up view demonstrating preserved marginal adaptation, surface integrity, and harmonious soft tissue contours.

Throughout the follow-up period, no discoloration, marginal discrepancy, or signs of gingival inflammation were observed. The patient reported satisfaction with the esthetic and functional outcome.

Discussion

Various treatment approaches have been described for the esthetic rehabilitation of anterior diastemas. Although orthodontic treatments and indirect ceramic restorations can provide predictable esthetic and functional outcomes, factors such as prolonged treatment duration, higher cost, and increased invasiveness may limit their acceptance by all patients in clinical practice.[4] In the present case, orthodontic treatment was not preferred due to the absence of underlying orthodontic indications, such as unfavorable axial inclinations or pathological

frenulum attachment, as well as the patient's desire for a shorter treatment duration. Indirect ceramic restorations were also not selected because of their more invasive nature and the requirement for irreversible tooth preparation. Considering the patient's esthetic expectations and preference for a conservative, single-visit approach, direct resin composite restorations were chosen as the most appropriate treatment option. Therefore, in recent years, direct resin composite restorations have gained prominence due to their minimally invasive nature and ability to provide esthetic results within a short treatment time. In the present case, direct resin composite restorations were preferred for anterior diastema closure based on similar clinical considerations.

The literature reports that in cases where composite restorations fail or do not meet patient expectations, minimally thick ceramic veneers may be considered as a subsequent treatment option.[14-16] This supports the concept that direct composite restorations can be positioned as a conservative first step within a stepwise treatment planning approach for esthetic rehabilitation. One of the most frequently reported complications in diastema closure is the formation of open embrasure spaces at the gingival level.[17] These spaces, referred to as 'black triangles,' not only compromise esthetics but also pose a risk to periodontal tissues by increasing plaque retention.[6] It has long been recognized that the presence of the interdental papilla is closely related to the vertical distance between the contact point and the alveolar bone crest.[8] Tarnow et al.[8] reported that when this distance is 5 mm or less, the interdental papilla is largely preserved, whereas papilla presence decreases significantly as the distance increases. Repositioning of the proximal contact area during restorative treatment played a key role in supporting interdental papilla adaptation and stability, rather than inducing active soft tissue adaptation. In the present case, interdental papilla adaptation was evaluated using the Papilla Presence Index (PPI) proposed by Cardaropoli et al.[11], allowing standardized assessment of soft tissue changes following restorative treatment. However, interdental papilla formation is not determined solely by the vertical distance. Horizontal interproximal spacing, root positioning, and proximal surface morphology also play a decisive role in papilla stability.[18] Wide interproximal spaces and excessively convex proximal contours may restrict the biological space required for the interdental papilla, leading to unfavorable gingival outcomes.[19] According to these approaches, the contact point, cementoenamel junction, alveolar bone level, and proximal surface contours should be evaluated collectively.[20] Although attempting to mechanically eliminate black triangles by means of overcontoured restorations may provide short-term esthetic improvement, it can adversely affect periodontal health in the long term.[21] Therefore, during diastema closure, the gingival–occlusal contouring of the proximal surfaces is of critical importance, in addition to the positioning of the contact area. In this case, careful attention was given to shaping the emergence profile in accordance with anatomical principles, taking into account the biological requirements of the interdental papilla and surrounding soft tissues.

In direct composite restorations, controlled formation of the proximal contact area using transparent matrix systems contributes to preservation of an appropriate space for the interdental papilla.[3] In restorations performed using a freehand technique, deliberate limitation of the restorative material in the gingival region and design of the proximal surfaces with a slightly flat or concave morphology, in combination with the use of a transparent Mylar strip, provide a clinically controllable and practical approach that supports physiological interdental papilla adaptation by preserving the biological space required for soft tissue fill. Accordingly, this method was preferred in the present case to allow controlled and predictable placement of the restoration in the gingival region. The esthetic properties of composite resins, enabled by a wide range of opacity and translucency options, allow for successful replication of natural tooth structure.[22] Nevertheless, it has been reported that long-term use of these materials may be associated with a reduction in surface gloss and changes in color stability.[16] However, these disadvantages can be readily

managed through regular clinical follow-ups and repolishing procedures when necessary. In the present case, sequential clinical evaluations performed immediately after treatment and at 1- and 6-month follow-up visits demonstrated consistent Alpha ratings according to modified USPHS criteria, indicating stable short-term esthetic and functional performance of the restorations. Nevertheless, the evaluation of secondary caries at 6 months reflects short-term clinical findings, and longer follow-up periods are required to draw definitive conclusions regarding caries development. Overall, when applied with appropriate case selection and biologically driven morphological design, direct resin composite restorations represent an effective and conservative treatment option for the esthetic rehabilitation of anterior diastemas. One of the limitations of this case report is the relatively short follow-up period of 6 months. Therefore, the findings should be interpreted as early clinical outcomes. Long-term prospective clinical studies are needed to evaluate secondary caries development, marginal stability, and soft tissue behavior over time.

Conclusion

Direct composite restorations are considered a conservative treatment option for anterior diastema closure, allowing preservation of tooth structure. Within this approach, appropriate positioning of the contact area and anatomically driven shaping of the proximal surfaces are among the key factors that may contribute to preventing the formation of black triangle spaces. Planning the restorative design in harmony with the interdental papilla is essential to support optimal soft tissue adaptation. In the present case, favorable interdental papilla adaptation was achieved following anterior diastema closure without surgical or periodontal intervention, emphasizing the role of restorative design in soft tissue stability. Within the limitations of this case report and the short-term follow-up period, direct composite restorations with biologically guided restorative design appear to be a conservative and clinically acceptable option for anterior diastema closure.

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Ethical Approval

Ethical approval is not necessary. An informed consent form is available.

Conflict of Interest

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