

**GÜNCEL
ENDODONTİ
ÇALIŞMALARI
X**

EDİTÖR
Oğuz YOLDAŞ



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BÖLÜM 1

ENDODONTİK TEDAVİ GÖRMÜŞ DİŞLERİN RESTORASYONU: GÜNCEL BİR BAKIŞ AÇISI

Derin Buğu YÜZER ¹

GİRİŞ

Bu derleme, restorasyonun niteliği ile endodontik tedavi uygulanmış dişlerin klinik başarısı arasında anlamlı bir ilişki olduğunu bildirmektedir (1). Endodontik tedavi sonrasında pulpal dokunun çıkarılması, dentinin sıvı içeriğinde belirli bir azalışa neden olmaktadır. Buna karşın, yapılan araştırmalar dentindeki sıvı kaybının minimal olduğunu, sertlik değerlerinin zamanla değişmediğini ve elastikiyetin uzun vadede olumsuz etkilenmediğini ortaya koymuştur (2). Güncel literatür, kırılmalığıdaki asıl belirleyici faktörün pulpa kaybından ziyade diş sert dokularındaki madde kaybı olduğunu ortaya koymaktadır (3).

Başlangıçta, endodontik tedavi görmüş dişlerin zamanla dehidratasyona uğradığı ve yapılarında yüksek oranda immatür çapraz bağlı kollajen bulunması nedeniyle vital dişlere kıyasla kırılmaya daha yatkın oldukları öne sürülmüştür. Pulpanın çıkarılmasının dişin nem içeriğini azalttığı ve dentinin daha kırılmalığı hale gelmesine neden olduğu yönündeki klasik görüş, günümüzde büyük ölçüde geçerliliğini yitirmiştir. Endodontik giriş kavitesi, kanal preparasyonu ve restoratif uygulamalar sırasında oluşan madde kaybı, dişin kırılmalığına sebep olan temel faktör olarak kabul edilmektedir. Özellikle marjinal sırtların ve kaspların kaybı, posterior dişlerde kırılma riskini belirgin şekilde arttırmaktadır (4).

Kök kanal sisteminin fonksiyonel bütünlüğünün sürdürülebilmesi amacıyla, preparasyon sonrasında kanal boşluğunun apikalden koronale doğru uzanan, üç boyutlu ve hermetik bir obturasyonla doldurulması gereklidir. Adeziv bağlanma tekniklerindeki gelişmeler, seramik materyallerdeki iyileşmeler ve dijital tarama ile üretim süreçlerindeki yenilikler sayesinde klinisyenlerin kullanabileceği restoratif seçenekler giderek artmıştır (5).

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minimal invaziv bir yaklaşım benimsenerek kanal tedavili dişlerde diş dokusunun maksimum düzeyde korunması mümkün olmaktadır (46).

SONUÇ

Endodontik tedavi görmüş dişlerin restorasyonunda planlama; kalan sağlam diş dokusu miktarı, dişin konumu, oklüzal yükler, parafonksiyonel alışkanlıklar ve biyomekanik gereksinimler dikkate alınarak bireysel olarak yapılmalıdır. Güncel kanıtlar, post uygulamasının diş güçlendiren bir unsur olmadığını; yalnızca yeterli koronal diş dokusu bulunmayan olgularda restorasyon için retansiyon sağladığını göstermektedir. Bu nedenle gereksiz post preparasyonlarından kaçınılmalı ve diş dokusunu korumak önceliklendirilmelidir.

Adeziv diş hekimliğinde kaydedilen gelişmeler ve dijital teknolojilerin klinik uygulamalarda giderek daha yaygın kullanılması, endodontik tedavi görmüş dişlerin restorasyonunda daha konservatif yaklaşımların benimsenmesini mümkün kılmıştır. Bu kapsamda, uygun vaka seçiminin yapıldığı durumlarda endokron restorasyonların, molar dişlerde post-kor ve kronlara biyomekanik açıdan uyumlu bir alternatif oluşturduğu bildirilmektedir. Ancak endokron restorasyonların uzun dönem klinik başarısı; adeziv simantasyonun etkinliği, oklüzal temasların doğru düzenlenmesi ve kullanılan restoratif materyalin özellikleri gibi birden fazla klinik faktörün birlikte değerlendirilmesini gerektirmektedir.

Sonuç olarak endodontik tedavili dişlerin restorasyonunda klinisyenin amacı yalnızca diş restore etmek değil; maksimum diş dokusu korumak biyolojik uyum ve uzun dönem başarı için bütüncül bir tedavi yaklaşımı benimsemek olmalıdır.

KAYNAKLAR

1. RAY HA, TROPE M. Periapical status of endodontically treated teeth in relation to the technical quality of the root filling and the coronal restoration. *Int Endod J* [Internet]. 1995 [cited 2026 Jan 22];28(1):12–8. Available from: <https://pubmed.ncbi.nlm.nih.gov/7642323/>
2. Fernandes Zancan R, Hadis M, Burgess D, Zhang ZJ, Di Maio A, Tomson P, et al. A matched irrigation and obturation strategy for root canal therapy. *Scientific Reports* 2021 11:1 [Internet]. 2021 Feb 25 [cited 2026 Jan 24];11(1):4666-. Available from: <https://www.nature.com/articles/s41598-021-83849-y>
3. Patel SR, Youngson C, Jarad F. Principles guiding the restoration of the root-filled tooth. *Br Dent J* [Internet]. 2025 Apr 11 [cited 2026 Jan 29];238(7):508–16. Available from: <https://pubmed.ncbi.nlm.nih.gov/40217033/>
4. Uslu G, Arıcan B, Gündoğar M, Özyürek T. How does endodontic access cavity design affect the biomechanics of a maxillary premolar?? a finite element analysis study. *BMC Oral Health* 2025 25:1 [Internet]. 2025 Sep 26 [cited 2026 Jan 27];25(1):1439-. Available from: <https://link.springer.com/article/10.1186/s12903-025-06769-7>
5. Alves de Carvalho I, Marques T, Araújo F, Azevedo L, Donato H, Correia A. Clinical Performance of CAD/CAM Tooth-Supported Ceramic Restorations: A Systematic Review. *Int J*

- Periodontics Restorative Dent [Internet]. 2018 Jul [cited 2026 Jan 21];38(4):e68–78. Available from: <https://pubmed.ncbi.nlm.nih.gov/29889916/>
6. Kimble P, Corso AM, Beattie M, Campos MS, Cavalcanti B. Biomimetics and the restoration of the endodontically treated tooth. *Braz Dent Sci* [Internet]. 2023 Jan 1 [cited 2026 Jan 27];26(1). Available from: https://www.researchgate.net/publication/367639400_Biomimetics_and_the_restoration_of_the_endodontically_treated_tooth
 7. Dammaschke T, Nykiel K, Sagheri D, Schäfer E. Influence of coronal restorations on the fracture resistance of root canal-treated premolar and molar teeth: A retrospective study. *Australian Endodontic Journal* [Internet]. 2013 Aug 1 [cited 2026 Jan 24];39(2):48–56. Available from: /doi/pdf/10.1111/aej.12002
 8. Saad KB, Bakry SI, AboElhassan RG. Fracture resistance of endodontically treated teeth, restored with two post-core systems in different post space diameters (in vitro study). *BMC Oral Health* 2023 23:1 [Internet]. 2023 Dec 11 [cited 2026 Jan 28];23(1):992-. Available from: <https://link.springer.com/article/10.1186/s12903-023-03730-4>
 9. Mannocci F, Bhuva B, Roig M, Zarow M, Bitter K, Dummer PMH, et al. European Society of Endodontology position statement: The restoration of root filled teeth. *Int Endod J* [Internet]. 2021 Nov 1 [cited 2026 Jan 22];54(11):1974–81. Available from: /doi/pdf/10.1111/iej.13607
 10. Salehrabi R, Rotstein I. Endodontic treatment outcomes in a large patient population in the USA: An epidemiological study. *J Endod* [Internet]. 2004 [cited 2026 Jan 21];30(12):846–50. Available from: <https://pubmed.ncbi.nlm.nih.gov/15564861/>
 11. Wuerschling SN, Moser L, Obermeier KT, Kollmuss M. Microleakage of Restorative Materials Used for Temporization of Endodontic Access Cavities. *J Clin Med* [Internet]. 2023 Jul 1 [cited 2026 Jan 28];12(14):4762. Available from: <https://www.mdpi.com/2077-0383/12/14/4762/htm>
 12. Paulo S, Abrantes AM, Xavier M, Brito AF, Teixo R, Coelho AS, et al. Microleakage Evaluation of Temporary Restorations Used in Endodontic Treatment—An Ex Vivo Study. *Journal of Functional Biomaterials* 2023, Vol 14, Page 264 [Internet]. 2023 May 9 [cited 2026 Jan 28];14(5):264. Available from: <https://www.mdpi.com/2079-4983/14/5/264/htm>
 13. Patel S, Bhuva B, Bose R. Present status and future directions: vertical root fractures in root filled teeth. *Int Endod J*. 2022 May 1;55(S3):804–26.
 14. Al-Nuaimi N, Ciapryna S, Chia M, Patel S, Mannocci F. A prospective study on the effect of coronal tooth structure loss on the 4-year clinical survival of root canal retreated teeth and retrospective validation of the Dental Practicality Index. *Int Endod J* [Internet]. 2020 Aug 1 [cited 2026 Jan 21];53(8):1040–9. Available from: <https://pubmed.ncbi.nlm.nih.gov/32383194/>
 15. Nagasiri R, Chitmongkolsuk S. Long-term survival of endodontically treated molars without crown coverage: A retrospective cohort study. *Journal of Prosthetic Dentistry* [Internet]. 2005 Feb [cited 2026 Jan 21];93(2):164–70. Available from: <https://pubmed.ncbi.nlm.nih.gov/15674228/>
 16. Aquilino SA, Caplan DJ. Relationship between crown placement and the survival of endodontically treated teeth. *Journal of Prosthetic Dentistry* [Internet]. 2002 [cited 2026 Jan 21];87(3):256–63. Available from: <https://pubmed.ncbi.nlm.nih.gov/11941351/>
 17. Pratt I, Aminoshariae A, Montagnese TA, Williams KA, Khalighinejad N, Mickel A. Eight-Year Retrospective Study of the Critical Time Lapse between Root Canal Completion and Crown Placement: Its Influence on the Survival of Endodontically Treated Teeth. *J Endod* [Internet]. 2016 Nov 1 [cited 2026 Jan 21];42(11):1598–603. Available from: <https://pubmed.ncbi.nlm.nih.gov/27625148/>
 18. Naumann M, Schmitter M, Frankenberger R, Krastl G. “Ferrule Comes First. Post Is Second!” Fake News and Alternative Facts? A Systematic Review. *J Endod* [Internet]. 2018 Feb 1 [cited 2026 Feb 3];44(2):212–9. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S0099239917311196>
 19. Xu M, Ren H, Liu C, Zhao X, Li X. Systematic review and meta-analysis of root morphology and canal configuration of permanent premolars using cone-beam computed tomography.

- BMC Oral Health 2024 24:1 [Internet]. 2024 Jun 4 [cited 2026 Jan 28];24(1):656-. Available from: <https://link.springer.com/article/10.1186/s12903-024-04419-y>
20. Haupt F, Wiegand A, Kanzow P. Risk Factors for and Clinical Presentations Indicative of Vertical Root Fracture in Endodontically Treated Teeth: A Systematic Review and Meta-analysis. J Endod [Internet]. 2023 Aug 1 [cited 2026 Jan 28];49(8):940–52. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S0099239923003230>
 21. Schmalz G, Widbiller M. Biocompatibility of Amalgam vs Composite - A Review. Oral Health Prev Dent [Internet]. 2022 Mar 14 [cited 2026 Jan 22];20(1):149–56. Available from: <https://pubmed.ncbi.nlm.nih.gov/35308016/>
 22. Plasmans PJJM, Creugers NHJ, Mulder J. Long-term survival of extensive amalgam restorations. J Dent Res [Internet]. 1998 [cited 2026 Jan 22];77(3):453–60. Available from: <https://pubmed.ncbi.nlm.nih.gov/9496918/>
 23. Sakaguchi RL, Ferracane J, Powers JM. Craig's Restorative Dental Materials - E-Book. Elsevier Health Sciences; 2018.
 24. J O Burgess, Richard Walker, J M Davidson. Posterior resin-based composite: review of the literature - PubMed. Pediatr Dent [Internet]. 2002 [cited 2026 Jan 22]; Available from: <https://pubmed.ncbi.nlm.nih.gov/12412962/>
 25. Kaptan Usul S, Aslan A, Lüleci HB, Ergüden B, Çöpoğlu MT, Oflaz H, et al. Investigation of antimicrobial and mechanical effects of functional nanoparticles in novel dental resin composites. J Dent [Internet]. 2022 Aug 1 [cited 2026 Jan 28];123. Available from: <https://pubmed.ncbi.nlm.nih.gov/35691455/>
 26. Sikka N, Brizuela M. Glass Ionomer Cement. StatPearls Publishing; 2025.
 27. Mas-López J, Melendez D, Tay LY. Current status of materials for posterior indirect adhesive restorations. Revista Facultad de Odontología Universidad de Antioquia [Internet]. 2025 Aug 12 [cited 2026 Jan 28];37(2):e354646–e354646. Available from: <https://revistas.udea.edu.co/index.php/odont/article/view/354646>
 28. Mas-López J, Melendez D, Tay LY. Current status of materials for posterior indirect adhesive restorations. Revista Facultad de Odontología. 2025;37(2).
 29. Söylemez Z, Doğan A. Posterior Indirect Adhesive Restorations and Preparation Designs. Current Research in Dental Sciences [Internet]. 2025 Apr 20 [cited 2026 Jan 28];35(2):169–73. Available from: <https://dergipark.org.tr/en/pub/currresdentosci/article/1677809>
 30. Yurdagüven GY, Çiftçiöğlü E, Kazokoğlu FŞ, Kayahan MB. 5-Year clinical performance of ceramic onlay and overlay restorations luted with light-cured composite resin. J Dent [Internet]. 2024 Oct 1 [cited 2026 Jan 28];149. Available from: <https://pubmed.ncbi.nlm.nih.gov/39067649/>
 31. Mannocci F, Cowie J. Restoration of endodontically treated teeth. Br Dent J [Internet]. 2014 Mar 21 [cited 2026 Jan 28];216(6):341–6. Available from: <https://pubmed.ncbi.nlm.nih.gov/24651340/>
 32. Nam SH, Chang HS, Min KS, Lee Y, Cho HW, Bae JM. Effect of the Number of Residual Walls on Fracture Resistances, Failure Patterns, and Photoelasticity of Simulated Premolars Restored with or without Fiber-reinforced Composite Posts. J Endod [Internet]. 2010 Feb [cited 2026 Jan 28];36(2):297–301. Available from: <https://pubmed.ncbi.nlm.nih.gov/20113794/>
 33. Cagidiaco MC, Radovic I, Simonetti M, Tay F, Ferrari M. Clinical performance of fiber post restorations in endodontically treated teeth: 2-year results. Int J Prosthodont [Internet]. 2007 [cited 2026 Jan 28];20(3):293–8. Available from: <https://pubmed.ncbi.nlm.nih.gov/17580463/>
 34. Mannocci F, Qualtrough AJE, Worthington H V., Watson TF, Pitt Ford TR. Randomized clinical comparison of endodontically treated teeth restored with amalgam or with fiber posts and resin composite: five-year results. Oper Dent [Internet]. 2005 Jan [cited 2026 Jan 28];30(1):9–15. Available from: <https://pubmed.ncbi.nlm.nih.gov/15765952/>
 35. Vogler JAH, Lehmann M, Rehmann P, Wöstmann B. Survival time of post and cores: A 16 year retrospective follow-up study. J Dent [Internet]. 2022 Feb 1 [cited 2026 Jan 28];117. Available

- from: <https://pubmed.ncbi.nlm.nih.gov/34953973/>
36. Giok KC, Veettill SK, Menon RK. Comparative effectiveness of fiber and metal posts in the restoration of endodontically treated teeth: A systematic review with network meta-analysis. *Journal of Prosthetic Dentistry* [Internet]. 2025 Sep 1 [cited 2026 Jan 28];134(3):597–615. Available from: <https://pubmed.ncbi.nlm.nih.gov/37827970/>
 37. Abdulrazaq LA, Ali AH, Foschi F. Minimally invasive access cavities in endodontics. *Journal of Baghdad College of Dentistry*, 35 (2) pp 65-75 (2023) [Internet]. 2023 Jun 15 [cited 2026 Jan 28];35(2):65–75. Available from: <http://dx.doi.org/10.26477/jbcd.v35i2.3406>
 38. Marvaniya J, Agarwal K, Mehta DN, Parmar N, Shyamal R, Patel J. Minimal Invasive Endodontics: A Comprehensive Narrative Review. 2022;
 39. Keir DM, Pinheiro LR, Pinheiro MCR, Cortes ARG. Digital workflow in endodontics. *Digital Dentistry: A Step-by-Step Guide and Case Atlas* [Internet]. 2022 Apr 29 [cited 2026 Jan 28];257–63. Available from: </doi/pdf/10.1002/9781119852025.ch8>
 40. Breschi L, Maravic T, Mazzitelli C, Josic U, Mancuso E, Cadenaro M, et al. The evolution of adhesive dentistry: From etch-and-rinse to universal bonding systems. *Dental Materials* [Internet]. 2025 Feb 1 [cited 2026 Jan 28];41(2):141–58. Available from: <https://www.sciencedirect.com/science/article/pii/S0109564124003397>
 41. PertekHatipoğlu F ABHÖ. Endodontik Tedavi Görmüş Dişlerde Koronal restorasyonlar. *Akademisyen Kitabevi*. 2020;25–38.
 42. Shams A, Sakrana AA, El-Farag SAA, Özcan M, Shams A. Assessment of Biomechanical Behavior of Endodontically Treated Premolar Teeth Restored with Novel Endocrown System. *Eur J Prosthodont Restor Dent* [Internet]. 2022 [cited 2026 Jan 28];30(1):20–35. Available from: <https://pubmed.ncbi.nlm.nih.gov/33934582/>
 43. Bindl A, Lüthy H, Mörmann WH. Strength and fracture pattern of monolithic CAD/CAM-generated posterior crowns. *Dental Materials*. 2006 Jan;22(1):29–36.
 44. Fages M, Raynal J, Tramini P, Cuisinier F, Durand JC. Chairside Computer-Aided Design/Computer-Aided Manufacture All-Ceramic Crown and Endocrown Restorations: A 7-Year Survival Rate Study. *Int J Prosthodont* [Internet]. 2017 Nov [cited 2026 Jan 21];30(6):556–60. Available from: <https://pubmed.ncbi.nlm.nih.gov/29084297/>
 45. Clinical performance of chairside CAD/CAM feldspathic ceramic posterior shoulder crowns and endocrowns up to 12 years - PubMed [Internet]. [cited 2026 Jan 21]. Available from: <https://pubmed.ncbi.nlm.nih.gov/26110927/>
 46. Aldabeeb DS, Alakeel NS, Al Jfshar RM, Alkhalid TK. Endocrowns: Indications, Preparation Techniques, and Material Selection. 2023;

BÖLÜM 2

ENDODONTİK RADYOLOJİ

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GİRİŞ

Dental radyoloji, diş hekimliğinde tanı koyma, tedavi planlama ve tedavi sonucunu takip edebilme açısından çok önemli bir konumdadır. Dental radyolojinin ilk çıktığı yıllarda yalnızca intraoral periapikal radyografilerle sınırlı olan kullanım günümüzde dijital radyografi, panoramik radyografi, sefalometri, konik ışınli bilgisayarlı tomografi (KIBT), manyetik rezonans görüntüleme (MR) ve ultrasonografi (USG) gibi geniş bir alana yayılmıştır (1). Bu alandaki gelişmeler sayesinde artık sadece temel endikasyonları belirlemekle sınırlı kalmayıp endodonti, implantoloji, maksillofasiyal cerrahi gibi birçok multidisipliner alanda da fayda sağlamaktadır (2). Bulut tabanlı sistemler sayesinde de görüntüler farklı disiplinler arasında kolayca paylaşılır hale gelmiştir. İki boyutlu (2D) periapikal ve panoramik radyografiler sıklıkla görüntü distorsiyonu göstermektedir. Bu sorun, üç boyutlu (3D) KIBT'nin klinik kullanıma girmesiyle büyük ölçüde çözülmüştür (3). Üç boyutlu görüntüleme teknikleri, gelişmeler sayesinde anatomik yapıları göstermekle kalmayıp ayrıca patolojilerin de bu yapılarla ilişkilerini belirlemekte ve tedavilerin sonuçlarını tahmin etmekte oldukça faydalı olmaktadır. Ancak üç boyutlu görüntülemenin artan kullanımının getirdiği radyasyon dozu ve etik sorumluluklar tartışma konusu olarak yer almaktadır (4). Güncel teknolojiler sayesinde daha düşük dozlarla daha yüksek çözünürlük elde edilmektedir. Ayrıca artefakt yönetimi, yazılım tabanlı rekonstrüksiyon teknikleri ve yapay zeka destekli karar sistemleri sayesinde tanısallık doğruluk artmaktadır (5).

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SONUÇ

KIBT, diş hekimliğinde tanısal doğruluğu arttıran üç boyutlu bilgi sağlayan bir görüntüleme yöntemidir. Ancak daha yüksek doz ve maliyet nedeniyle kullanımı yalnızca endike durumlarla sınırlı tutulmalıdır. Mikro-BT ise klinik uygulamadan çok araştırma ortamlarında değerli bir analiz aracı olarak öne çıkar (4, 25, 40).

KAYNAKLAR

1. Whaites E, Drage N. Essentials of Dental Radiography and Radiology E-Book: Essentials of Dental Radiography and Radiology E-Book: Elsevier Health Sciences; 2020.
2. Sarsam W, Davies J, Al-Salehi SK. The role of imaging in endodontics. *British Dental Journal*. 2025;238(7):448-57.
3. Antony DP, Thomas T, Nivedhitha M. Two-dimensional periapical, panoramic radiography versus three-dimensional cone-beam computed tomography in the detection of periapical lesion after endodontic treatment: A systematic review. *Cureus*. 2020;12(4).
4. Benavides E, Krecioch JR, Connolly RT, Allareddy T, Buchanan A, Spelic D, et al. Optimizing radiation safety in dentistry: clinical recommendations and regulatory considerations. *The Journal of the American Dental Association*. 2024;155(4):280-93. e4.
5. Wajer R, Dabrowski-Tumanski P, Wajer A, Kazimierczak N, Serafin Z, Kazimierczak W. Enhancing Image Quality in Dental-Maxillofacial CBCT: The Impact of Iterative Reconstruction and AI on Noise Reduction—A Systematic Review. *Journal of Clinical Medicine*. 2025;14(12):4214.
6. Yeung AWK, Wong NSM. Reject rates of radiographic images in dentomaxillofacial radiology: a literature review. *International Journal of Environmental Research and Public Health*. 2021;18(15):8076.
7. Mallya S, Lam E. White and Pharoah's oral radiology: principles and interpretation: Elsevier Health Sciences; 2018.
8. Stera G, Giusti M, Magnini A, Calistri L, Izzetti R, Nardi C. Diagnostic accuracy of periapical radiography and panoramic radiography in the detection of apical periodontitis: a systematic review and meta-analysis. *La radiologia medica*. 2024;129(11):1682-95.
9. Gupta A, Devi P, Srivastava R, Jyoti B. Intra oral periapical radiography-basics yet intrigue: A review. *Bangladesh Journal of Dental Research & Education*. 2014;4(2):83-7.
10. Kim Y, Lee S, Jo G, Kwon A, Kang J, Kim J, et al. Comparative analysis of clinical image evaluation charts for panoramic radiography. *Oral Radiology*. 2024;40(4):520-9.
11. Kweon HH-I, Lee J-H, Youk T-m, Lee B-A, Kim Y-T. Panoramic radiography can be an effective diagnostic tool adjunctive to oral examinations in the national health checkup program. *Journal of periodontal & implant science*. 2018;48(5):317-25.
12. Mupparapu M, Akintoye SO. Application of panoramic radiography in the detection of osteopenia and osteoporosis—Current state of the art. *Current Osteoporosis Reports*. 2023;21(4):354-9.
13. Gandhi JM, Govindaraju L. Evaluation of requirement of taking panoramic radiographs in children less than 6 years of age-A retrospective study. *Journal of Family Medicine and Primary Care*. 2022;11(5):2146-9.
14. Rushton V, Horner K, Worthington H. Routine panoramic radiography of new adult patients in general dental practice: relevance of diagnostic yield to treatment and identification of radiographic selection criteria. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*. 2002;93(4):488-95.
15. Lingam AS, Koppolu P, Abdulsalam R, Reddy RL, Anwarullah A, Koppolu D. Assessment of common errors and subjective quality of digital panoramic radiographs in dental institution,

- Riyadh. *Annals of African Medicine*. 2023;22(1):49-54.
16. MacDonald D, Stojkova BJ, Reitzik S. Positioning and preparation errors impacting dental panoramic radiographs in patients with mixed dentition. *Imaging Science in Dentistry*. 2024;54(4):336.
 17. Anbiaee N, Pahlavanzadeh P. Evaluation of Panoramic Radiography Diagnostic Accuracy in the Assessment of Interdental Alveolar Bone Loss Using CBCT. *Clinical and Experimental Dental Research*. 2024;10(6):e70042.
 18. Berghuis G, Cosyn J, De Bruyn H, Hommez G, Dierens M, Christiaens V. A controlled study on the diagnostic accuracy of panoramic and peri-apical radiography for detecting furcation involvement. *BMC Oral Health*. 2021;21(1):115.
 19. Turosz N, Chęcińska K, Chęciński M, Sielski M, Sikora M. Evaluation of dental panoramic radiographs by artificial intelligence compared to human reference: a diagnostic accuracy study. *Journal of Clinical Medicine*. 2024;13(22):6859.
 20. Mureşanu S, Hedeşiu M, Iacob L, Eftimie R, Olariu E, Dinu C, et al. Automating dental condition detection on panoramic radiographs: challenges, pitfalls, and opportunities. *Diagnostics*. 2024;14(20):2336.
 21. Kazimierczak W, Wajer R, Wajer A, Kalka K, Kazimierczak N, Serafin Z. Evaluating the diagnostic accuracy of an AI-driven platform for assessing endodontic treatment outcomes using panoramic radiographs: a preliminary study. *Journal of Clinical Medicine*. 2024;13(12):3401.
 22. Hennig C-L, Schüler IM, Scherbaum R, Buschek R, Scheithauer M, Jacobs C, et al. Frequency of dental X-ray diagnostics in children and adolescents: what is the radiation exposure? *Diagnostics*. 2023;13(3):394.
 23. Alshomrani F. Cone-beam computed tomography (CBCT)-based diagnosis of dental bone defects. *Diagnostics*. 2024;14(13):1404.
 24. Distefano S, Cannarozzo MG, Spagnuolo G, Bucci MB, Lo Giudice R. The “dedicated” CBCT in dentistry. *International Journal of Environmental Research and Public Health*. 2023;20(11):5954.
 25. Bromberg N, Brizuela M. Dental Cone Beam Computed Tomography. *StatPearls. Treasure Island (FL)2025*.
 26. Suomalainen A, Pakbaznejad Esmaeili E, Robinson S. Dentomaxillofacial imaging with panoramic views and cone beam CT. *Insights into imaging*. 2015;6(1):1-16.
 27. Tsuji T, Yoshida S, Hommyo M, Oyama A, Kumagai S, Shiraishi K, et al. Cone beam computed tomography image-quality improvement using “one-shot” super-resolution. *Journal of Imaging Informatics in Medicine*. 2025;38(4):2120-33.
 28. Polizzi A, Serra S, Leonardi R. Use of CBCT in orthodontics: A scoping review. *Journal of Clinical Medicine*. 2024;13(22):6941.
 29. Dogan Y, Sirin Y. Assessing oral surgery residents’ competencies and training needs in tomography interfaces through a usability framework. *BMC Medical Education*. 2025;25(1):1058.
 30. Kim N-H, Yang B-E, Kang S-H, Kim Y-H, Na J-Y, Kim J-E, et al. Preclinical and Preliminary Evaluation of Perceived Image Quality of AI-Processed Low-Dose CBCT Analysis of a Single Tooth. *Bioengineering*. 2024;11(6):576.
 31. Abesi F, Maleki M, Zamani M. Diagnostic performance of artificial intelligence using cone-beam computed tomography imaging of the oral and maxillofacial region: A scoping review and meta-analysis. *Imaging Science in Dentistry*. 2023;53(2):101.
 32. Pinto JC, de Faria Vasconcelos K, Leite AF, Wanderley VA, Pauwels R, Oliveira ML, et al. Image quality for visualization of cracks and fine endodontic structures using 10 CBCT devices with various scanning protocols and artefact conditions. *Scientific reports*. 2023;13(1):4001.
 33. Ozdede M, Akay G, Karadag Atas O, Koc EK, Yalcin O, Gungor K. Repeatability and effect of different voxel sizes on linear and volumetric tooth and pulp measurements using cone-beam computed tomography. *BMC oral health*. 2024;24(1):1472.
 34. Soltani P, Devlin H, Etemadi Sh M, Rengo C, Spagnuolo G, Baghaei K. Do metal artifact reduc-

- tion algorithms influence the detection of implant-related injuries to the inferior alveolar canal in CBCT images? *BMC Oral Health*. 2024;24(1):268.
35. Jo G-D, Park C-W, Jeon KJ, Han S-S. Quantitative evaluation of metal artifact reduction in CBCT under varying exposure modes and rod orientations. *Scientific Reports*. 2025;15(1):20645.
 36. Kazimierczak W, Kazimierczak N, Issa J, Wajer R, Wajer A, Kalka S, et al. Endodontic treatment outcomes in cone beam computed tomography Images—Assessment of the diagnostic accuracy of AI. *Journal of Clinical Medicine*. 2024;13(14):4116.
 37. Kolarkodi SH. The importance of cone-beam computed tomography in endodontic therapy: A review. *The Saudi Dental Journal*. 2023;35(7):780-4.
 38. Ren S, Wang W, Cheng M, Tang W, Zhao Y, Miao L. Guided endodontics in the application of personalized mini-invasive treatment in clinical cases: a literature review. *The Saudi Dental Journal*. 2025;37(4):20.
 39. Pai S, Edwards D, Taylor G. How effective is CBCT-guided endodontic access over 'brain-guided' accesses, and is this a likely addition to the general dental practitioner's armamentarium? *Evidence-Based Dentistry*. 2025;26(1):8-9.
 40. Lavanya A, Ali S, Tewari RK. Micro-computed tomography in endodontics. *Journal of Oral Research and Review*. 2023;15(1):80-6.
 41. Karobari MI, Batul R, Khan M, Patil SR, Basheer SN, Rezallah NNF, et al. Micro computed tomography (Micro-CT) characterization of root and root canal morphology of mandibular first premolars: a systematic review and meta-analysis. *BMC Oral Health*. 2024;24(1):1.
 42. Hristov K, Gigova R, Gateva N, Angelova L. Micro-computed tomography (micro-CT) evaluation of root canal morphology in immature maxillary third molars. *Journal of Clinical Pediatric Dentistry*. 2024;48(3).
 43. Agwan MAS, editor *Micro-Computed Tomography as a Transformative Tool in Endodontics: A Narrative Review*. *Medical Forum Monthly*; 2023.

BÖLÜM 3

PALATOGİNGİVAL OLUKLARDA TANI VE TEDAVİ: MULTİDİSİPLİNER YAKLAŞIM

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GİRİŞ

Palatogingival oluklar (PGO), dişin singulum bölgesinden başlayıp kök yüzeyi boyunca apikale doğru değişen uzunluk ve derinlikte ilerleyebilen gelişimsel anatomik anomalilerdir (1). Yıllar boyunca, bu anomaliyi tanımlamak için palatal veya damak-dişeti oluğu (2), gelişimsel radiküler anomali (3), distolingual oluk (4), radiküler lingual oluk (5), palatoradiküler oluk (6), radiküler oluk (7) ve singuloradiküler oluk (8) benzeri terimler kullanılmıştır. Klinik olarak yüzeysel bir oluk şeklinde görülebileceği gibi, derin bir invajinasyon biçiminde de karşımıza çıkabilir, bazı olgularda bifid kök ya da aksesuar kök benzeri morfolojik varyasyonlarla ilişkili olabilir (1,9). PGO'nun klinik önemi, plak retansiyon alanı oluşturarak lokalize periodontal yıkımı tetikleyebilmesi ve ileri olgularda sekonder olarak pulpanın etkilenmesi ile periapikal patoloji gelişimine zemin hazırlamasından kaynaklanır (10,11). PGO varlığında periodontal enfeksiyon apikale ilerleyerek kök kanal sistemiyle olası ileti yolları üzerinden pulpayı etkileyebileceği için endodonti açısından önemlidir (10,12). Bu nedenle PGO, açıklanamayan periapikal lezyonlar, tekrarlayan sinüs traktı veya endodontik tedavi sonrası iyileşmenin beklenenden düşük olduğu olgularda ayırıcı tanıda mutlaka değerlendirilmelidir.

PGO, literatürde düşük-orta sıklıkta bildirilen bir gelişimsel anomalidir. Mevcut çalışmalar, oranların özellikle incelenen diş grubuna göre değiştiğini göstermektedir. Everett ve arkadaşları lateral kesicilerde prevalansı %2,8 olarak bildirirken (4), Withers ve arkadaşları maksiller kesicilerde toplam oranı %2,3; lateral kesicilerde %4,4 ve santral kesicilerde %0,28 olarak rapor etmiştir (13). Daha geniş bir örnekleme Kogon ve arkadaşları, 3168 çekilmiş maksiller ön dişte PGO

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üç boyutlu değerlendirilmesi ve ayırıcı tanıda kök kırığı ile rezorptif lezyonların dışlanması yoluyla tedavi kararını doğrudan etkileyebilecek olgularda tercih edilmelidir. Radyasyon dozunun optimizasyonu açısından, olanaklı olduğunda sınırlı görüş alanı (limited FOV) protokolleri kullanılmalıdır (30). Apikale uzanım gösteren derin oluklar, karmaşık kanal morfolojisi ve periodontal–endodontik ileti olasılığındaki artış nedeniyle kombine lezyonlarla daha güçlü ilişki gösterebilir. Bu nedenle bu olgularda prognoz dikkatlice ele alınmalı ve tedavi planı endodonti ile periodontolojinin birlikte olduğu multidisipliner bir yaklaşımla oluşturulmalıdır (11,23). Bununla birlikte, mevcut kanıtların önemli kısmı retrospektif KIBT çalışmalarına dayandığından, morfolojiye göre standardize edilmiş prospektif sonuç çalışmalarına ihtiyaç devam etmektedir (20,29).

SONUÇ

Palatogingival oluklu dişlerde tedavi başarısı, olgunun yalnızca “endo” ya da “perio” ekseninde değerlendirilmesiyle değil, oluğun morfolojik özelliklerinin doğru analiz edilmesi, KIBT ile desteklenen ayrıntılı tanısal planlama ve disiplinler arası tedavi koordinasyonunun birlikte yürütülmesiyle sağlanır. Nadir görülmelerine rağmen (Maksiller lateral kesici dişlerde 2%), PGO’nun değişken anatomisi ve heterojen klinik yansımaları yönetimi güçleştirmektedir. Bu durum, lezyon tipine ve doku durumuna uyarlanmış tedavi stratejilerini gerekli kılmaktadır. Klinik hedef, periodontal ve endodontik komplikasyon riskini azaltıp, uzun dönem doku sağlığını ve fonksiyonel sürekliliğini korumaktır. PGO yönetiminde klinik başarı, morfolojik olarak yapılan risk sınıflaması, KIBT ile desteklenmiş hedefe yönelik tanılama ve endodonti–periodontoloji işbirliğini içeren kişiye göre oluşturulan tedavi planı ile artar.

KAYNAKLAR

1. Schwartz SA, Koch MA, Deas DE, Powell CA. Combined Endodontic-Periodontic Treatment of a Palatal Groove: A Case Report. *J Endod.* 2006 Jun 1;32(6):573–8.
2. Simon J, Glick D. Predictable endodontic and periodontic failures as a result of radicular anomalies. *Oral Surg Oral Med Oral Pathol.* 31 (1971), pp. 823-826
3. Everett F. The disto-lingual groove in the maxillary lateral incisor; a periodontal hazard. 1972 Jun ;43(6):352–61.
4. D.S. August The radicular lingual groove: an overlooked differential diagnosis. *J Am Dent Assoc,* 96 (1978), pp. 1037-1039
5. Kogon S L. The prevalence, location and conformation of palato-radicular grooves in maxillary incisors. 1986 Apr;57(4):231–4.
6. Pecora J D. Study of the Incidence of Radicular Grooves in Maxillary. *Braz Dent J.* 1992;3(1):11-6.
7. Assaf M. The cingulo-radicular groove: its significance and management--two case report. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1370000/>

- ps://pubmed.ncbi.nlm.nih.gov/1521267/
8. Aksoy U, Kermeoğlu F, Kalender A, Eren H, Kolsuz ME, Orhan K. Cone-beam computed tomography evaluation of palatogingival grooves: a retrospective study with literature review. *Oral Radiology* 2017 33:3. 2017 May 3;33(3):193–8.
 9. Arslan H, Ertas ET, Topçuoğlu HS, Şekerci AE, Atici MY, Ertas H, et al. Radicular grooves of maxillary anterior teeth in a Turkish population: A cone-beam computed tomographic study. *Arch Oral Biol*. 2014 Mar 1;59(3):297–301.
 10. Kim HJ, Choi Y, Yu MK, Lee KW, Min KS. Recognition and management of palatogingival groove for tooth survival: a literature review. *Restor Dent Endod*. 2017;42(2):77.
 11. Zhang R, Xiong J, Haapasalo M, Shen Y, Meng L. Palatogingival grooves associated with periodontal bone Loss of maxillary incisors in a Chinese population. *Aust Endod J*. 2022 Aug 1;48(2):313–21
 12. Gu YC. A Micro-Computed Tomographic Analysis of Maxillary Lateral Incisors with Radicular Grooves. *J Endod*. 2011 Jun 1 ;37(6):789–92.
 13. Withers JA, Brunsvold MA, Killoy WJ, Rahe AJ. The relationship of palato-gingival grooves to localized periodontal disease. Wiley Online Library|JA Withers, MA Brunsvold, WJ Killoy, AJ Rahe. *Journal of Periodontology*. 1981 Jan;52(1):41–4.
 14. Mazzi-Chaves, GB Leoni, JS Oliveira, YTC Silva-Sousa, RG Silva, R Pauwels. Brazilian oral research, *Braz Oral Res*. 2022 Jan 14;36:e005.
 15. Aljuailan AI, Aljuailan R, Gaikwad RN, Kolarkodi SH, Alamri NR. Prevalence of palatogingival groove affecting maxillary anterior teeth in Saudi subpopulation: A cone-beam computed tomographic study with literature review. *Saudi Dent J*. 2023 Dec 1;35(8):1039–47.
 16. Lekshmi MS, Sharma S, Gupta SR, Sharma S, Kumar V, Chawla A, et al. Prevalence and radiological characteristics of palatogingival groove: A retrospective cone-beam computed tomography study in an Indian cohort. *Journal of Conservative Dentistry*. 2021 Jul 1;24(4):359–63.
 17. Yildirim DP, Goker Kamali S. Prevalence of palatogingival groove and its association with periapical lesions and periodontal bone loss: a cone beam computed tomography study. *BMC Oral Health*. 2025 Dec 1;25(1).
 18. Alkahtany SM, Alrwais F, Altamimi A, Bukhary SM, Mirdad A. The incidence of radicular groove on maxillary lateral incisors of Saudi population: CBCT evaluation. *BMC Oral Health*. 2022 Dec 1;22(1).
 19. Li H, Tai Z, Dong J, Song Z. A classification of radicular grooves from the perspective of periodontology. *BMC Oral Health* 2025 25:1. 2025 Oct 6;25(1):1530-.
 20. Leuke Bandara D, Gunasena C, Jayasinghe RD. Cone-beam CT evaluation of palato-gingival grooves and associated periodontal bone loss in maxillary anterior teeth: Evidence from a Sri Lankan cohort. *Ceylon Journal of Science*. 2026 Jan 5;55(1):55–61.
 21. Sharma S, Deepak P, Vivek S, Dutta SR. Palatogingival Groove: Recognizing and Managing the Hidden Tract in a Maxillary Incisor: A Case Report. *J Int Oral Health*. 2015 Jun;7(6):110.
 22. Pinheiro TN, Cintra LTA, Azuma MM, Benetti F, Silva CC, Consolaro A. Palatogingival groove and root canal instrumentation. *Int Endod J*. 2020 May;53(5):660–70.
 23. Gaudex Y, Gandillot V, Fontanille I, Bouchard P, Kerner S, Carra MC. Palatal groove associated with periodontal lesions: a systematic review illustrated by a decisional tree for management. *BMC Oral Health* 2024 24:1. 2024 Sep 4;24(1):1037-.
 24. Ansari I, Miglani S, Yadav V, Hasan S. Management of Palatogingival Groove in Maxillary Lateral Incisor: A Report of a Rare Case With a Brief Review of Literature. *Cureus*. 2023 Oct 4 ;15(10).
 25. Ghahramani Y, Haghighi BS, Abbaszadegan A, Shahidi S. Cone-beam computed tomographic evaluation of radicular grooves in maxillary anterior teeth in a selected Iranian population. *Iran Endod J*. 2018;13(4):503–7.
 26. Reddy R, Venkatesha G, Mohan KR, Fenn M, Gokulraj S, Appusamy K. A Three-Dimensional Assessment of a Type I Shallow Palatogingival Groove by Cone Beam Computed Tomography:

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- A Case Report. *Cureus*. 2024 May 7;16(5):e59835.
27. Tan X, Zhang L, Zhou W, Li Y, Ning J, Chen X, et al. Palatal Radicular Groove Morphology of the Maxillary Incisors: A Case Series Report. *J Endod*. 2017 May 1;43(5):827–33.
 28. Giner-Lluesma T, Micó-Muñoz P, Prada I, Micó-Martínez P, Collado-Castellanos N, Manzano-Saiz A, et al. Role of cone-beam computed tomography (CBCT) in diagnosis and treatment planning of two-rooted maxillary lateral incisor with palatogingival groove. Case report. *J Clin Exp Dent*. 2020;12(7): e704–7.
 29. González OL, Salas Orozco MF, Marín NP, Abbott P V., Garcia-Font M, Sans FA. Prevalence of Palatal Grooves on Maxillary Anterior Teeth Using Cone-beam Computed Tomography: A Systematic Review and Meta-Analysis. *J Endod*. 2026 Jan 1.2026;52(1):14-23. e3.
 30. Patel S, Brown J, Semper M, Abella F, Mannocci F. European Society of Endodontology position statement: Use of cone beam computed tomography in Endodontics: European Society of Endodontology (ESE) developed by: *Int Endod J*. 2019 Dec 1 ;52(12):1675–8.
 31. Attam K, Tiwary R, Talwar S. Palatogingival groove: endodontic-periodontal management—case report. *Journal of endodontics*. *J Endod*. 2010 Oct;36(10):1717-20.
 32. Anderegg CR, Metzler DG. Treatment of the Palato-Gingival Groove with Guided Tissue Regeneration. Report of 10 Cases. *J Periodontol* 1993 Jan 1;64(1):72–4.
 33. Johns D, Shivashankar V, Shobha K, Johns M. An innovative approach in the management of palatogingival groove using Biodentine™ and platelet-rich fibrin membrane. *J Conserv Dent*. 2014 Jan;17(1):75–9.
 34. Yan H, Xu N, Wang H, Yu Q. Intentional Replantation with a 2-segment Restoration Method to Treat Severe Palatogingival Grooves in the Maxillary Lateral Incisor: A Report of 3 Cases. *J Endod*. 2019 Dec 1;45(12):1543–9.

BÖLÜM 4

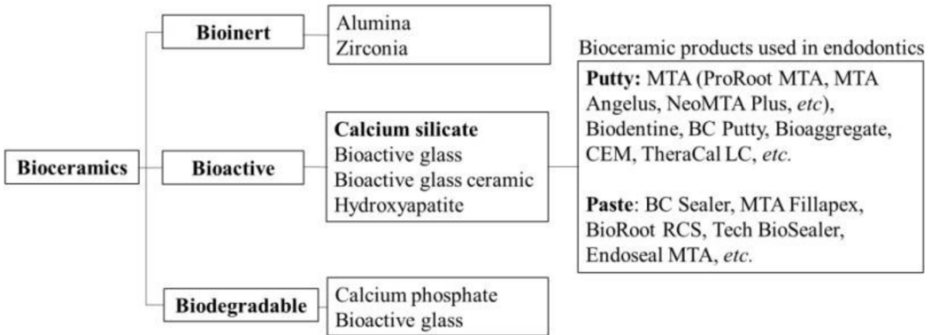
ENDODONTİDE KULLANILAN KALSİYUM SİLİKAT ESASLI BİYOMATERYALLERİN KLİNİK GERÇEKLİĞİ

Medine ÇİÇEK¹

GİRİŞ

Dünya Sağlık Örgütü düzenli ağız bakımını önermesine rağmen, tedavi edilmiş diş çürüklerinin küresel yükü hala yüksektir (1). Tedavi edilmeyen çürükler pulpitise ve periapikal periodontitise yol açmaktadır. Periapikal periodontitis yaygın bir hastalıktır ve endodontik tedavi, yara iyileşmesini teşvik etmenin en etkili yoludur. Ancak tedavinin başarısı, kullanılan yöntem ve materyallere bağlı olarak değişmektedir. Materyal biliminin gelişmesiyle kalsiyum silikat esaslı biyomateriyaller endodontik tedavide kullanılmaya başlanmıştır (1,2).

1990'lı yılların başlarında, yeni bir diş materyal grubu olarak endodonti alanında tanıtılan biyoseramikler, alümina, zirkonya, biyoaktif cam, cam seramik, hidroksiapatit, kalsiyum silikat ve kalsiyum fosfat dahil olmak üzere biyoyumlu seramik malzemeler veya metal oksitler olarak bilinmektedir (3). Çevre dokularla reaktivitelerine göre biyo inert, biyoaktif ve biyolojik olarak parçalanabilir materyaller olmak üzere 3 grupta sınıflandırılabilir (Şekil 1) (3).



Şekil 1: Biyoseramiklerin sınıflandırılması.

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KAYNAKLAR

1. Kassebaum NJ, Bernabé E, Dahiya M, et al. Global burden of untreated caries: a systematic review and metaregression. *Journal of Dental Research*. 2015;94(5):650-658. doi:10.1177/0022034515573272
2. Wang X, Xiao Y, Song W, et al. Clinical application of calcium silicate-based bioceramics in endodontics. *Journal of Translational Medicine*. 2023;21(1):853. doi:10.1186/s12967-023-04550-4
3. Dong X, Xu X. Bioceramics in Endodontics: Updates and Future Perspectives. *Bioengineering*. 2023;10(3):354. doi:10.3390/bioengineering10030354
4. Gangishetti S, Kolluri A, Raj KA, et al. Bioactivity of Calcium Silicate-Based Endodontic Materials: A Comparative in vitro Evaluation. *Journal of Pharmacy and Bioallied Sciences*. 2024;16(Suppl 2):S1716-S1720. doi: 10.4103/jpbs.jpbs_959_23
5. Hotta M, Li Y, Sekine I. Mineralization in bovine dentin adjacent to glass-ionomer restorations. *Journal of Dentistry*. 2001;29:211-5.
6. Ürkmez EŞ, Pınar AE. Bioactivity evaluation of calcium silicate-based endodontic materials used for apexification. *Australian Endodontic Journal*. 2020;46(1):60-67. doi: 10.1111/aej.12367
7. Parirokh M, Torabinejad M, Dummer PMH. Mineral trioxide aggregate and other bioactive endodontic cements: an updated overview - part I: vital pulp therapy. *International Endodontic Journal*. 2018;51(2):177-205.
8. Küçükçaya S, Görduysus MÖ, Zeybek ND, et al. In Vitro Cytotoxicity of Calcium Silicate-Based Endodontic Cement as Root-End Filling Materials. *Scientifica*. 2016;2016:9203932. doi: 10.1155/2016/9203932
9. Şimşek E, Akbulut MB. Physicochemical and Biological Properties of Current Calcium Silicate Based Root Repair Materials. *Türkiye Klinikleri Dişhekimliği Bilimleri Dergisi*. 2021;27(1): 117-128.
10. Raghavendra SS, Jadhav GR, Gathani KM, et al. Bioceramics in endodontics - a review. *Journal of Istanbul University Faculty of Dentistry*. 2017;51(3 Suppl 1):S128-S137. doi: 10.17096/jiufd.63659
11. Song JS, Mante FK, Romanow WJ, et al. Chemical analysis of powder and set forms of Portland cement, gray ProRoot MTA, white ProRoot MTA, and gray MTA-Angelus. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology*. 2006;102(6):809-15.
12. Malhotra N, Agarwal A, Mala K. Mineral trioxide aggregate: a review of physical properties. *Compendium of Continuing Education in Dentistry*. 2013;34(2):e25-32.
13. Song W, Sun W, Chen L, et al. In vivo Biocompatibility and Bioactivity of Calcium Silicate-Based Bioceramics in Endodontics. *Frontiers in Bioengineering and Biotechnology*. 2020;8:580954. doi: 10.3389/fbioe.2020.580954
14. Haglund R, He J, Jarvis J, et al. Effects of root-end filling materials on fibroblasts and macrophages in vitro. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology*. 2003;95(6):739-45.
15. Atabek D, Sillelioğlu H, Olmez A. Bond strength of adhesive systems to mineral trioxide aggregate with different time intervals. *Journal of Endodontics*. 2012;38(9):1288-92.
16. Yesilyurt C, Yildirim T, Taşdemir T, et al. Shear bond strength of conventional glass ionomer cements bound to mineral trioxide aggregate. *Journal of Endodontics*. 2009;35(10):1381-3.
17. Guven Y, Tuna EB, Dincol ME, et al. Long-Term Fracture Resistance of Simulated Immature Teeth Filled with Various Calcium Silicate-Based Materials. *BioMed Research International*. 2016;2016:2863817. doi: 10.1155/2016/2863817
18. El Sayed M, Saeed M. In vitro comparative study of sealing ability of Diadent BioAggregate and other root-end filling materials. *Journal of Conservative Dentistry*. 2012;15(3):249-52.
19. Song W, Li S, Tang Q, et al. In vitro biocompatibility and bioactivity of calcium silicatebased bioceramics in endodontics (Review). *International Journal of Molecular Medicine*. 2021;48(1):128. doi: 10.3892/ijmm.2021.4961

20. Ma J, Shen Y, Stojicic S, et al. Biocompatibility of two novel root repair materials. *Journal of Endodontics*. 2011;37(6):793-8. doi: 10.1016/j.joen.2011.02.029
21. Shi S, Bao ZF, Liu Y, et al. Comparison of in vivo dental pulp responses to capping with iRoot BP Plus and mineral trioxide aggregate. *International Endodontic Journal*. 2016;49(2):154-60. doi: 10.1111/iej.12439
22. Dawood AE, Parashos P, Wong RHK, et al. Calcium silicate-based cements: composition, properties, and clinical applications. *Journal of Investigative and Clinical Dentistry*. 2017;8(2). doi: 10.1111/jicd.12195
23. Ayatollahi F, Tabrizzadeh M, Zare BF, et al. Comparison of Marginal Adaptation of MTA and CEM Cement Apical Plugs in Three Different Media. *Iranian Endodontic Journal*. 2016;11(4):332-335. doi: 10.22037/iej.2016.15
24. Asgary S, Akbari KF, Taheri S. Evaluation of antimicrobial effect of MTA, calcium hydroxide, and CEM cement. *Iranian Endodontic Journal*. 2007;2(3):105-9.
25. Asgary S, Parirokh M, Eghbal MJ, et al. SEM evaluation of pulp reaction to different pulp capping materials in dog's teeth. *Iranian Endodontic Journal*. 2006;1(4):117-23.
26. Qureshi A, Soujanya E, Nandakumar, et al. Recent advances in pulp capping materials: an overview. *Journal of Clinical and Diagnostic Research*. 2014;8(1):316-21. doi: 10.7860/JCDR/2014/7719.3980
27. Poggio C, Lombardini M, Colombo M, et al. Solubility and pH of direct pulp capping materials: a comparative study. *Journal of Applied Biomaterials and Functional Materials*. 2015;13(2):e181-5. doi: 10.5301/jabfm.5000230
28. Meraji N, Camilleri J. Bonding over Dentin Replacement Materials. *Journal of Endodontics*. 2017;43(8):1343-1349. doi: 10.1016/j.joen.2017.03.025
29. Poggio C, Arciola CR, Beltrami R, et al. Cytocompatibility and antibacterial properties of capping materials. *The Scientific World Journal*. 2014;2014:181945. doi: 10.1155/2014/181945
30. Rodríguez-Lozano FJ, López-García S, García-Bernal D, et al. Cytocompatibility and bioactive properties of the new dual-curing resin-modified calcium silicate-based material for vital pulp therapy. *Clinical Oral Investigations*. 2021;25(8):5009-5024. doi: 10.1007/s00784-021-03811-0
31. Murata K, Washio A, Morotomi T, et al. Physicochemical Properties, Cytocompatibility, and Biocompatibility of a Bioactive Glass Based Retrograde Filling Material. *Nanomaterials (Basel)*. 2021;11(7):1828. doi: 10.3390/nano11071828
32. Ree MH, Schwartz RS. Long-term Success of Nonvital, Immature Permanent Incisors Treated With a Mineral Trioxide Aggregate Plug and Adhesive Restorations: A Case Series from a Private Endodontic Practice. *Journal of Endodontics*. 2017;43(8):1370-1377. doi: 10.1016/j.joen.2017.02.017
33. von Arx T, Jensen SS, Janner SFM, et al. A 10-year Follow-up Study of 119 Teeth Treated with Apical Surgery and Root-end Filling with Mineral Trioxide Aggregate. *Journal of Endodontics*. 2019;45(4):394-401. doi: 10.1016/j.joen.2018.12.015
34. Uğur AZ, Toptaş O, Göller BD, et al. Effects of root-end filling on the fractal dimension of the periapical bone after periapical surgery: retrospective study. *Clinical Oral Investigations*. 2019;23(9):3645-3651. doi: 10.1007/s00784-019-02967-0
35. Paños-Crespo A, Sánchez-Torres A, Gay-Escoda C. Retrograde filling material in periapical surgery: a systematic review. *Medicina Oral Patología Oral y Cirugía Bucal*. 2021;26(4):e422-e429. doi: 10.4317/medoral.24262
36. Abusrewil SM, McLean W, Scott JA. The use of Bioceramics as root-end filling materials in periradicular surgery: A literature review. *Saudi Dental Journal*. 2018;30(4):273-282. doi: 10.1016/j.sdentj.2018.07.004
37. Shinbori N, Grama AM, Patel Y, et al. Clinical outcome of endodontic microsurgery that uses EndoSequence BC root repair material as the root-end filling material. *Journal of Endodontics*. 2015;41(5):607-12. doi: 10.1016/j.joen.2014.12.028
38. von Arx T, Janner SFM, Haenni S, et al. Bioceramic root repair material (BCRRM) for ro-

- ot-end obturation in apical surgery. An analysis of 174 teeth after 1 year. *Swiss Dental Journal*. 2020;130(5):390-396. doi: 10.61872/sdj-2020-05-644
39. Becker BD. Intentional Replantation Techniques: A Critical Review. *Journal of Endodontics*. 2018;44(1):14-21. doi: 10.1016/j.joen.2017.08.002
 40. Jang Y, Lee SJ, Yoon TC, et al. Survival Rate of Teeth with a C-shaped Canal after Intentional Replantation: A Study of 41 Cases for up to 11 Years. *Journal of Endodontics*. 2016;42(9):1320-5. doi: 10.1016/j.joen.2016.05.010
 41. Asgary S, Talebzadeh B. Intentional replantation of a molar with several endodontic complications. *Journal of Stomatology Oral and Maxillofacial Surgery*. 2019;120(5):489-492. doi: 10.1016/j.jormas.2018.11.019
 42. Liu M, He L, Wang H, et al. Comparison of in vitro biocompatibility and antibacterial activity of two calcium silicate-based materials *Journal of Materials Science: Materials in Medicine*. 2021;32(5):52. doi: 10.1007/s10856-021-06523-9
 43. Girish K, Mandava J, Chandra RR, et al. Effect of obturating materials on fracture resistance of simulated immature teeth. *Journal of Conservative Dentistry*. 2017;20(2):115-119. doi: 10.4103/0972-0707.212238
 44. Luczaj-Cepowicz E, Marczuk-Kolada G, Pawinska M, et al. Direct Pulp Capping in Primary Molars using Mineral Trioxide Aggregate: An in Vivo Study. *Journal of Clinical Pediatric Dentistry*. 2017;41(6):446-449. doi: 10.17796/1053-4628-41.6.5
 45. Katge FA, Patil DP. Comparative Analysis of 2 Calcium Silicate-based Cements (Biodentine and Mineral Trioxide Aggregate) as Direct Pulp-capping Agent in Young Permanent Molars: A Split Mouth Study. *Journal of Endodontics*. 2017;43(4):507-513. doi: 10.1016/j.joen.2016.11.026
 46. Hoseinifar R, Eskandarizadeh A, Parirokh M, et al. Histological evaluation of human pulp response to direct pulp capping with MTA, CEM cement, and biodentine. *Journal of Dentistry*. 2020;21(3):177.
 47. Abdul MSM, Murali N, Rai P, et al. Clinico-Histological Evaluation of Dentino-Pulpal Complex of Direct Pulp Capping Agents: A Clinical Study. *ournal of Pharmacy and Bioallied Sciences*. 2021;13(1):S194-S198. doi: 10.4103/jpbs.JPBS_665_20
 48. Liu SY, Gong WY, Liu MQ, et al. Clinical efficacy observation of direct pulp capping using iRoot BP Plus therapy in mature permanent teeth with carious pulp exposure. *Zhonghua Kou Qiang Yi Xue Za Zhi*. 2020;55(12):945-951. doi: 10.3760/cma.j.cn112144-20200327-00173
 49. Bakhurji E. Mineral Trioxide Aggregate Could Have a Better Success Rate Than Calcium Hydroxide for Partial Pulpotomy of Symptomatic Mature Permanent Molars. *ournal of Evidence-Based Dental Practice*. 2020;20(1):101341. doi: 10.1016/j.jebdp.2019.101341
 50. Tran XV, Ngo LTQ, Boukpepsi T. Biodentine™ Full Pulpotomy in Mature Permanent Teeth with Irreversible Pulpitis and Apical Periodontitis. *Healthcare (Basel)*. 2021;9(6):720. doi: 10.3390/healthcare9060720
 51. Çelik BN, Mutluay MS, Arıkan V, et al. The evaluation of MTA and Biodentine as a pulpotomy materials for carious exposures in primary teeth. *Clinical Oral Investigations*. 2019;23(2):661-666. doi: 10.1007/s00784-018-2472-4
 52. Taha NA, Abdelkader SZ. Outcome of full pulpotomy using Biodentine in adult patients with symptoms indicative of irreversible pulpitis *International Endodontic Journal*. 2018 Aug;51(8):819-828. doi: 10.1111/iej.12903
 53. Guan X, Zhou Y, Yang Q, et al. Vital Pulp Therapy in Permanent Teeth with Irreversible Pulpitis Caused by Caries: A Prospective Cohort Study. *Journal of Personalized Medicine*. 2021;11(11):1125. doi: 10.3390/jpm11111125
 54. Xie Y, Lu F, Hong Y, et al. Revascularisation versus apexification for treatment of immature teeth based on periapical healing and root development: A systematic review and meta-analysis. *European Journal of Paediatric Dentistry*. 2021;22(3):207-214. doi: 10.23804/ejpd.2021.22.03.6
 55. Chung H, Kim M, Yang W, et al. An interesting healing outcome of a replanted immature permanent tooth: a case report. *Dental Traumatology*. 2011;27(1):77-80. doi: 10.1111/j.1600-

- 9657.2010.00940.x
56. Yadav P, Pruthi PJ, Naval RR, et al. Novel use of platelet-rich fibrin matrix and MTA as an apical barrier in the management of a failed revascularization case. *Dental Traumatology*. 2015;31(4):328-31. doi: 10.1111/edt.12168
 57. Demiriz L, Hazar BE. Retrospective evaluation of healing of periapical lesions after unintentional extrusion of mineral trioxide aggregate. *Journal of Applied Biomaterials & Functional Materials*. 2017;15(4):e382-e386. doi: 10.5301/jabfm.5000359
 58. Santos JM, Diogo P, Dias S, et al. Long-Term Outcome of Nonvital Immature Permanent Teeth Treated With Apexification and Corono-Radicular Adhesive Restoration: A Case Series. *Journal of Endodontics*. 2022;48(9):1191-1199. doi: 10.1016/j.joen.2022.06.007
 59. Sharma S, Sharma V, Passi D, et al. Large Periapical or Cystic Lesions in Association with Roots Having Open Apices Managed Nonsurgically Using 1-step Apexification Based on Platelet-rich Fibrin Matrix and Biodentine Apical Barrier: A Case Series. *Journal of Endodontics*. 2018;44(1):179-185. doi: 10.1016/j.joen.2017.08.036
 60. El Ashiry EA, Farsi NM, Abuzeid ST, et al. Dental Pulp Revascularization of Necrotic Permanent Teeth with Immature Apices. *Journal of Clinical Pediatric Dentistry*. 2016;40(5):361-6. doi: 10.17796/1053-4628-40.5.361
 61. John A, Hegde AM, Shetty P, et al. Revascularization of an Immature Permanent Central Incisor with Complicated Crown Root Fracture: A Case Report. *International Journal of Clinical Pediatric Dentistry*. 2019;12(1):59-63. doi: 10.5005/jp-journals-10005-1574
 62. Chung SY, Kim YH, Chae YK, et al. Void characteristics and tortuosity of calcium silicate-based cements for regenerative endodontics: a micro-computed tomography analysis. *BMC Oral Health*. 2021;21(1):565. doi: 10.1186/s12903-021-01940-2
 63. Wattanapakkavong K, Srisuwan T. Release of Transforming Growth Factor Beta 1 from Human Tooth Dentin after Application of Either ProRoot MTA or Biodentine as a Coronal Barrier. *Journal of Endodontics*. 2019;45(6):701-705. doi: 10.1016/j.joen.2019.03.011
 64. Bukhari S, Kohli MR, Setzer F, et al. Outcome of Revascularization Procedure: A Retrospective Case Series. *Journal of Endodontics*. 2016;42(12):1752-1759. doi: 10.1016/j.joen.2016.06.021
 65. Saed SM, Ashley MP, Darcey J. Root perforations: aetiology, management strategies and outcomes. The hole truth. *British Dental Journal*. 2016;220(4):171-80. doi: 10.1038/sj.bdj.2016.132
 66. Gorni FG, Andreano A, Ambrogi F, et al. Patient and Clinical Characteristics Associated with Primary Healing of Iatrogenic Perforations after Root Canal Treatment: Results of a Long-term Italian Study. *Journal of Endodontics*. 2016;42(2):211-5. doi: 10.1016/j.joen.2015.11.006
 67. Borkar S, de Noronha de Ataide I. Management of a massive resorptive lesion with multiple perforations in a molar: case report. *Journal of Endodontics*. 2015;41(5):753-8. doi: 10.1016/j.joen.2014.12.022.
 68. Mohan D, Singh AK, Kuriakose F, et al. Evaluation of Sealing Potential of Different Repair Materials in Furcation Perforations Using Dye Penetration: An *In Vitro* Study. *Journal of Contemporary Dental Practice*. 2021;22(1):80-83.
 69. Aslan T, Esim E, Üstün Y, et al. Evaluation of Stress Distributions in Mandibular Molar Teeth with Different Iatrogenic Root Perforations Repaired with Biodentine or Mineral Trioxide Aggregate: A Finite Element Analysis Study. *Journal of Endodontics*. 2021;47(4):631-640. doi: 10.1016/j.joen.2020.11.018.
 70. Wang M, Yin S, Wang Q, et al. Study of molar furcal perforation repaired with iRoot BP. *Hua Xi Kou Qiang Yi Xue Za Zhi*. 2013;31(3):257-259.
 71. Aminov L, Moscalu M, Melian A, et al. Clinical-radiological study on the role of biostimulating materials in iatrogenic furcation lesions. *Revista Medico-Chirurgicala a Societatii de Medici si Naturalisti din Iasi*. 2012;116(3):907-13.
 72. Miao H, Chen M, Otgonbayar T, et al. Papillary reconstruction and guided tissue regeneration for combined periodontal-endodontic lesions caused by palatogingival groove and additional root: a case report. *Clinical Case Reports*. 2015;3(12):1042-9. doi: 10.1002/ccr3.441

73. Arnold M. Reparative Endodontic Treatment of a Perforating Internal Inflammatory Root Resorption: A Case Report. *Journal of Endodontics*. 2021;47(1):146-155. doi: 10.1016/j.joen.2020.09.022
74. Khalil WA, Alghamdi F, Aljahdali E. Strengthening effect of bioceramic cement when used to repair simulated internal resorption cavities in endodontically treated teeth. *Dental and Medical Problems*. 2020;57(2):165-169. doi: 10.17219/dmp/116743
75. Karypidou A, Chatzinikolaou ID, Kouros P, et al. Management of bilateral invasive cervical resorption lesions in maxillary incisors using a novel calcium silicate-based cement: A case report. *Quintessence International*. 2016;47(8):637-42. doi: 10.3290/j.qi.a36385
76. Nosrat A, Nekoofar MH, Bolhari B, et al. Unintentional extrusion of mineral trioxide aggregate: a report of three cases. *International Endodontic Journal*. 2012;45(12):1165-76. doi: 10.1111/j.1365-2591.2012.02082.x
77. Asgary S, Fayazi S. Endodontic Surgery of a Symptomatic Overfilled MTA Apical Plug: A Histological and Clinical Case Report. *Iranian Endodontic Journal*. 2017;12(3):376-380. doi: 10.22037/iej.v12i3.17689
78. Tahan E, Celik D, Er K, et al. Effect of unintentionally extruded mineral trioxide aggregate in treatment of tooth with periradicular lesion: a case report. *Journal of Endodontics*. 2010;36(4):760-3. doi: 10.1016/j.joen.2009.11.026
79. Nagmode PS, Satpute AB, Patel AV, et al. The Effect of Mineral Trioxide Aggregate on the Peri-apical Tissues after Unintentional Extrusion beyond the Apical Foramen. *Case Reports in Dentistry*. 2016;2016:3590680. doi: 10.1155/2016/3590680
80. da Silva EJNL, Versiani MA. The paradox of calcium silicate-based sealers: a reflection on bio-activity, solubility and clinical meaning. *International Endodontic Journal*. 2025. doi: 10.1111/iej.70083



BÖLÜM 5

ENDODONTİDE KIRIK ALET YÖNETİMİ: KLİNİK DEĞERLENDİRME, KARAR VERME SÜRECİ VE TEDAVİ SEÇENEKLERİ

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GİRİŞ

Kök kanal tedavisi sırasında endodontik alet kırığı, her düzeyde klinisyenin karşılaşılabileceği, tedavinin seyrini ve prognozunu doğrudan etkileyen önemli bir iatrojenik komplikasyondur. Gelişen nikel-titanyum (NiTi) döner sistemlere, artan klinik deneyime ve modern görüntüleme olanaklarına rağmen, kırık alet insidansı tamamen ortadan kalkmamış; aksine daha karmaşık kanal anatomilerinin tedavi edilmesiyle birlikte klinik karar verme sürecini zorlaştıran bir sorun olarak varlığını sürdürmüştür. Kırık aletin varlığı, yalnızca mekanik bir engel değil; aynı zamanda kanal dezenfeksiyonunun etkinliği, periapikal iyileşme potansiyeli ve dişin uzun dönem prognozu üzerinde belirleyici biyolojik sonuçlar doğurabilen çok boyutlu klinik bir durumdur.

Kırık aletle karşılaşıldığında klinisyenin temel sorusu çoğu zaman “nasıl çıkarılacağı” olsa da asıl kritik nokta “çıkarılmasının gerçekten gerekli olup olmadığı”dır. Kırık aletin kanal içindeki konumu, kanal anatomisi ve eğriliği, çevre dentin kalınlığı, pulpal ve periapikal dokuların durumu, dişin restoratif olarak korunabilirliği ve olası iatrojenik riskler; bu kararın verilmesinde birlikte değerlendirilmesi gereken temel unsurlardır. Plansız ve agresif çıkarma girişimleri, perforasyon, aşırı dentin kaybı, kök fraktürü veya ikinci bir alet kırığı gibi geri dönüşü olmayan komplikasyonlara yol açabilirken; uygun şekilde seçilmiş konservatif yaklaşımlar, kırık aletin varlığına rağmen uzun dönem klinik başarıyı mümkün kılabilmektedir.

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Kırık aletin kök yüzeyine çok yakın olduğu veya dış konkaviteyle komşu olduğu durumlarda perforasyon riski belirgin şekilde artar ve konservatif olarak kırık aletin çıkarılması mümkün olmayabilir. Bu gibi durumlarda cerrahi olmayan kırık alet çıkarma teknikleri yerine cerrahi müdahale, kasıtlı replantasyon veya çekim daha düşük riskli seçenekler olabilir (40). Ayrıca, vital ya da enfekte olmayan kanallarda kırık aletin çıkarılmasının prognozu anlamlı şekilde iyileştirmediği durumlarda kırık aletin kanalda bırakılması, tedavi açısından kabul edilebilir bir yaklaşım olarak değerlendirilmektedir (25). Bu yaklaşım özellikle genç hastalarda ve kanal dezenfeksiyonunun büyük oranda sağlandığı vital dişlerde tercih edilebilir.

KAYNAKLAR

1. McGuigan MB, Louca C, Duncan HF. Endodontic instrument fracture: causes and prevention. *Br Dent J.* 2013 Apr;214(7):341–8.
2. Madarati AA, Hunter MJ, Dummer PMH. Management of Intracanal Separated Instruments. *J Endod.* 2013 May;39(5):569–81.
3. Shemesh H, Roeleveld AC, Wesselink PR, Wu MK. Damage to Root Dentin During Retreatment Procedures. *J Endod.* 2011 Jan;37(1):63–6.
4. Ward JR, Parashos P, Messer HH. Evaluation of an ultrasonic technique to remove fractured rotary nickel-titanium endodontic instruments from root canals: an experimental study. *J Endod.* 2003 Nov;29(11):756–63.
5. Wu J, Lei G, Yan M, Yu Y, Yu J, Zhang G. Instrument separation analysis of multi-used ProTaper Universal rotary system during root canal therapy. *J Endod.* 2011 Jun;37(6):758–63.
6. Farid H, Khan FR, Rahman M. ProTaper rotary instrument fracture during root canal preparation: a comparison between rotary and hybrid techniques. *Oral Health Dent Manag.* 2013 Mar;12(1):50–5.
7. Cujé J, Bargholz C, Hülsmann M. The outcome of retained instrument removal in a specialist practice. *Int Endod J.* 2010 Jul;43(7):545–54.
8. Shen Y, Peng B, Cheung GSP. Factors associated with the removal of fractured NiTi instruments from root canal systems. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2004 Nov;98(5):605–10.
9. Fu M, Zhang Z, Hou B. Removal of broken files from root canals by using ultrasonic techniques combined with dental microscope: a retrospective analysis of treatment outcome. *J Endod.* 2011 May;37(5):619–22.
10. Kaul R, Gupta R, Chhabra S, Koul R. Dental Operating Microscope-guided Retrieval of Broken Instrument from a Deciduous Molar Using Ultrasonics. *Int J Clin Pediatr Dent.* 2022;15(Suppl 1):S114–8.
11. Crump MC, Natkin E. Relationship of broken root canal instruments to endodontic case prognosis: a clinical investigation. *J Am Dent Assoc.* 1970 Jun;80(6):1341–7.
12. Lin LM, Rosenberg PA, Lin J. Do procedural errors cause endodontic treatment failure? *J Am Dent Assoc.* 2005 Feb;136(2):187–93; quiz 231.
13. Lo Giudice R, Nicita F, Puleio F, Alibrandi A, Cervino G, Lizio AS, et al. Accuracy of Periapical Radiography and CBCT in Endodontic Evaluation. *Int J Dent.* 2018;2018:2514243.
14. Baratto-Filho F, Vavassori de Freitas J, Fagundes Tomazinho FS, Leão Gabardo MC, Mazzi-Chaves JF, Damião Sousa-Neto M. Cone-Beam Computed Tomography Detection of Separated Endodontic Instruments. *J Endod.* 2020 Nov;46(11):1776–81.

15. Ayatollahi F, Tabrizzadeh M, Razavi H, Mowji M. Diagnostic Value of Cone-Beam Computed Tomography and Digital Periapical Radiography in Detection of Separated Instruments. *Iran Endod J.* 2019;14(1):14–7.
16. Venskutonis T, Plotino G, Juodzbaly G, Mickevičienė L. The Importance of Cone-beam Computed Tomography in the Management of Endodontic Problems: A Review of the Literature. *J Endod.* 2014 Dec;40(12):1895–901.
17. Nouroloyouni A, Salem Milani A, Etminan A, Noorolouny S, Tavakkol E, Mikaieli Xiavi H, et al. Cone-Beam Computed Tomography Assessment of Quality of Endodontic Treatment and Prevalence of Procedural Errors in Mandibular Molars. *Int J Clin Pract.* 2023 May 19;2023:1–8.
18. Carter L, Farman AG, Geist J, Scarfe WC, Angelopoulos C, Nair MK, et al. American Academy of Oral and Maxillofacial Radiology executive opinion statement on performing and interpreting diagnostic cone beam computed tomography. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology.* 2008 Oct;106(4):561–2.
19. Hülsmann M, Schinkel I. Influence of several factors on the success or failure of removal of fractured instruments from the root canal. *Endod Dent Traumatol.* 1999 Dec;15(6):252–8.
20. Dioguardi M, Dello Russo C, Scarano F, Esperouz F, Ballini A, Sovereto D, et al. Analysis of Endodontic Successes and Failures in the Removal of Fractured Endodontic Instruments during Retreatment: A Systematic Review, Meta-Analysis, and Trial Sequential Analysis. *Healthcare (Basel).* 2024 Jul 11;12(14).
21. Shao T, Guan R, Zhang C, Hou B. Influence of operator's experience on complications of root canal treatment using contemporary techniques: a retrospective study. *BMC Oral Health.* 2024 Jan 17;24(1):96.
22. SOUTER N, MESSER H. Complications Associated with Fractured File Removal Using an Ultrasonic Technique. *J Endod.* 2005 Jun;31(6):450–2.
23. Kalogeropoulos K, Xiropotamou A, Koletsi D, Tzanetakis GN. The Effect of Cone-Beam Computed Tomography (CBCT) Evaluation on Treatment Planning after Endodontic Instrument Fracture. *Int J Environ Res Public Health.* 2022 Mar 30;19(7).
24. Nevaes G, Cunha RS, Zuolo ML, da Silveira Bueno CE. Success Rates for Removing or Bypassing Fractured Instruments: A Prospective Clinical Study. *J Endod.* 2012 Apr;38(4):442–4.
25. Panitvisai P, Parunnit P, Sathorn C, Messer HH. Impact of a Retained Instrument on Treatment Outcome: A Systematic Review and Meta-analysis. *J Endod.* 2010 May;36(5):775–80.
26. Harada T, Harada K, Nozoe A, Tanaka S, Kogo M. A Novel Surgical Approach for the Successful Removal of Overextruded Separated Endodontic Instruments. *J Endod.* 2021 Dec;47(12):1942–6.
27. Nasiri K, Wrbas KT. Management of separated instruments in root canal therapy. *J Dent Sci.* 2023 Jul;18(3):1433–4.
28. Terauchi Y, Ali WT, Abielhassan MM. Present status and future directions: Removal of fractured instruments. *Int Endod J.* 2022 May;55 Suppl 3:685–709.
29. Terauchi Y, Sexton C, Bakland LK, Bogen G. Factors Affecting the Removal Time of Separated Instruments. *J Endod.* 2021 Aug;47(8):1245–52.
30. Suter B, Lussi A, Sequeira P. Probability of removing fractured instruments from root canals. *Int Endod J.* 2005 Feb 24;38(2):112–23.
31. Lambrianidis T. Therapeutic Options for the Management of Fractured Instruments. In: *Management of Fractured Endodontic Instruments.* Cham: Springer International Publishing; 2018. p. 75–195.
32. CHEUNG GSP. Instrument fracture: mechanisms, removal of fragments, and clinical outcomes. *Endod Topics.* 2007 Mar 21;16(1):1–26.
33. Karim MH, Faraj BM. Comparative Evaluation of a Dynamic Navigation System versus a Three-dimensional Microscope in Retrieving Separated Endodontic Files: An In Vitro Study. *J Endod.* 2023 Sep;49(9):1191–8.
34. Plotino G, Pamejjer C, Mariagrande N, Somma F. Ultrasonics in Endodontics: A Review of the

- Literature. J Endod. 2007 Feb;33(2):81–95.
35. Krell K V, Fuller MW, Scott GL. The conservative retrieval of silver cones in difficult cases. J Endod. 1984 Jun;10(6):269–73.
 36. Darcangelo C, Varvara G, Defazio P. Broken Instrument Removal—Two Cases. J Endod. 2000 Jun;26(6):368–70.
 37. Fu M, Huang X, Zhang K, Hou B. Effects of Ultrasonic Removal of Fractured Files from the Middle Third of Root Canals on the Resistance to Vertical Root Fracture. J Endod. 2019 Nov;45(11):1365–70.
 38. Umre U, Sedani S, Nikhade PP, Mishra A, Bansod A. The Good Old Masserann Technique for the Retrieval of a Separated Instrument: An Endodontic Challenge. Cureus. 2023 Sep 23;
 39. Terauchi Y, O’Leary L, Suda H. Removal of Separated Files from Root Canals With a New File-removal System: Case Reports. J Endod. 2006 Aug;32(8):789–97.
 40. RUDDLE C. Nonsurgical Retreatment. J Endod. 2004 Dec;30(12):827–45.
 41. Roig-Greene JL. The retrieval of foreign objects from root canals: A Simple aid. J Endod. 1983 Sep;9(9):394–7.
 42. Yu Dg, Kimura Y, Tomita Y, Nakamura Y, Watanabe H, Matsumoto K. Study on Removal Effects of Filling Materials and Broken Files from Root Canals Using Pulsed Nd:YAG Laser. J Clin Laser Med Surg. 2000 Feb;18(1):23–8.
 43. Cunningham CJ, Senia ES. A three-dimensional study of canal curvatures in the mesial roots of mandibular molars. J Endod. 1992 Jun;18(6):294–300.

BÖLÜM 6

ENDODONTİK ENFEKSİYONLARIN MİKROBİYOLOJİSİ VE TANI YÖNTEMLERİ

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GİRİŞ

Endodonti, pulpa–dentin kompleksi ve periapikal dokuların fizyolojisi, patolojisi, tanısı, korunması ve tedavisi ile ilgilenen diş hekimliği disiplini. Diş pulpasını etkileyen hastalıkların en sık nedenleri çürük ve travma olup, mevcut pulpal patolojiler anatomik ve fonksiyonel ilişkileri nedeniyle periapikal dokularda patolojik değişikliklerin gelişmesine yol açabilmektedir. Bu patolojik süreçlerin gelişiminde mikrobiyal faktörler temel etiyolojik unsur olarak kabul edilmektedir(1). Kök kanal enfeksiyonları, dental pulpa içerisine penetre olarak kök kanal sistemini kolonize eden mikroorganizmalar tarafından oluşturulmaktadır(2). Bu mikroorganizmalar ve metabolik ürünleri, apikal veya lateral foraminaller aracılığıyla periradiküler dokulara ulaşarak inflamatuvar yanıtın başlamasına neden olmaktadır. Gelişen inflamasyon sürecinde, başta nötrofiller ve makrofajlar olmak üzere immün hücrelerin proteolitik aktiviteleri ve osteoklastların aktivasyonu sonucunda periradiküler yumuşak ve sert dokularda yıkım meydana gelmektedir. Bu süreç, hücresel artıklar, mimmün hücreler ve kemik rezorpsiyonu ile karakterize bir lezyon oluşumuna yol açmakta olup, kök kanal sistemi içerisindeki mikrobiyal topluluklar tarafından tetiklenen bu periradiküler inflamatuvar tablo apikal periodontitis olarak tanımlanmaktadır(3).

Endodontik enfeksiyonlarda kök kanal sistemi içerisinde yer alan mikrobiyal topluluklar, yüksek bireysel değişkenlik gösteren ve farklı bakteri cins ve türlerini içeren polimikrobiyal bir yapı sergilemektedir(4). Ayrıca, kök kanalın koronal ve apikal uçlülerinde yerleşen mikroorganizmalar arasında belirgin farklılıklar bulunduğu bildirilmiştir. Apikal bölgede düşük oksijen gerilimi ve periapikal

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lirli mikroorganizmaların saptanmasında duyarlılığı artırmış olsa da önceden belirlenmiş hedeflere bağımlı olmaları nedeniyle mikrobiyal ekosistemin bütüncül değerlendirilmesini sınırlamıştır. Bu bağlamda, yeni nesil dizileme (NGS) teknolojileri, kök kanal mikrobiyotasının daha önce tanımlanmamış geniş bir taksonomik çeşitliliğe sahip olduğunu ortaya koyarak endodontik enfeksiyonların biyolojik doğasına ilişkin paradigmanın yeniden şekillenmesine katkıda bulunmuştur.

NGS temelli çalışmalar, primer, sekonder ve persistan endodontik enfeksiyonlar arasında mutlak ve sabit mikrobiyal profillerden ziyade, benzer taksonların farklı yoğunluk düzeyleriyle bir arada bulunduğu dinamik bir mikrobiyom yapısına işaret etmektedir. Bu bulgular, endodontik enfeksiyonların patogenezinde mikrobiyal kompozisyonundan çok, topluluk yapısı ve fonksiyonel kapasitenin önemini vurgulamaktadır. Bununla birlikte, moleküler ve NGS temelli yaklaşımların canlılık, metabolik aktivite ve klinik anlamlılık açısından yorumlanmasında bazı metodolojik sınırlılıkların bulunduğu da göz ardı edilmemelidir.

Sonuç olarak, endodontik enfeksiyonların mikrobiyolojik tanısı ve anlaşılmasında en doğru yaklaşım; kültür temelli, moleküler ve yeni nesil dizileme yöntemlerinden elde edilen verilerin birbirini tamamlayacak şekilde bütüncül olarak değerlendirilmesidir. Gelecekte yapılacak analizlerin klinik verilerle entegre edilmesi, endodontik enfeksiyonların patogenezinin daha derinlemesine anlaşılmasına ve daha hedefe yönelik, etkili tedavi stratejilerinin geliştirilmesine olanak sağlayacaktır.

KAYNAKÇA

1. Duncan HF, Kirkevang LL, Peters OA, El-Karim I, Krastl G, Del Fabbro M, et al. Treatment of pulpal and apical disease: the European Society of Endodontology (ESE) S3-level clinical practice guideline. *International Endodontic Journal*. 2023;56:238-95.
2. Wong J, Manoel D, Näsman P, Belibasakis GN, Neelakantan P. Microbiological aspects of root canal infections and disinfection strategies: an update review on the current knowledge and challenges. *Frontiers in Oral Health*. 2021;2:672887.
3. Lin L, Huang GT. *Pathobiology of apical periodontitis. Pathways of the pulp*: Mosby; 2013.
4. Siqueira Jr JF, Silva WO, Romeiro K, Gominho LF, Alves FR, Rôças IN. Apical root canal microbiome associated with primary and posttreatment apical periodontitis: A systematic review. *International Endodontic Journal*. 2024;57(8):1043-58.
5. Prada I, Micó-Muñoz P, Giner-Lluesma T, Micó-Martínez P, Collado-Castellano N, Manzano-Saiz A. Influence of microbiology on endodontic failure. Literature review. *Medicina oral, patología oral y cirugía bucal*. 2019;24(3):e364.
6. Hernández SR, Siqueira Jr JF, Voigt DD, Soimu G, Brasil SC, Provenzano JC, et al. Bacteriologic conditions of the apical root canal system of teeth with and without posttreatment apical periodontitis: a correlative multianalytical approach. *Journal of Endodontics*. 2024;50(2):154-63.
7. Zhu Y, Wang Y, Zhang S, Li J, Li X, Ying Y, et al. Association of polymicrobial interactions with dental caries development and prevention. *Frontiers in microbiology*. 2023;14:1162380.
8. Bjørndal L, Simon S, Tomson P, Duncan H. Management of deep caries and the exposed pulp.

- International endodontic journal. 2019;52(7):949-73.
9. Siqueira Jr JF. Endodontic infections: concepts, paradigms, and perspectives. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*. 2002;94(3):281-93.
 10. Siqueira Jr J, Rôças I. Exploiting molecular methods to explore endodontic infections: part 2—redefining the endodontic microbiota. *Journal of endodontics*. 2005;31(7):488-98.
 11. JC B. Bacteria in the apical 5mm of infected root canal. *J Endod*. 1991;17:380-3.
 12. de Oliveira JCM, Siqueira Jr JF, Alves GB, Hirata Jr R, Andrade AF. Detection of *Porphyromonas endodontalis* in infected root canals by 16S rRNA gene-directed polymerase chain reaction. *Journal of endodontics*. 2000;26(12):729-32.
 13. Rôças IN, Siqueira Jr JF, Santos KR, Coelho AM, de Janeiro R. “Red complex”(Bacteroides forsythus, Porphyromonas gingivalis, and Treponema denticola) in endodontic infections: a molecular approach. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*. 2001;91(4):468-71.
 14. Siqueira Jr JF, Rôças IN, Souto R, de Uzeda M, Colombo AP. Microbiological evaluation of acute periradicular abscesses by DNA-DNA hybridization. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*. 2001;92(4):451-7.
 15. Sundqvist G. Bacteriological studies of necrotic dental pulps: Umeå University; 1976.
 16. Gomes B, Lilley J, Drucker D. Clinical significance of dental root canal microflora. *Journal of dentistry*. 1996;24(1-2):47-55.
 17. Haapasalo M, Ranta H, Ranta K, Shah H. Black-pigmented Bacteroides spp. in human apical periodontitis. *Infection and Immunity*. 1986;53(1):149-53.
 18. Finlay BB, Falkow S. Common themes in microbial pathogenicity. *Microbiological reviews*. 1989;53(2):210-30.
 19. Kolenbrander P. Environmental sensing mechanisms and virulence factors of bacterial pathogen. *Topley and Wilson’s Microbiology and Microbial Infections*. 1998;2:307-26.
 20. Siqueira Jr JF, Rôças IN, Oliveira JCM, Santos KR. Molecular detection of black-pigmented bacteria in infections of endodontic origin. *Journal of endodontics*. 2001;27(9):563-6.
 21. Siqueira Jr JF, Rôças IN. Clinical implications and microbiology of bacterial persistence after treatment procedures. *Journal of endodontics*. 2008;34(11):1291-301. e3.
 22. Hong B-Y, Lee T-K, Lim S-M, Chang SW, Park J, Han SH, et al. Microbial analysis in primary and persistent endodontic infections by using pyrosequencing. *Journal of endodontics*. 2013;39(9):1136-40.
 23. Chugal N, Wang J-K, Wang R, He X, Kang M, Li J, et al. Molecular characterization of the microbial flora residing at the apical portion of infected root canals of human teeth. *Journal of endodontics*. 2011;37(10):1359-64.
 24. Sundqvist G, Figdor D, Persson S, Sjögren U. Microbiologic analysis of teeth with failed endodontic treatment and the outcome of conservative re-treatment. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*. 1998;85(1):86-93.
 25. Chávez De Paz L, Dahlén G, Molander A, Möller Å, Bergenholtz G. Bacteria recovered from teeth with apical periodontitis after antimicrobial endodontic treatment. *International endodontic journal*. 2003;36(7):500-8.
 26. Siqueira Jr JF, Alves FR, Rôças IN. Pyrosequencing analysis of the apical root canal microbiota. *Journal of Endodontics*. 2011;37(11):1499-503.
 27. Anderson AC, Al-Ahmad A, Elamin F, Jonas D, Mirghani Y, Schilhabel M, et al. Comparison of the bacterial composition and structure in symptomatic and asymptomatic endodontic infections associated with root-filled teeth using pyrosequencing. *PloS one*. 2013;8(12):e84960.
 28. Santos AL, Siqueira Jr JF, Rôças IN, Jesus EC, Rosado AS, Tiedje JM. Comparing the bacterial diversity of acute and chronic dental root canal infections. *Plos one*. 2011;6(11):e28088.
 29. Tennert C, Fuhrmann M, Wittmer A, Karygianni L, Altenburger MJ, Pelz K, et al. New bacterial composition in primary and persistent/secondary endodontic infections with respect to clinical and radiographic findings. *Journal of endodontics*. 2014;40(5):670-7.

30. Costerton JW. The biofilm primer: Springer; 2007.
31. Donlan RM, Costerton JW. Biofilms: survival mechanisms of clinically relevant microorganisms. *Clinical microbiology reviews*. 2002;15(2):167-93.
32. Sharma S, Mohler J, Mahajan SD, Schwartz SA, Bruggemann L, Aalinkeel R. Microbial biofilm: a review on formation, infection, antibiotic resistance, control measures, and innovative treatment. *Microorganisms*. 2023;11(6):1614.
33. Chen L, Ren Z, Zhou X, Zeng J, Zou J, Li Y. Inhibition of *Streptococcus mutans* biofilm formation, extracellular polysaccharide production, and virulence by an oxazole derivative. *Applied microbiology and biotechnology*. 2016;100(2):857-67.
34. Chałas R, Wójcik-Chęcińska I, Woźniak MJ, Grzonka J, Świąszkowski W, Kurzydłowski KJ. Dental plaque as a biofilm-a risk in oral cavity and methods to prevent. *Postepy higieny i medycyny doświadczalnej (Online)*. 2015;69:1140-8.
35. Foschi F, Cavrini F, Montebugnoli L, Stashenko P, Sambri V, Prati C. Detection of bacteria in endodontic samples by polymerase chain reaction assays and association with defined clinical signs in Italian patients. *Oral microbiology and immunology*. 2005;20(5):289-95.
36. Flemming H-C, Wingender J. The biofilm matrix. *Nature reviews microbiology*. 2010;8(9):623-33.
37. Hall-Stoodley L, Stoodley P. Evolving concepts in biofilm infections. *Cellular microbiology*. 2009;11(7):1034-43.
38. Parsek MR, Singh PK. Bacterial biofilms: an emerging link to disease pathogenesis. *Annual Reviews in Microbiology*. 2003;57(1):677-701.
39. Molven O, Olsen I, Kerekes K. Scanning electron microscopy of bacteria in the apical part of root canals in permanent teeth with periapical lesions. *Dental Traumatology*. 1991;7(5):226-9.
40. Ricucci D, Siqueira Jr JF. Biofilms and apical periodontitis: study of prevalence and association with clinical and histopathologic findings. *Journal of endodontics*. 2010;36(8):1277-88.
41. Sen B, Piskin B, Demirci T. Observation of bacteria and fungi in infected root canals and dentinal tubules by SEM. *Dental Traumatology*. 1995;11(1):6-9.
42. Sjögren U, Figdor D, Persson S, Sundqvist G. Influence of infection at the time of root filling on the outcome of endodontic treatment of teeth with apical periodontitis. *International endodontic journal*. 1997;30(5):297-306.
43. Waltimo T, Trope M, Haapasalo M, Ørstavik D. Clinical efficacy of treatment procedures in endodontic infection control and one year follow-up of periapical healing. *Journal of endodontics*. 2005;31(12):863-6.
44. Gomes BP, Pinheiro ET, Gadê-Neto C, Sousa EL, Ferraz CC, Zaia AA, et al. Microbiological examination of infected dental root canals. *Oral microbiology and immunology*. 2004;19(2):71-6.
45. Park DH, Park O-J, Yoo Y-J, Perinpanayagam H, Cho E-B, Kim K, et al. Microbiota association and profiling of gingival sulci and root canals of teeth with primary or secondary/persistent endodontic infections. *Journal of Endodontics*. 2024;50(8):1124-33.
46. Tzanetakakis GN, Azcarate-Peril MA, Zachaki S, Panopoulos P, Kontakiotis EG, Madianos PN, et al. Comparison of bacterial community composition of primary and persistent endodontic infections using pyrosequencing. *Journal of endodontics*. 2015;41(8):1226-33.
47. Vengerfeldt V, Špilka K, Saag M, Preem J-K, Oopkaup K, Truu J, et al. Highly diverse microbiota in dental root canals in cases of apical periodontitis (data of illumina sequencing). *Journal of endodontics*. 2014;40(11):1778-83.
48. Zandi H, Petronijevic N, Mdala I, Kristoffersen AK, Enersen M, Rôças IN, et al. Outcome of endodontic retreatment using 2 root canal irrigants and influence of infection on healing as determined by a molecular method: a randomized clinical trial. *Journal of endodontics*. 2019;45(9):1089-98. e5.
49. Gatti J, Dobeck J, Smith C, White R, Socransky S, Skobe Z. Bacteria of asymptomatic periradicular endodontic lesions identified by DNA-DNA hybridization. *Dental Traumatology*.

- 2000;16(5):197-204.
50. Siqueira Jr JF, Rôças IN. Polymerase chain reaction–based analysis of microorganisms associated with failed endodontic treatment. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*. 2004;97(1):85-94.
 51. do Cabo Fernandes C, Rechenberg D-K, Zehnder M, Belibasakis GN. Identification of Synergistetes in endodontic infections. *Microbial pathogenesis*. 2014;73:1-6.
 52. Munson M, Pitt-Ford T, Chong B, Weightman A, Wade W. Molecular and cultural analysis of the microflora associated with endodontic infections. *Journal of dental research*. 2002;81(11):761-6.
 53. Rôças I, Siqueira Jr J. Root canal microbiota of teeth with chronic apical periodontitis. *Journal of clinical microbiology*. 2008;46(11):3599-606.
 54. Pinheiro E, Gomes B, Ferraz C, Sousa E, Teixeira F, Souza-Filho F. Microorganisms from canals of root-filled teeth with periapical lesions. *International endodontic journal*. 2003;36(1).
 55. Sakamoto M, Siqueira Jr J, Rôças I, Benno Y. Molecular analysis of the root canal microbiota associated with endodontic treatment failures. *Oral microbiology and immunology*. 2008;23(4):275-81.
 56. Ordinola-Zapata R, Noblett WC, Perez-Ron A, Ye Z, Vera J. Present status and future directions of intracanal medicaments. *International endodontic journal*. 2022;55:613-36.
 57. Amaral RR, Braga T, Siqueira Jr JF, Rôças IN, da Costa Rachid CTC, Oliveira AGG, et al. Root canal microbiome associated with asymptomatic apical periodontitis as determined by high-throughput sequencing. *Journal of Endodontics*. 2022;48(4):487-95.
 58. Siqueira Jr JF, Rôças IN. Present status and future directions: Microbiology of endodontic infections. *International endodontic journal*. 2022;55:512-30.
 59. Shin JM, Luo T, Lee KH, Guerreiro D, Botero TM, McDonald NJ, et al. Deciphering endodontic microbial communities by next-generation sequencing. *Journal of Endodontics*. 2018;44(7):1080-7.
 60. Ordinola-Zapata R, Costalonga M, Nixdorf D, Dietz M, Schuweiler D, Lima BP, et al. Taxonomic abundance in primary and secondary root canal infections. *International Endodontic Journal*. 2023;56(2):278-88.
 61. Marchesi J, Ravel J. The vocabulary of microbiome research: a proposal. *Microbiome*. 2015; 3: 31.
 62. Siqueira Jr J, Rôças I. Exploiting molecular methods to explore endodontic infections: part 1—current molecular technologies for microbiological diagnosis. *Journal of endodontics*. 2005;31(6):411-23.
 63. Pace NR. A molecular view of microbial diversity and the biosphere. *Science*. 1997;276(5313):734-40.
 64. Ward DM, Weller R, Bateson MM. 16S rRNA sequences reveal numerous uncultured microorganisms in a natural community. *Nature*. 1990;345(6270):63-5.
 65. Amann RL, Ludwig W, Schleifer K-H. Phylogenetic identification and in situ detection of individual microbial cells without cultivation. *Microbiological reviews*. 1995;59(1):143-69.
 66. Paster BJ, Boches SK, Galvin JL, Ericson RE, Lau CN, Levanos VA, et al. Bacterial diversity in human subgingival plaque. *Journal of bacteriology*. 2001;183(12):3770-83.
 67. Suau A, Bonnet R, Sutren M, Godon J-J, Gibson GR, Collins MD, et al. Direct analysis of genes encoding 16S rRNA from complex communities reveals many novel molecular species within the human gut. *Applied and environmental microbiology*. 1999;65(11):4799-807.
 68. Wilson KH, Blichington RB. Human colonic biota studied by ribosomal DNA sequence analysis. *Applied and Environmental Microbiology*. 1996;62(7):2273-8.
 69. Fredricks DN, Marrazzo JM. Azithromycin versus penicillin for early syphilis. *Clin Microbiol Rev*. 1996;9:18-33.
 70. Reiman DA. The identification of uncultured microbial pathogens. *Journal of Infectious Diseases*. 1993;168(1):1-8.

71. Siqueira Jr JF, Rôças IN, Oliveira JCM, Santos KR. Detection of putative oral pathogens in acute periradicular abscesses by 16S rDNA-directed polymerase chain reaction. *Journal of Endodontics*. 2001;27(3):164-7.
72. Xia T, Baumgartner JC, David L. Isolation and identification of *Prevotella tanneriae* from endodontic infections. *Oral Microbiology and Immunology: Short communication*. 2000;15(4):273-5.
73. Jung I-Y, Choi B-k, Kum K-Y, Yoo Y-J, Yoon T-C, Lee S-J, et al. Identification of oral spirochetes at the species level and their association with other bacteria in endodontic infections. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*. 2001;92(3):329-34.
74. Rolph H, Lennon A, Riggio M, Saunders W, MacKenzie D, Coldero L, et al. Molecular identification of microorganisms from endodontic infections. *Journal of clinical microbiology*. 2001;39(9):3282-9.
75. Yarza P, Yilmaz P, Pruesse E, Glöckner FO, Ludwig W, Schleifer K-H, et al. Uniting the classification of cultured and uncultured bacteria and archaea using 16S rRNA gene sequences. *Nature Reviews Microbiology*. 2014;12(9):635-45.
76. Goodwin S, McPherson JD, McCombie WR. Coming of age: ten years of next-generation sequencing technologies. *Nature reviews genetics*. 2016;17(6):333-51.
77. Manoil D, Al-Manei K, Belibasakis GN. A systematic review of the root canal microbiota associated with apical periodontitis: lessons from next-generation sequencing. *PROTEOMICS—Clinical Applications*. 2020;14(3):1900060.
78. Lazarevic V, Whiteson K, Gaia N, Gizard Y, Hernandez D, Farinelli L, et al. Analysis of the salivary microbiome using culture-independent techniques. *Journal of clinical bioinformatics*. 2012;2(1):4.
79. Schmidt TS, Matias Rodrigues JF, von Mering C. Ecological consistency of SSU rRNA-based operational taxonomic units at a global scale. *PLoS computational biology*. 2014;10(4):e1003594.
80. Escapa IF, Chen T, Huang Y, Gajare P, Dewhirst FE, Lemon KP. New insights into human nostril microbiome from the expanded human oral microbiome database (eHOMD): a resource for the microbiome of the human aerodigestive tract. *Msystems*. 2018;3(6):10.1128/msystems.00187-18.
81. Bouillaguet S, Manoil D, Girard M, Louis J, Gaia N, Leo S, et al. Root microbiota in primary and secondary apical periodontitis. *Frontiers in microbiology*. 2018;9:2374.
82. Wicher K, Abbruscato F, Wicher V, Collins DN, Auger I, Horowitz HW. Identification of persistent infection in experimental syphilis by PCR. *Infection and immunity*. 1998;66(6):2509-13.
83. Kennedy N, Gillespie S, Saruni A, Kisyombe G, McNerney R, Ngowi F, et al. Polymerase chain reaction for assessing treatment response in patients with pulmonary tuberculosis. *Journal of Infectious Diseases*. 1994;170(3):713-6.
84. Bernardi G. Chromatography of nucleic acids on hydroxyapatite. *Nature*. 1965;206(4986):779-83.
85. Leduc A, Grenier D, Mayrand D. Outer membrane-associated deoxyribonuclease activity of *Porphyromonas gingivalis*. *Anaerobe*. 1995;1(2):129-34.
86. McCarty SC, Atlas RM. Effect of amplicon size on PCR detection of bacteria exposed to chlorine. *Genome Research*. 1993;3(3):181-5.
87. Keer J, Birch L. Molecular methods for the assessment of bacterial viability. *Journal of microbiological methods*. 2003;53(2):175-83.

BÖLÜM 7

ELEKTRONİK APEKS BULUCULAR VE ENTEGRE ENDOMOTOR SİSTEMLERİ

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KÖK KANAL ANATOMİSİ

Kök kanalının sement–dentin birleşiminden başlayıp periodontal ligamente kadar uzanan ters koni şeklindeki bölgesi Black aralığı olarak tanımlanır. Bu bölgenin tabanını majör apikal foramen, tepe noktasını ise minör apikal foramen veya diğer adıyla apikal daralım oluşturur. Anatomik apeks kökün morfolojik olarak en ucunu ifade ederken, radyografik apeks anatomik apeksin radyografide görülen karşılığıdır. Apikal foramen çoğu zaman kökün tam ucunda yer almaz; genellikle lateral konumdadır ve anatomik apeks ile arasında 3 mm’ye kadar mesafe bulunabilir (Şekil 1) (1, 2).

Sement–dentin birleşimi, pulpal dokuların sonlandığı ve periodontal dokuların başladığı histolojik sınırdır; mikroskopik kesitlerde gözlemlenebilir, ancak klinik olarak belirlenmesi mümkün değildir (1).

Apikal foramen, damar ve sinir paketinin dışı terk ettiği bölgedir. Majör foramen olarak da adlandırılır. Kökün lateralinde konumlanmış olması nedeniyle her zaman anatomik apeksle çakışmaz (3).

Apikal konstriksiyon veya minör apikal çap, kök kanalının en dar bölgesidir ve endodontik tedavilerde temel referans noktalarından biridir (4). Genellikle majör apikal foramenden 0,5–1,5 mm daha koronalde yer alır. Şekillendirme, dezenfeksiyon ve obtürasyon işlemlerinin bu bölgede sonlandırılması, periodontal dokuların daha kısa sürede iyileşmesini sağlarken post-operatif ağrı oluşumunu da azaltır (5).

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KAYNAKLAR

1. Kuttler Y. Microscopic investigation of root apices. *The Journal of the American Dental Association*. 1955;50(5):544-52.
2. Green D. Stereomicroscopic study of 700 root apices of maxillary and mandibular posterior teeth. *Oral Surgery, Oral Medicine, Oral Pathology*. 1960;13(6):728-33.
3. Tsesis I, Blazer T, Ben-Izhack G, Taschieri S, Del Fabbro M, Corbella S, et al. The precision of electronic apex locators in working length determination: a systematic review and meta-analysis of the literature. *Journal of endodontics*. 2015;41(11):1818-23. doi: 10.1016/j.joen.2015.08.012
4. Vertucci FJ. Root canal morphology and its relationship to endodontic procedures. *Endodontic topics*. 2005;10(1):3-29. doi: 10.1111/j.1601-1546.2005.00129.x
5. Palmer M, Weine F, Healey H. Position of the apical foramen in relation to endodontic therapy. *Journal of the Canadian Dental Association*. 1971;37(8):305-8.
6. Chugal N, Mallya SM, Kahler B, Lin LM. Endodontic treatment outcomes. *Dental Clinics*. 2017;61(1):59-80. doi: 10.1016/j.cden.2016.08.009
7. Alaçam, T. Endodonti. Ankara: Özyurt Matbaacılık; 2012.
8. Ricucci. Apical limit of root canal instrumentation and obturation, part 1. Literature review. *International Endodontic Journal*. 1998;31(6):384-93. doi: 10.1046/j.1365-2591.1998.00184.x
9. Stock C. Endodontics--position of the apical seal. *British dental journal*. 1994;176(9):329. doi: 10.1038/sj.bdj.4808442
10. Brown D. Paper points revisited: risk of cellulose fibre shedding during canal length confirmation. *International endodontic journal*. 2017;50(6):620-6. doi: 10.1111/iej.12663
11. Tınaz C. Kanal tedavisinde çalışma boyutu. *Gazi Üniversitesi Diş Hekimliği Fakültesi Dergisi*. 2001;18(1):31-7.
12. Schaeffer MA, White RR, Walton RE. Determining the optimal obturation length: a meta-analysis of literature. *Journal of endodontics*. 2005;31(4):271-4. doi: 10.1097/01.don.0000140585.52178.78
13. Kim E, Lee S-J. Electronic apex locator. *Dental Clinics*. 2004;48(1):35-54. doi: 10.1016/j.cden.2003.10.005
14. Ebrahim A, Wadachi R, Suda H. An in vitro evaluation of the accuracy of Dentaport ZX apex locator in enlarged root canals. *Australian dental journal*. 2007;52(3):193-7. doi: 10.1111/j.1834-7819.2007.tb00488.x
15. Nekoofar M, Ghandi M, Hayes S, Dummer P. The fundamental operating principles of electronic root canal length measurement devices. *International endodontic journal*. 2006;39(8):595-609. doi: 10.1111/j.1365-2591.2006.01131.x
16. Custer L. Exact methods of locating the apical foramen. *The Journal of the National Dental Association*. 1918;5(8):815-9.
17. Suzuki K. Experimental study on iontophoresis. *Jpn J Stomatology*. 1942;16:411-29.
18. Gordon M, Chandler N. Electronic apex locators. *International endodontic journal*. 2004;37(7):425-37. doi: 10.1111/j.1365-2591.2004.00835.x
19. Bridges JE. Non-perceptible body current ELF effects as defined by electric shock safety data. *Bioelectromagnetics: Journal of the Bioelectromagnetics Society, The Society for Physical Regulation in Biology and Medicine, The European Bioelectromagnetics Association*. 2002;23(7):542-4. doi: 10.1002/bem.10063
20. Niple J, Daigle J, Zaffanella L, Sullivan T, Kavet R. A portable meter for measuring low frequency currents in the human body. *Bioelectromagnetics: Journal of the Bioelectromagnetics Society, The Society for Physical Regulation in Biology and Medicine, The European Bioelectromagnetics Association*. 2004;25(5):369-73. doi: 10.1002/bem.20000
21. Kim PJ, Kim HG, Cho BH. Evaluation of electrical impedance ratio measurements in accuracy of electronic apex locators. *Restor Dent Endod*. 2015;40(2):113-22. doi: 10.5395/rde.2015.40.2.113
22. Pommer O, Stamm O, Attin T. Influence of the canal contents on the electrical assisted de-

- termination of the length of root canals. *Journal of Endodontics*. 2002;28(2):83-5. doi: 10.1097/00004770-200202000-00002
23. Stock CJ, Gulabivala K, Walker RT. Endodontics. Edinburgh: Mosby/Elsevier Ltd; 2004.
 24. Soi S, Mohan S, Kaur VVP. Electronic apex locators. *J Dent Sci Oral Rehabil*. 2013;24-29.
 25. Kobayashi C, Matoba K, Suda H, Sunada I. New practical model of the division method electronic root canal length measuring device. *J Jpn Endodon Assoc*. 1991;12:143-8.
 26. Lucena-Martin C, Robles-Gijon V, Ferrer-Luque C, de Mondelo JN-R. In vitro evaluation of the accuracy of three electronic apex locators. *Journal of Endodontics*. 2004;30(4):231-3. doi: 10.1097/00004770-200404000-00012.
 27. Kaufman A, Keila S, Yoshpe M. Accuracy of a new apex locator: an in vitro study. *International endodontic journal*. 2002;35(2):186-92. doi: 10.1046/j.1365-2591.2002.00468.x
 28. Mancini M, Felici R, Conte G, Costantini M, Cianconi L. Accuracy of three electronic apex locators in anterior and posterior teeth: an ex vivo study. *Journal of endodontics*. 2011;37(5):684-7. doi: 10.1016/j.joen.2010.12.009
 29. Bonilla M, Sayin TC, Schobert B, Hardigan P. Accuracy of a new apex locator in ex-vivo teeth using scanning electron microscopy. *Endod Pract*. 2014;16:14-20.
 30. Stoll R, Urban-Klein B, Roggendorf M, Jablonski-Momeni A, Strauch K, Frankenberger R. Effectiveness of four electronic apex locators to determine distance from the apical foramen. *International Endodontic Journal*. 2010;43(9):808-17. doi: 10.1111/j.1365-2591.2010.01751.x
 31. Bhatt A, Gupta V, Rajkumar B, Arora R. Working Length Determination-The soul of Root Canal Therapy a Review. *Int J Dent Health Sci*. 2015;2(1):105-15.
 32. Akisue E, Gavini G, de Figueiredo JAP. Influence of pulp vitality on length determination by using the Elements Diagnostic Unit and Apex Locator. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*. 2007;104(4):e129-e32. doi: 10.1016/j.tripleo.2007.04.018
 33. Bilaiya S, Patni PM, Jain P, Pandey SH, Raghuwanshi S, Bagulkar B. Comparative Evaluation of Accuracy of Ipex, Root Zx Mini, and Epex Pro Apex Locators in Teeth with Artificially Created Root Perforations in Presence of Various Intracanal Irrigants. *European endodontic journal*. 2020;5(1):6-9. doi: 10.14744/ej.2019.07279
 34. Shekarbaghani SA, Bolhari B, Khalilak Z. The effect of different root canal irrigations on the accuracy of apex locators: A systematic review. *Journal of Clinical and Experimental Dentistry*. 2024;16(12):e1538.
 35. López-Maekawa A, García Rupay CR. Accuracy of Four Apex Locators in Premolars with Root Resorption: An In vitro Study. *Iran Endod J*. 2022;17(1):20-6. doi: 10.22037/iej.v17i1.35498
 36. Kararia N, Kararia V, Sharma D, Gupta S, Chaturvedi S, Chaturvedi Y. Comparative evaluation of the accuracy of two electronic apex locators in detecting simulated incomplete vertical root fractures: An in vitro stereomicroscopic study. *J Conserv Dent Endod*. 2024;27(5):540-4. doi: 10.4103/jcde.jcde_132_24
 37. Nekoofar M, Sadeghi K, Akha ES, Namazikhah MS. The accuracy of the Neosono Ultima EZ apex locator using files of different alloys: an in vitro study. *Journal of the California Dental Association*. 2002;30(9):681-4. doi: 10.1080/19424396.2002.12223308
 38. Kobayashi C. Electronic canal length measurement. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*. 1995;79(2):226-31. doi: 10.1016/S1079-2104(05)80288-4
 39. de Almeida Gardelin V, Vinholes JIAM, Grazziotin-Soares R, Pappen FG, Barletta FB. Influence of rotary and reciprocating kinematics on the accuracy of an integrated apex locator. *Australian Endodontic Journal*. 2023;49:202-8. doi:10.1111/aej.12717
 40. Shirazi Z, Al-Jadaa A, Saleh AR. Electronic apex locators and their implications in contemporary clinical practice: a review. *The Open Dentistry Journal*. 2023;17(1). doi:10.2174/18742106-v16-e221227-2022-67
 41. Technomedics. FKG Rooter X3000 Kullanım Kılavuzu 2021. (01/02/2026 tarihinde https://www.technomedics.no/wpcontent/uploads/2020/03/FGK_Rooter20X3000_User20Manual_

Güncel Endodonti Çalışmaları X

- EN_WEB_20210121.pdf. Adresinden ulaşılmıştır.)
42. Usta SN, Magan-Fernandez A, Aydın C. Evaluation of the effects of different file systems and apical functions of integrated endodontic motors on debris extrusion: an ex vivo experimental study. *Restor Dent Endod.* 2025;50(2):e14. doi: 10.5395/rde.2025.50.e14
 43. Equipment. A. Woodpecker Yoshi Ai Endo Motor Ürün Tanıtımı. (01/02/2026 tarihinde <https://www.aluroequipment.co.nz/> adresinden ulaşılmıştır.)
 44. Bailey D, Anderson R, Brady K, Kwon P, Browne D, Amaral RR. An ex-vivo study comparing the accuracy of the E-connect S+ and Morita Tri Auto ZX2+ endodontic handpieces in root canal length determination. *Journal of endodontics.* 2024;50(7):1004-10. doi:10.1016/j.joen.2024.04.007

BÖLÜM 8

REJENERATİF ENDODONTİDE GÜNCEL DEZENFEKSİYON STRATEJİLERİ VE BİYOLOJİK YAKLAŞIMLAR

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GİRİŞ

1. Rejeneratif Endodonti Nedir ?

Rejeneratif endodonti, hasar görmüş, hastalıklı veya eksik diş yapılarının (dentin, kök yapıları ve pulpa-dentin kompleksi hücreleri) fizyolojik olarak yenisiyle değiştirilmesi için tasarlanmış biyolojik temelli prosedürlerdir(1). Bu yaklaşımlar; kök hücreler, biyoyumlu iskeleler ve sinyal molekülleri arasındaki etkileşim sayesinde kök kanal boşluğunda vaskülarize bir dokunun gelişimini hedeflemektedir. Temel amaç, kök kanal sistemi içerisinde yeni vasküler doku oluşumunu teşvik ederek kök gelişiminin devamını sağlamak, dentin duvar kalınlığını artırmak ve buna bağlı olarak dişin kırılma direncini yükseltmektir. Böylece tedavi edilen dişin uzun dönem biyomekanik dayanıklılığı ve klinik prognozu iyileştirilmektedir(2). Rejeneratif endodontik prosedür (REP), kök kanal sisteminin antimikrobiyal irrigasyonlar ile dezenfekte edilmesini ve periapikal bölgeden kontrollü kanama indüklenerek apikal papilla kaynaklı kök hücrelerin (SCAP) kanal içerisine yönlendirilmesini içeren iki aşamalı bir klinik protokoldür. Bu süreci takiben, oluşan biyolojik iskelenin stabilize edilmesi ve sement-mine birleşimi (CEJ) seviyesinde biyoyumlu bir materyal ile koronal sızdırmazlığın sağlanması önerilmektedir(3)

Doku Mühendisliği Triadı: Rejenerasyonun Temel Bileşenleri

Rejeneratif endodontik tedavilerin başarısı, kök hücreler, biyolojik yapı iskeleleri ve büyüme faktörleri arasındaki koordineli etkileşime dayanmaktadır(4)

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yonları ve düşük dozlarda etkinlik göstermeleri sayesinde klasik irrigantlara umut verici alternatifler sunmaktadır(22-27).

Ayrıca, oktenidin dihidroklorür gibi yeni nesil ve hücre dostu antiseptiklerin, kök kanal patojenlerine karşı etkin antimikrobiyal aktivite sağlarken SCAP ve DPSC canlılığını daha iyi koruduğu gösterilmiştir(39, 40). Bu özellikleri ile oktenidin, rejeneratif endodontik prosedürlerde antimikrobiyal kontrol ile rejeneratif potansiyelin dengelenmesine katkı sağlayan dikkat çekici bir irrigant adaydır(40).

Sonuç olarak, rejeneratif endodontide geleceğin klinik protokollerinin; biyolojik uyumluluğu ön planda tutan, çok modlu dezenfeksiyon stratejilerini içeren ve doku mühendisliği prensipleri ile entegre edilmiş yaklaşımlar üzerine şekilleneceği öngörülmektedir(14, 21). Bu alanda yapılacak ileri düzey in vitro, in vivo ve randomize klinik çalışmalar, yeni nesil antiseptiklerin ve biyomateryallerin standart tedavi protokollerine entegrasyonunu mümkün kılacak; böylece rejeneratif endodontik tedavilerin öngörülebilirliği ve uzun dönem klinik başarısı daha da artırılabilecektir(7, 10, 22).

KAYNAKLAR

1. Mandras N, Pancini N, Roana J, et al. The Bactericidal Effect of Calcium Hydroxide and Triple Antibiotic Paste During Regenerative Endodontic Procedures. *Applied Sciences*. 2025;15(23):12478. doi:10.3390/app152312478
2. Takimoto K, Widbillier M, Diogenes A. Expression of toll-like receptors in stem cells of the apical papilla and its implication for regenerative endodontics. *Cells*. 2023;12(20):2502. doi:10.3390/cells12202502
3. Galler K, Krastl G, Simon S, et al. European Society of Endodontology position statement: revitalization procedures. *International Endodontic Journal*. 2016;49(8):717–23. doi:10.1111/iej.12629
4. Sedgley C, Cherkas P, Chogle S, et al. Endodontics: colleagues for excellence, vol. *Spring Chicago: American Association of Endodontists Foundation*. 2013:1–8.
5. Kakehashi S, Stanley H, Fitzgerald R. The effects of surgical exposures of dental pulps in germ-free and conventional laboratory rats. *Oral Surgery, Oral Medicine, Oral Pathology*. 1965;20(3):340–9. doi:10.1016/0030-4220(65)90166-0
6. Yanpiset K, Trope M. Pulp revascularization of replanted immature dog teeth after different treatment methods. *Dental Traumatology*. 2000;16(5):211–7. doi:10.1034/j.1600-9657.2000.016005211
7. Kahler B, Lin LM. A review of regenerative endodontics: current protocols and future directions. *Journal of Istanbul University Faculty of Dentistry*. 2017;51(3 Suppl 1):41–51. doi:10.17096/jiufd.53911
8. Saravanan E, Ravindran V. Evaluation of Cytotoxicity of Premixed Triple Antibiotic Paste on Stem Cells of Apical Papilla Using MTT Assay: An In Vitro Study. *International Journal of Clinical Pediatric Dentistry*. 2025;18(9):1082. doi:10.5005/jp-journals-10005-3242
9. Jamshidi D, Ansari M, Gheibi N. Cytotoxicity and genotoxicity of calcium hydroxide and two antibiotic pastes on human stem cells of the apical papilla. *European Endodontic Journal*. 2021;6(3):303. doi: 10.14744/eej.2021.97658.
10. Ramachandran VS, Radhakrishnan M, Ravindran MB, et al. Functionalized nanoparticles: a

- paradigm shift in regenerative endodontic procedures. *Cureus*. 2022;14(12). doi:10.7759/cureus.32678
11. Karkehabadi H, Khoshbin E, Abbasi R, et al. Effects of Final Root Canal Irrigants in Conventional and Regenerative Endodontic Treatments: A Systematic Review. 2024. doi: 10.34172/ajdr.1764
 12. Endodontists A A o. AAE clinical considerations for a regenerative procedure. American association of Endodontists Chicago, IL, USA; 2016.
 13. Arya A, Marwaha J, Batra D, et al. Impact of Photoactivated Disinfection on Dentin Permeability and Bacterial Eradication. *Journal of Pharmacy and Bioallied Sciences*. 2025;17(Suppl 2):S1628–S30. doi: 10.4103/jpbs.jpbs_197_25
 14. Liu H, Lu J, Jiang Q, et al. Biomaterial scaffolds for clinical procedures in endodontic regeneration. *Bioactive Materials*. 2022;12:257–77. doi: 10.1016/j.bioactmat.2021.10.008
 15. Liu S, Liang Z, Guo J, et al. Concentration-dependent effects of modified triple antibiotic paste on human periodontal ligament stem cells and antibacterial efficacy: an in vitro study. *The Saudi Dental Journal*. 2025;37(10):74. doi: 10.1007/s44445-025-00082-3
 16. Şahin E, Bodrumlu EH. Daimi İmmatür Dişlerde Rejeneratif Endodontik Tedavi: Üç Olgu Sunumu. *Journal of International Dental Sciences (Uluslararası Diş Hekimliği Bilimleri Dergisi)*. 2023;9(3):164–7 doi:10.21306/dishekimligi.1369909
 17. Divya D, Naik SV, Raju O, et al. Conceptual combination of disinfection in regenerative endodontics: Conventional versus laser-assisted disinfection. *Journal of Conservative Dentistry and Endodontics*. 2021;24(3):252–9. doi: 10.4103/jcd.jcd_96_21
 18. Baghdadi LF, Alshehri TA, Reda HA, et al. Role of Triple Antibiotic Paste in Regenerative Endodontics. 2024. doi:10.52533/JOHS.2024.41213
 19. Zancan RF, Cavenago BC, Oda DF, et al. Antimicrobial activity and physicochemical properties of antibiotic pastes used in regenerative endodontics. *Brazilian Dental Journal*. 2019;30:536–41. doi:10.1590/0103-6440201902613
 20. Karczewski A, Feitosa SA, Hamer EI, et al. Clindamycin-modified triple antibiotic nanofibers: a stain-free antimicrobial intracanal drug delivery system. *Journal of Endodontics*. 2018;44(1):155–62. doi:10.1016/j.joen.2017.08.024
 21. Ariwala FI, Calcuttawala MS. Rooted in Regeneration: An Overview on Regenerative Endodontics. *Medical Research Archives*. 2025;13(10). doi:10.18103/mra.v13i10.6981
 22. Dave AG, Mallya PL. Nanoparticles in Regenerative Endodontics: A Current Status Review. *Trends in Biomaterials and Artificial Organs*. 2025;39(1):108–12. doi:10.5281/zenodo.16793189
 23. Wong J, Zou T, Lee AHC, et al. The potential translational applications of nanoparticles in endodontics. *International Journal of Nanomedicine*. 2021:2087–106. doi:10.2147/IJN.S293518
 24. Akbarianrad N, Mohammadian F, Alhuyi Nazari M, et al. Applications of nanotechnology in endodontic: A Review. *Nanomedicine Journal*. 2018;5(3):121–6. doi: 10.22038/nmj.2018.005.0001
 25. Afkhami F, Forghan P, Gutmann JL, et al. Silver nanoparticles and their therapeutic applications in endodontics: A narrative review. *Pharmaceutics*. 2023;15(3):715. doi:10.3390/pharmaceutics15030715
 26. Oncu A, Huang Y, Amasya G, et al. Silver nanoparticles in endodontics: recent developments and applications. *Restorative Dentistry & Endodontics*. 2021;46(3). doi:10.5395/rde.2021.46.e38
 27. Pecci-Lloret MP, Gea-Alcocer S, Murcia-Flores L, et al. Use of nanoparticles in Regenerative Dentistry: a systematic review. *Biomimetics*. 2024;9(4):243. doi:10.3390/biomimetics9040243
 28. Shoaria SA, Jafarpoura A, Bagheria R, et al. Polymeric nano-biomaterials in regenerative endodontics. *Nanotechnology*. 2021;1:4. doi: 10.22034/ecc.2021.122105
 29. Antunes PVS, Flamini LES, Chaves JFM, et al. Comparative effects of final canal irrigation with chitosan and EDTA. *Journal of Applied Oral Science*. 2019;28:e20190005. doi:10.1590/1678-7757-2019-0005
 30. Bhatia S, Vaidya M, Hegde V, et al. Comparative Evaluation of the Effect of EDTA, Chitosan, Etidronic Acid, and Silver Citrate on the Mineral Content of Root Canal Dentin Using

- Energy Dispersive X-ray Spectroscopy: An In-Vitro Study. *European Endodontic Journal*. 2025;10(2):173.
31. Nagpal R, Singh S, Singh P, et al. Photoactivated Disinfection in Endodontics. *Indian Journal of Contemporary Dentistry*. 2015;3(1):29–33 doi:10.5958/2320-5962.2015.00007.8
 32. Mohan D, Maruthingal S, Indira R, et al. Photoactivated disinfection (PAD) of dental root canal system—An ex-vivo study. *Saudi Journal of Biological Sciences*. 2016;23(1):122–7. doi:10.1016/j.sjbs.2015.01.013
 33. Ali IAA, Neelakantan P. Light Activated Disinfection in Root Canal Treatment—A Focused Review. *Dentistry Journal*. 2018;6(3):31. doi:10.3390/dj6030031
 34. Johns DA, Shivashankar VY, Krishnamma S, et al. Use of photoactivated disinfection and platelet-rich fibrin in regenerative Endodontics. *Journal of Conservative Dentistry and Endodontics*. 2014;17(5):487–90. doi: 10.4103/0972-0707.139850
 35. Chrepa V, Kotsakis GA, Pagonis TC, et al. The effect of photodynamic therapy in root canal disinfection: a systematic review. *Journal of Endodontics*. 2014;40(7):891–8. doi:10.1016/j.joen.2014.03.005.
 36. Yong J, Gröger S, Wu Z, et al. Photobiomodulation therapy and pulp-regenerative endodontics: A narrative review. *Bioengineering*. 2023;10(3):371. doi:10.3390/bioengineering10030371
 37. Sabeti M, Ghobrial D, Zanjir M, et al. Treatment outcomes of regenerative endodontic therapy in immature permanent teeth with pulpal necrosis: A systematic review and network meta-analysis. *International Endodontic Journal*. 2024;57(3):238–55. doi:10.1111/iej.13999
 38. Farjaminejad R, Farjaminejad S, Garcia-Godoy F. Regenerative Endodontic Therapies: Harnessing Stem Cells, Scaffolds, and Growth Factors. *Polymers*. 2025;17(11):1475. doi:10.3390/polym17111475
 39. Fayek MA, Abouelenien SS. Influence of sodium hypochlorite used in combination with EDTA versus sodium hypochlorite mixed with etidronate irrigants on coronal fracture resistance of endodontically treated bleached teeth (a comparative in-vitro study). *Advanced Dental Journal*. 2023;5(3):651–8. doi: 10.21608/adjc.2023.209833.1306
 40. Adham AH, Ali AH, Mannocci F. Continuous chelation concept in endodontics. *Journal of Baghdad College of Dentistry*. 2022;34(4):59–69. doi:10.26477/jbcd.v34i4.3287.
 41. Cassiano AFB, Coaguila-Llerena H, Santos CS, et al. The effect of octenidine on proliferation, migration, and osteogenic differentiation of human dental pulp and apical papilla stem cells. *Journal of Endodontics*. 2022;48(12):1502–1510. doi:10.1016/j.joen.2022.09.010
 42. Bukhary S, Balto H. Antibacterial efficacy of octenisept, alexidine, chlorhexidine, and sodium hypochlorite against *Enterococcus faecalis* biofilms. *Journal of Endodontics*. 2017;43(4):643–7. doi:10.1016/j.joen.2016.09.013
 43. Durai P, Mohan M, Ramalingam H, et al. Propolis in Endodontics—Unveiling Its Therapeutic Potential: A Narrative Review. *World Journal of Dentistry*. 2025;16(10):959–66. doi:10.5005/jp-journals-10015-2619
 44. Alghutaimel H, Matoug-Elwerfelli M, Nagendrababu V, et al. Endodontic applications of propolis in primary and permanent teeth: A scoping review of clinical studies. *European Endodontic Journal*. 2024;9(3):167. doi:10.14744/eej.2024.65487

BÖLÜM 9

SONLU ELEMANLAR ANALİZİ VE ENDODONTİ

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GİRİŞ

Sonlu elemanlar analizi (SEA), bir materyalin ya da modelin tanımlanan mekanik özellikler altında maruz kalacağı gerilme durumlarının bilgisayar ortamında simüle edilmesine olanak tanıyan sayısal bir analiz yöntemidir (1). Bu yöntem ilk olarak mühendislik alanında geliştirilmiş ve yaygın biçimde kullanılmıştır (2). Zaman içerisinde hesaplama kapasitesinin ve modelleme tekniklerinin gelişmesiyle birlikte, 1970'li yıllardan itibaren diş hekimliği alanında da uygulanmaya başlanmıştır (3). Günümüzde sonlu elemanlar stres analizi, dental yapılarda oluşan karmaşık stres dağılımlarının incelenmesine imkân tanıyan en kapsamlı ve ayrıntılı yöntemlerden biri olarak kabul edilmektedir (4). Bu yaklaşımda incelenen yapı, çok sayıda küçük ve sonlu elemana ayrılarak her bir elemanın davranışı matematiksel olarak tanımlanır ve sistemin bütününe ait sonuçlar bu elemanların etkileşimi üzerinden elde edilir (5). Bu sayede, deneysel veya klinik olarak doğrudan ölçülmesi güç olan gerilme, deformasyon ve ısı dağılımları ayrıntılı biçimde analiz edilebilmektedir (6). Bu yaklaşımda incelenen yapı, çok sayıda küçük ve sonlu elemana ayrılarak her bir elemanın davranışı matematiksel olarak tanımlanır ve sistemin bütününe ait sonuçlar bu elemanların etkileşimi üzerinden elde edilir (5). Bu sayede, deneysel veya klinik olarak doğrudan ölçülmesi güç olan gerilme, deformasyon ve ısı dağılımları ayrıntılı biçimde analiz edilebilmektedir (6).

Kök kanal tedavisi sırasında uygulanan işlemler, diş ve çevre dokularda farklı düzeylerde biyomekanik gerilimler oluşturmaktadır. Bu nedenle, endodontik tedavilerin mekanik etkilerinin anlaşılması klinik başarı açısından kritik öneme sahiptir. Sonlu elemanlar analizi, diş ve periodontal dokularda oluşan mekanik ve termal gerilmelerin değerlendirilmesine, farklı tedavi yaklaşımlarının ve ma-

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yalnızca estetik açıdan değil, fonksiyonel dayanım ve uzun dönem stabilite açısından da optimize edilmiş tedavi stratejileri geliştirebilmektedir.

SONUÇ

SEA modelleme teknikleri, endodontik uygulamaların mekanik ve termal sonuçlarının öngörülmesinde etkili bir araç olarak öne çıkmaktadır (23). Diş ve çevre dokuların dijital ortamda gerçekçi biçimde temsil edilmesi, şekillendirme, obturasyon ve restoratif işlemler sırasında oluşabilecek gerilme dağılımları ile sıcaklık değişimlerinin klinik uygulama öncesinde değerlendirilmesine olanak tanımaktadır (50). Bu sayede frez seçimi, ısı aktivasyon süreleri ve restoratif materyal tercihleri gibi kritik parametrelerin biyomekanik etkileri sanal ortamda analiz edilerek olası doku hasarı riskleri azaltılabilmektedir (37).

Kanal tedavisi ve takip eden restoratif aşamalar için geliştirilen modeller, malzeme özellikleri ve yükleme koşullarının doğru tanımlanmasıyla klinik açıdan anlamlı ve karşılaştırılabilir sonuçlar üretmektedir (55). PDL'nin termal tolerans sınırlarının korunması, radiküler dentinde stres yoğunlaşmalarının kontrol altına alınması ve cerrahi girişimlerde rezeksiyon tiplerinin kemik-kök etkileşimine etkilerinin önceden değerlendirilmesi, bu yaklaşımın pratik katkıları arasındadır (35).

Sonuç olarak, anatomik doğruluğu yüksek modeller ve güvenilir mekanik girişimlerle desteklenen sayısal analizler, endodontik tedavilerin biyomekanik ve termal açıdan optimize edilmesine olanak sağlayarak hem klinik güvenliği hem de uzun dönem tedavi başarısını destekleyen temel bir yöntem niteliği taşımaktadır (23).

KAYNAKLAR

1. Hammond D, Whitty J. Finite element analysis and dentistry. *Faculty Dental Journal*. 2015;6(3):134-9. doi: 10.1308/rcsfjd.2015.134
2. Thresher R W, Saito G E. The stress analysis of human teeth. *Journal of biomechanics*. 1973;6(5):443-9. doi: 10.1016/0021-9290(73)90003-1
3. Farah J, Craig R G. Finite element stress analysis of a restored axisymmetric first molar. *Journal of dental research*. 1974;53(4):859-66. doi: 10.1177/00220345740530041701
4. Versluis A, Tantbirojn D. Relationship between shrinkage and stress. *Dental computing and applications: advanced techniques for clinical dentistry*: IGI Global; 2009. p. 45-64. doi: 10.4018/978-1-60566-292-3.ch003.
5. Moatamedi M, Khawaja H. Finite element analysis: CRC Press; 2018. doi: 10.1201/9780429453076
6. Bandela V, Kanaparthi S. Finite element analysis and its applications in dentistry. *Finite Element Methods and Their Applications*: IntechOpen; 2020.
7. Aktı A, Kaya D. Finite Element Analysis and Application in Dental Implantology. *Stress*. 2020;17:18.

8. Jm P. Craig's restorative dental materials. Mechanical properties. 2006:51-96.
9. Fung Y-c. Biomechanics: mechanical properties of living tissues: Springer Science & Business Media; 2013.
10. Marghitu D B. Mechanical engineer's handbook: Elsevier; 2001, Sung S J, Baik H S, Moon Y S, et al. A comparative evaluation of different compensating curves in the lingual and labial techniques using 3D FEM. *American journal of orthodontics and dentofacial orthopedics*. 2003;123(4):441-50. doi: 10.1067/mod.2003.9
11. Küçükkurt S. Sonlu Elemanlar Stres Analiz Yöntemi ve Dental İmplantoloji Alanında Yapılan Araştırmalar. *Atatürk Üniversitesi Diş Hekimliği Fakültesi Dergisi*. 2019;29(4):701-10.
12. Rho J Y, Ashman R B, Turner C H. Young's modulus of trabecular and cortical bone material: ultrasonic and microtensile measurements. *Journal of biomechanics*. 1993;26(2):111-9. doi: 10.1016/0021-9290(93)90042-D
13. Baccouch M. A brief summary of the finite element method for differential equations: IntechOpen; 2021. doi: 10.5772/intechopen.95423
14. Reddy J N. An Introduction to Nonlinear Finite Element Analysis: with applications to heat transfer, fluid mechanics, and solid mechanics: Oxford university press; 2015.
15. Dorado S, Arias A, Jimenez-Octavio J R. Biomechanical modelling for tooth survival studies: mechanical properties, loads and boundary conditions—a narrative review. *Materials*. 2022;15(21):7852. doi: 10.3390/ma15217852
16. Atif M, Tewari N, Reshikesh M, et al. Methods and applications of finite element analysis in dental trauma research: A scoping review. *Dental Traumatology*. 2024;40(4):366-88. doi: 10.1111/edt.12933
17. Morakul S, Hiran-us S, Singhatanadgid P. Finite element analysis of the mechanical behaviors of endodontic nickel–titanium rotary files: a review. *Engineering Journal*. 2023;27(8):29-49. doi: 10.4186/ej.2023.27.8.29
18. Conte J P, Vijalapura P, Meghella M. Consistent finite-element response sensitivity analysis. *Journal of Engineering Mechanics*. 2003;129(12):1380-93. doi: 10.1061/(ASCE)0733-9399(2003)129:12(138)
19. Meirelles L C F, Pierre F Z, Tribst J P M, et al. Influence of preparation design, restorative material and load direction on the stress distribution of ceramic veneer in upper central incisor. *Brazilian Dental Science*. 2021;24(3). doi: 10.14295/bds.2021.v24i3.2494
20. Jamshid U M, Rohit R, Shajahan P. The Effect of Stress Distribution by Fiberglass Post System With Different Designs on Endodontically Treated Maxillary Central Incisors: A Three-Dimensional Finite Element Analysis. *Cureus*. 2025;17(3). doi: 10.7759/cureus.81545
21. Boolakee O, Geier M, De Lorenzis L. Dirichlet and Neumann boundary conditions for a lattice Boltzmann scheme for linear elastic solids on arbitrary domains. *Computer Methods in Applied Mechanics and Engineering*. 2023;415:116225. doi: 10.1016/j.cma.2023.116225
22. Uzel Ö S, Ayna B. Farklı Fiberle Güçlendirilmiş Kompozit Rezinler ile Tedavi Edilen Kök Kanal Tedavili Maksiller Kesici Dişlerde Oluşan Stres Dağılımının Sonlu Elemanlar Analizi ile Değerlendirilmesi. *HRU International Journal of Dentistry and Oral Research*. 3(2):91-8. doi: 10.61139/ijdor.1310349
23. Abdelhafeez M M. Applications of finite element analysis in endodontics: a systematic review and Meta-analysis. *Journal of Pharmacy and Bioallied Sciences*. 2024;16(Suppl 3):S1977-S80. doi: 10.4103/jpbs.jpbs_393_24
24. Yu M, Li Y, Zhao M, et al. Computational fluid dynamics investigation on the irrigation of a real root canal with a side-vented needle. *BMC Oral Health*. 2024;24(1):321. doi: 10.1186/s12903-024-03966-8
25. Silva B R d, Ferreira N C, Moreira-Neto J J S, et al. Stress distribution on maxillary central incisor under similar traumatic situations with different loading forces: a 3-D finite element analysis. *Arquivos em Odontologia*. 2013;49(2):52-9.
26. Mitra D, Gurav P, Rodrigues S, et al. Evaluation of stress distribution in and around dental imp-

- lants using three different implant–abutment interfaces with platform-switched and non-platform-switched abutments: A three-dimensional finite element analysis. *Journal of Dental Research, Dental Clinics, Dental Prospects*. 2023;17(4):256. doi: 10.34172/jodddd.2023.40723
27. Mohamed A M A, Askar M G, El Homossany M E-M B. Stresses induced by one piece and two piece dental implants in All-on-4° implant supported prosthesis under simulated lateral occlusal loading: non linear finite element analysis study. *BMC Oral Health*. 2022;22(1):196. doi: 10.1186/s12903-022-02228-9
 28. Reddy K U K, Seth A, Vuppuluri A, et al. Exploring the bio-mechanical behavior of PEEK and CFR-PEEK materials for dental implant applications using finite element analysis. *Journal of Prosthodontic Research*. 2024;69(1):41-8. doi: 10.2186/jpr.JPR_D_23_00296
 29. Satpathy M, Duan Y, Betts L, et al. Effect of bone remodeling on dental implant fatigue limit predicted using 3D finite element analysis. *Journal of dentistry and oral epidemiology*. 2022;2(1). doi: 10.54289/jdoe2200102.
 30. Huang M, Wang B, Zhang K, et al. Comparative analysis of stress distribution in residual roots with different canal morphologies: evaluating CAD/CAM glass fiber and other post-core materials. *BMC Oral Health*. 2024;24(1):337.
 31. Ellendula Y, Sekar A C, Nalla S, et al. Biomechanical evaluation of stress distribution in equicrestal and sub-crestally placed, platform-switched Morse taper dental implants in D3 bone: Finite Element Analysis. *Cureus*. 2022;14(4).
 32. Nikolova N, Raykovska M, Petkov N, et al. The Integration of Micro-CT Imaging and Finite Element Simulations for Modelling Tooth-Inlay Systems for Mechanical Stress Analysis: A Preliminary Study. *Journal of Functional Biomaterials*. 2025;16(7):267.
 33. Dal Piva A M d O, Tribst J P M, Borges A L S, et al. CAD-FEA modeling and analysis of different full crown monolithic restorations. *Dental Materials*. 2018;34(9):1342-50.
 34. Gomes É A, Gueleri D B, da Silva S R C, et al. Three-dimensional finite element analysis of endodontically treated teeth with weakened radicular walls restored with different protocols. *The Journal of Prosthetic Dentistry*. 2015;114(3):383-9.
 35. Cen R, Wang R, Cheung G S. Periodontal blood flow protects the alveolar bone from thermal injury during thermoplasticized obturation: a finite element analysis study. *Journal of Endodontics*. 2018;44(1):139-44. doi: 10.1016/j.joen.2017.08.004
 36. Zhou X, Chen Y, Wei X, et al. Heat transfers to periodontal tissues and gutta-percha during thermoplasticized root canal obturation in a finite element analysis model. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*. 2010;110(2):257-63. doi: 10.1016/j.tripleo.2010.04.005
 37. Guerrero L G S, Balseca M A, Freitas K M S, et al. Mechanical evaluation of EGUH burs in dentin during guided endodontics: Finite element analysis. *Saudi Endodontic Journal*. 2025;15(3):237-44. doi: 10.4103/sej.sej_11_25
 38. Haider A. Enhancing Transparency and Reproducibility in Finite Element Analysis through Comprehensive Reporting Parameters A Review. *El-Cezeri*. 2024;11(3):212-22. doi: 10.31202/ecjse.1436203
 39. Tanaka R, Yamaguchi S, Takahashi Y, et al. Mechanical behavior of endodontically treated teeth: A three-dimensional finite element analysis using displacement vector. *Journal of Prosthodontics*. 2025;34(3):281-9. doi: 10.1111/jopr.13810
 40. Rivera-Peña M E, Duarte M A H, Alcalde M P, et al. A novel ultrasonic tip for removal of filling material in flattened/oval-shaped root canals: a microCT study. *Brazilian Oral Research*. 2018;32:e88. doi: 10.1590/1807-3107bor-2018.vol32.0088
 41. Gharechahi M, Moezzi S, Karimpour S. Comparative analysis of stress distribution through finite-element models of 3 NiTi endodontic instruments while operating in different canal types. *Journal of Dentistry*. 2023;24(1):60. doi: 10.30476/DENTJODS.2022.90785.1522
 42. Esim E, Er Ö, Aslan T, et al. Finite Element Analysis of 3D Transient Linear Temperature Changes in the Periodontal Ligament During Thermoplasticized Gutta-Percha Obturation Tech-

- niques. *Meandros Medical And Dental Journal*. 2024;25(4):379-95. doi: 10.69601/meandrosmdj.1541566
43. Hegde V R, Jain P B, Bhagat P S. Assessment of heat transfer to periodontal tissues and stress distribution in a tooth with simulated internal resorption cavities at different root levels using two thermoplasticized obturation systems–A finite element analysis study. *Endodontology*. 2022;34(4):275-81. doi: 10.4103/endo.endo_144_22
 44. Zheng L, Yang S, Gao H, et al. Micromechanical Modeling and Damage Mechanism Analysis of M55J High-Modulus Carbon Fiber Composites With Diverse Fiber Arrangements. *Polymer Composites*. 2026;47(2):1644-60. doi: 10.1002/pc.70242
 45. Mon A, Kim M-E, Kum K-Y, et al. 3D finite element analysis of stress distribution on the shape of resected root-end or with/without bone graft of a maxillary premolar during endodontic microsurgery. *Journal of Dental Sciences*. 2024;19(2):837-45. doi: 10.1016/j.jds.2023.08.029
 46. Kaiser A H, Bourauel C. Towards a reduced order model of the periodontal ligament. *Scientific Reports*. 2025;15(1):5779. doi: 10.1038/s41598-025-88767-x
 47. Wang D, Akbari A, Jiang F, et al. The effects of different types of periodontal ligament material models on stresses computed using finite element models. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2022;162(6):e328-e36. doi: 10.1016/j.ajodo.2022.09.008
 48. Battle H, Lallier T E, Boenke L, et al. Comparing Gutta Percha Backfill Leakage Over Multiple Heating Cycles. *SVOA Dentistry*. 2025;6(4). doi: 10.58624/SVOADE.2025.06.019
 49. Chi J, Yin L, Ma S, et al. 3D Printed Guides and Finite Element Analysis in Dental Autotransplantation: Biomechanical Efficiency and Clinical Workflow Optimization. *Dental Traumatology*. 2026;42(1):104-13. doi: 10.1111/edt.13087
 50. Kırmalı Ö, Akar M B, Çelik H K, et al. Stress distribution in endodontically treated and differently restored teeth with periapical lesions: a 3D FEA study. *BMC Oral Health*. 2025;25(1):1326. doi: 10.1186/s12903-025-06682-z
 51. Kharboutly N A-D, Allaf M, Kanout S. Three-dimensional finite element study of endodontically treated maxillary central incisors restored using different post and crown materials. *Cureus*. 2023;15(1):e33778. doi: 10.7759/cureus.33778
 52. Çelik Köycü B, İmirzalıoğlu P. Heat transfer and thermal stress analysis of a mandibular molar tooth restored by different indirect restorations using a three-dimensional finite element method. *Journal of Prosthodontics*. 2017;26(5):460-73. doi: 10.1111/jopr.12397
 53. Toparli M, Sasaki S. Finite element analysis of the temperature and thermal stress in a postrestored tooth. *Journal of oral rehabilitation*. 2003;30(9):921-6. doi: 10.1046/j.1365-2842.2003.01071.x
 54. Babaei B, Shouha P, Birman V, et al. The effect of dental restoration geometry and material properties on biomechanical behaviour of a treated molar tooth: A 3D finite element analysis. *Journal of the mechanical behavior of biomedical materials*. 2022;125. doi: 10.1016/j.jmbm.2021.104892
 55. Kırmalı Ö, İcen G, Çelik H K, et al. Evaluation of stress distribution on an endodontically treated maxillary central tooth with lesion restored with different crown materials: A finite element analysis. *Heliyon*. 2024;10(3). doi: 10.1016/j.heliyon.2024.e25829

BÖLÜM 10

ENDODONTİK TEDAVİDE HİDROLİK MATERYALLER

Sine GÜNGÖR US¹

GİRİŞ

Modern diş hekimliğinde, vital pulpa tedavilerinin, rejeneratif yaklaşımların ve doku koruma stratejilerinin önem kazanmasıyla birlikte endodonti alanı, onarımdan ziyade rejenerasyonu destekleyen biyoaktif materyallerin kullanımına doğru evrilmiştir (1). Bu bağlamda, hidrolik kalsiyum silikat bazlı simanlar (hydraulic calcium silicate cements; HCSCs) üstün fiziksel, kimyasal ve biyolojik özellikleri nedeniyle endodontik tedavilerin vazgeçilmez bir unsuru haline gelmiştir (2). “Biyoseramikler” olarak da adlandırılan bu materyaller, doku sıvılarıyla temas ettiklerinde çözünmeyen, hermetik bir tıkaç sağlayan ve sert doku oluşumunu indükleme kapasitesine sahip yapılarıyla öne çıkmaktadır (1, 3). Bu materyaller için literatürde kabul gören en doğru terminoloji, kimyasal yapıları ve sertleşme mekanizmalarını yansıtan ‘hidrolik kalsiyum silikat bazlı simanlar’dır (4).

“Hidrolik” terimi, Yunanca su anlamına gelen *hydra* kelimesinden türetilmiştir. Hidrolik simanlar, su ile temas ettiğinde sertleşir ve nemli ortamda stabil kalır (3). Diş hekimliğinde bu materyallerin kökeni, 1878 yılında kök kanallarını doldurmak amacıyla Portland çimentosunun kullanılmasına kadar uzansa da, klinik pratikte yaygınlaşmaları 1990’lı yıllarda Mineral Trioksit Agregat’ın (MTA) tanıtılmasıyla başlamıştır (2, 5, 6).

MTA, biyoyumluluğu ve nem varlığında sertleşebilme özelliği sayesinde endodontide yeni bir dönemin başlangıcı olarak kabul edilmiştir (7, 8). Bu özellikleri sayesinde MTA; dentin replasmanı, pulpa kapatma/pulpotomi, açık apeksli dişlerde apikal bariyer oluşturulması, perforasyon ve rezorptif defekt onarımları ile ortograd/retrograd kök kanal dolguları gibi çok sayıda endikasyonda klinik kullanıma girmiştir (2, 9).

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yali kullanmaktan ziyade, doğru endikasyonda doğru materyalin, bilimsel kanıta dayalı ve titiz bir klinik uygulama ile seçilmesine bağlıdır.

KAYNAKLAR

1. Sanz JL, Rodríguez-Lozano FJ, Lopez-Gines C, et al. Dental stem cell signaling pathway activation in response to hydraulic calcium silicate-based endodontic cements: A systematic review of in vitro studies. *Dental Materials*. 2021;37(4): e256-e268. doi:10.1016/j.dental.2021.01.025
2. Prati C, Gandolfi MG. Calcium silicate bioactive cements: Biological perspectives and clinical applications. *Dental Materials*. 2015;31(4): 351-370. doi:10.1016/j.dental.2015.01.004
3. Camilleri J, Atmeh A, Li X, et al. Present status and future directions: Hydraulic materials for endodontic use. *International Endodontic Journal*. 2022;55 Suppl 3(Suppl 3): 710-777. doi:10.1111/iej.13709
4. Cardinali F, Camilleri J. A critical review of the material properties guiding the clinician's choice of root canal sealers. *Clinical Oral Investigations*. 2023;27(8): 4147-4155. doi:10.1007/s00784-023-05140-w
5. Witte D. The filling of a root canal with Portland cement. *J Cent Assoc Ger Dent*. 1878;18(153-154).
6. Viola NV, Tanomaru Filho M, Cerri PS. MTA versus Portland cement: review of literature. *Revista Sul-Brasileira de Odontologia*. 2011;8(4): 446-452.
7. Torabinejad M, Watson TF, Pitt Ford TR. Sealing ability of a mineral trioxide aggregate when used as a root end filling material. *Journal of Endodontics*. 1993;19(12): 591-595. doi:10.1016/s0099-2399(06)80271-2
8. Lee SJ, Monsef M, Torabinejad M. Sealing ability of a mineral trioxide aggregate for repair of lateral root perforations. *Journal of Endodontics*. 1993;19(11): 541-544. doi:10.1016/s0099-2399(06)81282-3
9. Niu LN, Jiao K, Wang TD, et al. A review of the bioactivity of hydraulic calcium silicate cements. *Journal of Dentistry*. 2014;42(5): 517-533. doi:10.1016/j.jdent.2013.12.015
10. Camilleri J. Classification of hydraulic cements used in dentistry. *Frontiers in Dental Medicine*. 2020;1(9).
11. Eskandari F, Razavian A, Hamidi R, et al. An Updated Review on Properties and Indications of Calcium Silicate-Based Cements in Endodontic Therapy. *International Dental Journal*. 2022;2022(6858088). doi:10.1155/2022/6858088
12. Dutta A, Saunders WP. Calcium silicate materials in endodontics. *Dental Update*. 2014;41(8): 708-722.
13. Islam I, Chng HK, Yap AU. Comparison of the physical and mechanical properties of MTA and portland cement. *Journal of Endodontics*. 2006;32(3): 193-197. doi:10.1016/j.joen.2005.10.043
14. Parirokh M, Torabinejad M. Mineral trioxide aggregate: a comprehensive literature review-- Part I: chemical, physical, and antibacterial properties. *Journal of Endodontics*. 2010;36(1): 16-27. doi:10.1016/j.joen.2009.09.006
15. Parirokh M, Torabinejad M. Calcium silicate-based cements. In: (ed.) Mineral trioxide aggregate: Properties and clinical applications. 2014. p. 281-332.
16. Camilleri J. The chemical composition of mineral trioxide aggregate. *Journal of Conservative Dentistry and Endodontics*. 2008;11(4): 141-143.
17. Asgary S, Parirokh M, Eghbal MJ, et al. Chemical differences between white and gray mineral trioxide aggregate. *Journal of Endodontics*. 2005;31(2): 101-103. doi:10.1097/01.don.0000133156.85164.b2
18. Camilleri J, Montesin FE, Brady K, et al. The constitution of mineral trioxide aggregate. *Dental Materials*. 2005;21(4): 297-303. doi:10.1016/j.dental.2004.05.010
19. Kogan P, He J, Glickman GN, et al. The effects of various additives on setting properties of

- MTA. *Journal of Endodontics*. 2006;32(6): 569-572.
20. Parirokh M, Torabinejad M. Mineral trioxide aggregate: a comprehensive literature review-- Part III: Clinical applications, drawbacks, and mechanism of action. *Journal of Endodontics*. 2010;36(3): 400-413. doi:10.1016/j.joen.2009.09.009
 21. Oliveira MG, Xavier CB, Demarco FF, et al. Comparative chemical study of MTA and Portland cements. *Brazilian Dental Journal*. 2007;18(1): 3-7. doi:10.1590/s0103-64402007000100002
 22. Madfa AA, Al-Sanabani FA, Al-Kudami NH. Endodontic repair filling materials: A review article. *British Journal of Medicine and Medical Research*. 2014;4(16): 3059-3079.
 23. Grech L, Mallia B, Camilleri J. Investigation of the physical properties of tricalcium silicate cement-based root-end filling materials. *Dental Materials*. 2013;29(2): e20-28. doi:10.1016/j.dental.2012.11.007
 24. Grech L, Mallia B, Camilleri J. Characterization of set Intermediate Restorative Material, Biodentine, Bioaggregate and a prototype calcium silicate cement for use as root-end filling materials. *International Endodontic Journal*. 2013;46(7): 632-641. doi:10.1111/iej.12039
 25. Shokouhinejad N, Nekoofar MH, Razmi H, et al. Bioactivity of EndoSequence root repair material and bioaggregate. *International Endodontic Journal*. 2012;45(12): 1127-1134. doi:10.1111/j.1365-2591.2012.02083.x
 26. Arandi NZ, Thabet M. Minimal Intervention in Dentistry: A Literature Review on Biodentine as a Bioactive Pulp Capping Material. *BioMed Research International*. 2021;2021(5569313). doi:10.1155/2021/5569313
 27. Koutroulis A, Kapralos V, Ørstavik D, et al. Root-filling materials for endodontic surgery: biological and clinical aspects. *Biomaterial Investigations in Dentistry*. 2024;11(42172). doi:10.2340/biid.v11.42172
 28. Yune JY, Lee D, Kim SY. The Combined Effects of Hydraulic Calcium Silicate Cement and Enamel Matrix Derivative Regarding Osteogenic and Dentinogenic Differentiation on Human Dental Pulp Stem Cells. *Materials (Basel)*. 2023;16(11): doi:10.3390/ma16114003
 29. Schuster L, Sielker S, Kleinheinz J, et al. Effect of light-cured pulp capping materials on human dental pulp cells in vitro. *International Endodontic Journal*. 2025;58(7): 1060-1072. doi:10.1111/iej.14242
 30. Pedano MS, Li X, Li S, et al. Freshly-mixed and setting calcium-silicate cements stimulate human dental pulp cells. *Dental Materials*. 2018;34(5): 797-808. doi:10.1016/j.dental.2018.02.005
 31. Setzer FC, Kratchman SI. Present status and future directions: Surgical endodontics. *International Endodontic Journal*. 2022;55 Suppl 4(1020-1058). doi:10.1111/iej.13783
 32. Rajasekharan S, Martens LC, Cauwels R, et al. Biodentine™ material characteristics and clinical applications: a 3 year literature review and update. *European Archives of Paediatric Dentistry*. 2018;19(1): 1-22. doi:10.1007/s40368-018-0328-x
 33. Kebudi Benezra M, Schembri Wismayer P, Camilleri J. Interfacial Characteristics and Cyto-compatibility of Hydraulic Sealer Cements. *Journal of Endodontics*. 2018;44(6): 1007-1017. doi:10.1016/j.joen.2017.11.011
 34. Hansen SW, Marshall JG, Sedgley CM. Comparison of intracanal EndoSequence Root Repair Material and ProRoot MTA to induce pH changes in simulated root resorption defects over 4 weeks in matched pairs of human teeth. *Journal of Endodontics*. 2011;37(4): 502-506. doi:10.1016/j.joen.2011.01.010
 35. Zhou HM, Shen Y, Zheng W, et al. Physical properties of 5 root canal sealers. *Journal of Endodontics*. 2013;39(10): 1281-1286. doi:10.1016/j.joen.2013.06.012
 36. Dong X, Xu X. Bioceramics in Endodontics: Updates and Future Perspectives. *Bioengineering (Basel)*. 2023;10(3): doi:10.3390/bioengineering10030354
 37. Ree M, Schwartz R. Clinical applications of bioceramics materials in endodontics. *Endodontic Practice*. 2014;7(32-40).
 38. Jiang Y, Zheng Q, Zhou X, et al. A comparative study on root canal repair materials: a cyto-compatibility assessment in L929 and MG63 cells. *Scientific World Journal*. 2014;2014(463826).

- doi:10.1155/2014/463826
39. Gandolfi MG, Siboni F, Prati C. Chemical-physical properties of TheraCal, a novel light-curable MTA-like material for pulp capping. *International Endodontic Journal*. 2012;45(6): 571-579. doi:10.1111/j.1365-2591.2012.02013.x
 40. Qureshi A, E S, Nandakumar, et al. Recent advances in pulp capping materials: an overview. *Journal of Clinical and Diagnostic Research*. 2014;8(1): 316-321. doi:10.7860/jcdr/2014/7719.3980
 41. Jeanneau C, Laurent P, Rombouts C, et al. Light-cured Tricalcium Silicate Toxicity to the Dental Pulp. *Journal of Endodontics*. 2017;43(12): 2074-2080. doi:10.1016/j.joen.2017.07.010
 42. Assmann E, Scarparo RK, Böttcher DE, et al. Dentin bond strength of two mineral trioxide aggregate-based and one epoxy resin-based sealers. *Journal of Endodontics*. 2012;38(2): 219-221. doi:10.1016/j.joen.2011.10.018
 43. Gandolfi MG, Taddei P, Siboni F, et al. Development of the foremost light-curable calcium-silicate MTA cement as root-end in oral surgery. Chemical-physical properties, bioactivity and biological behavior. *Dental Materials*. 2011;27(7): e134-157. doi:10.1016/j.dental.2011.03.011
 44. Gancedo-Caravia L, Garcia-Barbero E. Influence of humidity and setting time on the push-out strength of mineral trioxide aggregate obturations. *Journal of Endodontics*. 2006;32(9): 894-896. doi:10.1016/j.joen.2006.03.004
 45. Walsh RM, Woodmansey KF, Glickman GN, et al. Evaluation of compressive strength of hydraulic silicate-based root-end filling materials. *Journal of Endodontics*. 2014;40(7): 969-972. doi:10.1016/j.joen.2013.11.018
 46. Camilleri J, Sorrentino F, Damidot D. Investigation of the hydration and bioactivity of radiopacified tricalcium silicate cement, Biodentine and MTA Angelus. *Dental Materials*. 2013;29(5): 580-593. doi:10.1016/j.dental.2013.03.007
 47. Nekoofar MH, Stone DF, Dummer PM. The effect of blood contamination on the compressive strength and surface microstructure of mineral trioxide aggregate. *International Endodontic Journal*. 2010;43(9): 782-791. doi:10.1111/j.1365-2591.2010.01745.x
 48. Torabinejad M, Higa RK, McKendry DJ, et al. Dye leakage of four root end filling materials: effects of blood contamination. *Journal of Endodontics*. 1994;20(4): 159-163. doi:10.1016/s0099-2399(06)80326-2
 49. Iacono F, Gandolfi MG, Huffman B, et al. Push-out strength of modified Portland cements and resins. *American Journal of Dentistry*. 2010;23(1): 43-46.
 50. Dawood AE, Manton DJ, Parashos P, et al. The physical properties and ion release of CPP-ACP-modified calcium silicate-based cements. *Australian Dental Journal*. 2015;60(4): 434-444. doi:10.1111/adj.12255
 51. Gandolfi MG, Siboni F, Botero T, et al. Calcium silicate and calcium hydroxide materials for pulp capping: biointeractivity, porosity, solubility and bioactivity of current formulations. *Journal of Applied Biomaterials and Functional Materials*. 2015;13(1): 43-60. doi:10.5301/jabfm.5000201
 52. Marciano MA, Costa RM, Camilleri J, et al. Assessment of color stability of white mineral trioxide aggregate angelus and bismuth oxide in contact with tooth structure. *Journal of Endodontics*. 2014;40(8): 1235-1240. doi:10.1016/j.joen.2014.01.044
 53. Camilleri J. Color stability of white mineral trioxide aggregate in contact with hypochlorite solution. *Journal of Endodontics*. 2014;40(3): 436-440. doi:10.1016/j.joen.2013.09.040
 54. Kaur M, Singh H, Dhillon JS, et al. MTA versus Biodentine: Review of Literature with a Comparative Analysis. *Journal of Clinical and Diagnostic Research*. 2017;11(8): Zg01-zg05. doi:10.7860/jcdr/2017/25840.10374
 55. Li X, Pedano MS, Camargo B, et al. Experimental tricalcium silicate cement induces reparative dentinogenesis. *Dental Materials*. 2018;34(9): 1410-1423. doi:10.1016/j.dental.2018.06.016
 56. Atmeh AR, Chong EZ, Richard G, et al. Dentin-cement interfacial interaction: calcium silicates and polyalkenoates. *Journal of Dental Research*. 2012;91(5): 454-459. doi:10.1177/0022034512443068

57. Song X, Díaz-Cuenca A. Sol-Gel Synthesis of Endodontic Cements: Post-Synthesis Treatment to Improve Setting Performance and Bioactivity. *Materials (Basel)*. 2022;15(17): doi:10.3390/ma15176051
58. Rodrigues NS, França CM, Tahayeri A, et al. Biomaterial and Biofilm Interactions with the Pulp-Dentin Complex-on-a-Chip. *Journal of Dental Research*. 2021;100(10): 1136-1143. doi:10.1177/00220345211016429
59. Paula A, Laranjo M, Marto CM, et al. Biodentine™ Boosts, WhiteProRoot® MTA Increases and Life® Suppresses Odontoblast Activity. *Materials (Basel)*. 2019;12(7): doi:10.3390/ma12071184
60. Manaspon C, Jongwannasiri C, Chumprasert S, et al. Human dental pulp stem cell responses to different dental pulp capping materials. *BMC Oral Health*. 2021;21(1): 209. doi:10.1186/s12903-021-01544-w
61. Yousefi-Koma AA, Assadian H, Mohaghegh S, et al. Comparative Biocompatibility and Odontogenic/Osteogenesis Effects of Hydraulic Calcium Silicate-Based Cements in Simulated Direct and Indirect Approaches for Regenerative Endodontic Treatments: A Systematic Review. *Journal of Functional Biomaterials*. 2023;14(9): doi:10.3390/jfb14090446
62. Ha YJ, Lee D, Kim SY. The Combined Effects on Human Dental Pulp Stem Cells of Fast-Set or Premixed Hydraulic Calcium Silicate Cements and Secretome Regarding Biocompatibility and Osteogenic Differentiation. *Materials (Basel)*. 2024;17(2): doi:10.3390/ma17020305
63. Duncan HF, Galler KM, Tomson PL, et al. European Society of Endodontology position statement: Management of deep caries and the exposed pulp. *Int Endod J*. 2019;52(7): 923-934. doi:10.1111/iej.13080
64. Staffoli S, Plotino G, Nunez Torrijos BG, et al. Regenerative Endodontic Procedures Using Contemporary Endodontic Materials. *Materials (Basel)*. 2019;12(6): doi:10.3390/ma12060908
65. Herbst SR, Pitchika V, Herbst CS, et al. Effectiveness of calcium hydroxide compared to hydraulic calcium silicate cements for direct pulp capping in managing deep caries in vital permanent teeth: A systematic review and meta-analysis. *International Endodontic Journal*. 2025;58(8): 1110-1125. doi:10.1111/iej.14256
66. Choi M, Kwon J, Jang JH, et al. Enhancing the Biological Properties of Organic-Inorganic Hybrid Calcium Silicate Cements: An In Vitro Study. *Journal of Functional Biomaterials*. 2024;15(11): doi:10.3390/jfb15110337
67. Duncan HF, El-Karim I. Endodontic S3-level clinical practice guidelines: the European Society of Endodontology process and recommendations. *British Dental Journal*. 2025;238(7): 580-586. doi:10.1038/s41415-025-8335-x

BÖLÜM 11

MTA MODİFİKASYONUNDA KULLANILAN NANOPARTİKÜLLER

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GİRİŞ

Mineral trioksit agregat (MTA), kalsiyum silikat bazlı biyoseramik materyaller arasında endodontide en yaygın kullanılan ve en fazla araştırılan materyallerden biridir. Biyoseramiklerin 1990'lı yılların başında endodonti alanına girmesiyle birlikte biyoyumlu ve bioaktif materyallere yönelik ilgi artmakta; bu süreçte MTA, kök ucu dolgu materyali olarak kullanılması amacıyla geliştirilen ilk bioaktif seramik materyaldir ve daha sonra birçok klinik endikasyonda kullanılmaya başlanmıştır (1). MTA'nın Portland çimentosu temelli yapısı, yüksek biyoyumluluğu ve üstün sızdırmazlık özellikleri, endodontik tedavilerde öngörülebilir iyileşme ve başarılı klinik sonuçlar ile ilişkilendirilmektedir (2).

Kimyasal olarak MTA, başlıca trikalsiyum silikat, dikalsiyum silikat ve trikalsiyum alüminat bileşenlerinden oluşmakta ve radyopasite sağlamak amacıyla bizmut oksit içermektedir (3). Hidratasyon reaksiyonu sonucunda kalsiyum hidroksit açığa çıkmakta ve alkalın bir ortam oluşmaktadır; bu durum hem antimikrobiyal etkiyi desteklemekte hem de sert doku oluşumunu ve biyolojik iyileşmeyi teşvik etmektedir (4). Hidrolik yapısı sayesinde nem varlığında sertleşebilmesi, materyalin klinik koşullarda uygulanabilirliğini artırmaktadır (1, 5).

MTA; pulpa kaplama, pulpotomi, apeksifikasyon, rejeneratif endodontik tedavi, perforasyon onarımı ve retrograd dolgu uygulamaları gibi geniş bir klinik kullanım alanına sahiptir. Bu uygulamalardaki başarısı; biyoyumluluğu, sızdırmazlık yeteneği ve sert doku oluşumunu indükleyici özellikleri ile açıklanmaktadır (6). Bununla birlikte, uzun sertleşme süresi, manipülasyon zorluğu, renklenme potansiyeli ve maliyet gibi bazı dezavantajlar materyalin klinik kullanımını sınırlandırmaktadır (7).

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Nanopartiküllerle modifiye edilmiş MTA'nın biyouyumluluk, sitotoksisite ve uzun dönem klinik performansı gibi parametrelerinin daha kapsamlı biçimde değerlendirilmesi gerekmektedir. Özellikle *in vitro* bulguların klinik çalışmalara aktarılması, biyolojik güvenilirlik sınırlarının belirlenmesi ve materyalin gerçek klinik koşullardaki davranışının incelenmesi gelecekteki araştırmalar için öncelikli alanlar arasında yer almaktadır.

Sonuç olarak nanoteknoloji, MTA'nın mevcut sınırlılıklarını azaltmaya ve endodontik biyomateryallerin performansını artırmaya yönelik güçlü bir yaklaşım sunmaktadır. Nanopartikül temelli modifikasyonların, daha etkili, biyouyumlu ve klinik olarak öngörülebilir yeni nesil endodontik materyallerin geliştirilmesine katkı sağlayacağı düşünülmektedir.

KAYNAKLAR

1. Parirokh M, Torabinejad M. Mineral trioxide aggregate: a comprehensive literature review—part I: chemical, physical, and antibacterial properties. *Journal of Endodontics*. 2010;36(1):16-27.
2. Dong X, Xu X. Bioceramics in endodontics: updates and future perspectives. *Bioengineering*. 2023;10(3):354.
3. Mohammadi Z, Shalavi S, Soltani MK. Mineral trioxide aggregate (MTA)-like materials: an update review. *Compendium of continuing education in dentistry (Jamesburg, NJ: 1995)*. 2014;35(8):557-61: quiz 62.
4. Estrela C, Cintra LTA, Duarte MAH, et al. Mechanism of action of bioactive endodontic materials. *Brazilian Dental Journal*. 2023;34(1):1-11.
5. Huang T-H, Shie M-Y, Kao C-T, et al. The effect of setting accelerator on properties of mineral trioxide aggregate. *Journal of endodontics*. 2008;34(5):590-3.
6. Wang X, Xiao Y, Song W, et al. Clinical application of calcium silicate-based bioceramics in endodontics. *Journal of translational medicine*. 2023;21(1):853.
7. Pushpalatha C, Dhareshwar V, Sowmya S, et al. Modified mineral trioxide aggregate—A versatile dental material: An insight on applications and newer advancements. *Frontiers in bioengineering and biotechnology*. 2022;10:941826.
8. Morita M, Kitagawa H, Nakayama K, et al. Antibacterial activities and mineral induction abilities of proprietary MTA cements. *Dental Materials Journal*. 2021;40(2):297-303.
9. Bolhari B, Sooratgar A, Pourhajibagher M, et al. Evaluation of the antimicrobial effect of mineral trioxide aggregate mixed with fluorohydroxyapatite against *E. faecalis* *in vitro*. *The Scientific World Journal*. 2021;2021(1):6318690.
10. Saghiri M, Asgar K, Lotfi M, et al. Nanomodification of mineral trioxide aggregate for enhanced physiochemical properties. *International endodontic journal*. 2012;45(11):979-88.
11. Saghiri MA, Asatourian A, Orangi J, et al. Effect of particle size on calcium release and elevation of pH of endodontic cements. *Dental Traumatology*. 2015;31(3):196-201.
12. Kıvanç M, Barutca B, Kopal AT, et al. Effects of hexagonal boron nitride nanoparticles on antimicrobial and antibiofilm activities, cell viability. *Materials Science and Engineering: C*. 2018;91:115-24.
13. Vandekar M, Pendse G, Toprani N, et al. Evaluation of antimicrobial efficacy of mineral trioxide aggregate with and without silver nanoparticles: A systematic review and meta-analysis. *Journal of Conservative Dentistry and Endodontics*. 2025;28(9):859-66.
14. Samiei M, Aghazadeh M, Lotfi M, et al. Antimicrobial efficacy of mineral trioxide aggregate

- with and without silver nanoparticles. *Iranian endodontic journal*. 2013;8(4):166.
15. Jonaidi-Jafari N, Izadi M, Javidi P. The effects of silver nanoparticles on antimicrobial activity of ProRoot mineral trioxide aggregate (MTA) and calcium enriched mixture (CEM). *Journal of Clinical and Experimental Dentistry*. 2016;8(1):e22.
 16. Mousavi SM, Hashemi SA, Ghasemi Y, et al. Green synthesis of silver nanoparticles toward bio and medical applications: review study. *Artificial cells, nanomedicine, and biotechnology*. 2018;46(sup3):855-72.
 17. Hong X, Wen J, Xiong X, et al. Shape effect on the antibacterial activity of silver nanoparticles synthesized via a microwave-assisted method. *Environmental science and pollution research*. 2016;23(5):4489-97.
 18. Béltéky P, Rónavári A, Zakupszky D, et al. Are smaller nanoparticles always better? Understanding the biological effect of size-dependent silver nanoparticle aggregation under biorelevant conditions. *International journal of nanomedicine*. 2021:3021-40.
 19. Zand V, Lotfi M, Aghbali A, et al. Tissue reaction and biocompatibility of implanted mineral trioxide aggregate with silver nanoparticles in a rat model. *Iranian endodontic journal*. 2015;11(1):13.
 20. Samiei M, Adibkia K, Ghasemi N, et al. Effect of Silver Nanoparticles of Herbal Origin on the Compressive and Push-out Bond Strengths of Mineral Trioxide Aggregate. *Iranian endodontic journal*. 2023;18(3):159.
 21. Oncu A, Huang Y, Amasya G, et al. Silver nanoparticles in endodontics: recent developments and applications. *Restorative Dentistry & Endodontics*. 2021;46(3).
 22. Gladyshev VN, Arnér ES, Berry MJ, et al. Selenoprotein gene nomenclature. *Journal of Biological Chemistry*. 2016;291(46):24036-40.
 23. Hosnedlova B, Kepinska M, Skalickova S, et al. Nano-selenium and its nanomedicine applications: a critical review. *International journal of nanomedicine*. 2018:2107-28.
 24. Bisht N, Phalswal P, Khanna PK. Selenium nanoparticles: A review on synthesis and biomedical applications. *Materials Advances*. 2022;3(3):1415-31.
 25. Kumar H, Bhardwaj K, Nepovimova E, et al. Antioxidant functionalized nanoparticles: A combat against oxidative stress. *Nanomaterials*. 2020;10(7):1334.
 26. Wang H, Zhang J, Yu H. Elemental selenium at nano size possesses lower toxicity without compromising the fundamental effect on selenoenzymes: comparison with selenomethionine in mice. *Free Radical Biology and Medicine*. 2007;42(10):1524-33.
 27. Shehab NF, Hasan NH, Ismail HK. Investigating the effect of selenium nanoparticles on mineral trioxide aggregates as a promising novel dental material. *Journal of International Society of Preventive and Community Dentistry*. 2024;14(1):16-27.
 28. Doğan MS. Relation of trace elements on dental health. *Trace Elements-Human Health and Environment*. 2018:5.
 29. Shehab NF, Hasan NH, Ismail HK. Investigating the Alkaline Potential of Mineral Trioxide Aggregate Repair Using Selenium Nanoparticles. *Brazilian Dental Journal*. 2024;35:e24-5760.
 30. Vu TT, Nguyen PTM, Pham NH, et al. Green synthesis of selenium nanoparticles using *Cleistanthus operculatus* leaf extract and their acute oral toxicity study. *Journal of Composites Science*. 2022;6(10):307.
 31. Joudeh N, Linke D. Nanoparticle classification, physicochemical properties, characterization, and applications: a comprehensive review for biologists. *Journal of nanobiotechnology*. 2022;20(1):262.
 32. Rayman MP. Selenium and human health. *The Lancet*. 2012;379(9822):1256-68.
 33. Menon S, Ks SD, Kumar V. Selenium nanoparticles: A potent chemotherapeutic agent and an elucidation of its mechanism. *Colloids and Surfaces B: Biointerfaces*. 2018;170:280-92.
 34. Khurana A, Tekula S, Saifi MA, et al. Therapeutic applications of selenium nanoparticles. *Bio-medicine & Pharmacotherapy*. 2019;111:802-12.
 35. Mondal S, Park S, Choi J, et al. Hydroxyapatite: A journey from biomaterials to advanced fun-

- ctional materials. *Advances in colloid and interface science*. 2023;321:103013.
36. Sipert CR, Hussne RP, Nishiyama CK, et al. In vitro antimicrobial activity of fill canal, sealapex, mineral trioxide aggregate, Portland cement and endorez. *International endodontic journal*. 2005;38(8):539-43.
 37. Akbarpour MR, Farajnezhad F, Poureshagh AH, et al. Effects of Copper Doping on Fluorohydroxyapatite Coating: Analysis of Microstructure, Biocompatibility, Corrosion Resistance, and Cell Adhesion Characteristics. *Inorganic Chemistry*. 2024;63(43):20314-24.
 38. Bolhari B, Chitsaz N, Nazari S, et al. Effect of fluorohydroxyapatite on biological and physical properties of MTA angelus. *The Scientific World Journal*. 2023;2023(1):7532898.
 39. Eskandarinezhad M, Ghodrati M, Azar FP, et al. Effect of incorporating hydroxyapatite and zinc oxide nanoparticles on the compressive strength of white mineral trioxide aggregate. *Journal of dentistry*. 2020;21(4):300.
 40. Pushpalatha C, Suresh J, Gayathri V, et al. Zinc oxide nanoparticles: a review on its applications in dentistry. *Frontiers in bioengineering and biotechnology*. 2022;10:917990.
 41. Baek M, Chung H-E, Yu J, et al. Pharmacokinetics, tissue distribution, and excretion of zinc oxide nanoparticles. *International journal of nanomedicine*. 2012;2:3081-97.
 42. Guerreiro-Tanomaru JM, Figueiredo Pereira K, Almeida Nascimento C, et al. Use of nanoparticulate zinc oxide as intracanal medication in endodontics: pH and antimicrobial activity. *Acta Odontológica Latinoamericana*. 2013;26(3):167-72.
 43. Prada I, Micó-Muñoz P, Giner-Lluesma T, et al. Influence of microbiology on endodontic failure. Literature review. *Medicina oral, patologia oral y cirugía bucal*. 2019;24(3):e364.
 44. Bianchini Fulindi R, Domingues Rodrigues J, Lemos Barbosa TW, et al. Zinc-based nanoparticles reduce bacterial biofilm formation. *Microbiology Spectrum*. 2023;11(2):e04831-22.
 45. Nair N, James B, Devadathan A, et al. Comparative Evaluation of Antibiofilm Efficacy of Chitosan Nanoparticle-and Zinc Oxide Nanoparticle-Incorporated Calcium Hydroxide-Based Sealer: An In vitro Study. *Contemporary clinical dentistry*. 2018;9(3):434-9.
 46. Rengaraj K, Paramasivan M, Perumal G, et al. Nanotechnology-based electrochemical approach for effective root canal irrigation. *Journal of Microbiological Methods*. 2025:107189.
 47. Vaidya S, Joshi M, Ghosh S, et al. Bioactive ZnO Decorated PVDF-Based Piezoelectric, Osteoconductive Nanofibrous Coatings for Orthopedic Implants. *Journal of Biomedical Materials Research Part A*. 2025;113(8):e37971.
 48. Azimi R, Shahgholi M, Khandan A. Fabrication and characterization of reinforced glass ionomer cement by zinc oxide and hydroxyapatite nanoparticles. *Heliyon*. 2024;10(20).
 49. Sirelkhatim A, Mahmud S, Seeni A, et al. Review on zinc oxide nanoparticles: antibacterial activity and toxicity mechanism. *Nano-micro letters*. 2015;7(3):219-42.
 50. Camilleri J. Hydration mechanisms of mineral trioxide aggregate. *International endodontic journal*. 2007;40(6):462-70.
 51. Kakali G, Tsvilis S, Aggeli E, et al. Hydration products of C3A, C3S and Portland cement in the presence of CaCO₃. *Cement and concrete Research*. 2000;30(7):1073-7.
 52. Sato T, Beaudoin JJ. Effect of nano-CaCO₃ on hydration of cement containing supplementary cementitious materials. *Advances in Cement Research*. 2011;23(1):33-43.
 53. Camiletti J, Soliman AM, Nehdi ML. Effect of nano-calcium carbonate on early-age properties of ultra-high-performance concrete. *Magazine of Concrete Research*. 2013;65(5):297-307.
 54. Bernardi A, Bortoluzzi E, Felipe W, et al. Effects of the addition of nanoparticulate calcium carbonate on setting time, dimensional change, compressive strength, solubility and pH of MTA. *International endodontic journal*. 2017;50(1):97-105.
 55. Teixeira CdS, Wasielewsky JC, Dos Santos GS, et al. Effect of the addition of nanoparticles of CaCO₃ and different water-to-powder ratios on the physicochemical properties of white Portland cement. *Microscopy research and technique*. 2021;84(4):592-601.
 56. Cao M, Ming X, He K, et al. Effect of macro-, micro-and nano-calcium carbonate on properties of cementitious composites—A review. *Materials*. 2019;12(5):781.

57. Qin L, Gao X, Li Q. Upcycling carbon dioxide to improve mechanical strength of Portland cement. *Journal of Cleaner Production*. 2018;196:726-38.
58. Garcia-Contreras R, Sugimoto M, Umemura N, et al. Alteration of metabolomic profiles by titanium dioxide nanoparticles in human gingivitis model. *Biomaterials*. 2015;57:33-40.
59. Shahi S, Samiei M, Bahari M, et al. Effect of incorporating titanium dioxide nanoparticles into white portland cement, white mineral trioxide aggregate, and calcium enriched mixture cement on the push-out bond strength to furcal area dentin. *Journal of dentistry*. 2023;24(4):422.
60. Bayat N, Lopes VR, Schölermann J, et al. Vascular toxicity of ultra-small TiO₂ nanoparticles and single walled carbon nanotubes in vitro and in vivo. *Biomaterials*. 2015;63:1-13.
61. Samiei M, Janani M, Asl-Aminabadi N, et al. Effect of the TiO₂ nanoparticles on the selected physical properties of mineral trioxide aggregate. *Journal of Clinical and Experimental Dentistry*. 2017;9(2):e191.
62. Ziental D, Czarzynska-Goslinska B, Mlynarczyk DT, et al. Titanium dioxide nanoparticles: prospects and applications in medicine. *Nanomaterials*. 2020;10(2):387.
63. Bichile ML, Mahaparale R, Mattigatti S, et al. Push-out bond strength of mineral trioxide aggregate with addition of titanium dioxide, silver, and silicon dioxide nanoparticles: An in vitro comparative study. *Journal of Conservative Dentistry and Endodontics*. 2022;25(5):541-6.
64. Saingern S, Monmatrapoj N, Sinsareekul C, et al. The comparison of physicochemical and bioactivity properties of different nanoparticles modified calcium silicate-based cement. *BMC Oral Health*. 2025;25(1):1335.
65. Besinis A, De Peralta T, Handy RD. The antibacterial effects of silver, titanium dioxide and silica dioxide nanoparticles compared to the dental disinfectant chlorhexidine on *Streptococcus mutans* using a suite of bioassays. *Nanotoxicology*. 2014;8(1):1-16.
66. Akbari M, Zebarjad SM, Nategh B, et al. Effect of nano silica on setting time and physical properties of mineral trioxide aggregate. *Journal of endodontics*. 2013;39(11):1448-51.
67. Jo B-W, Kim C-H, Tae G-h, et al. Characteristics of cement mortar with nano-SiO₂ particles. *Construction and building materials*. 2007;21(6):1351-5.
68. Quercia G, Brouwers H, editors. Application of nano-silica (nS) in concrete mixtures. 8th fib International Ph D Symposium in Civil Engineering Lyngby; 2010.
69. He H, Hao B, Xiong X, et al. Effect of Nano-Silica on Mechanical Properties and Cytotoxicity of Calcium-Silicate-Based Root Canal Filling Materials. *Crystals (2073-4352)*. 2025;15(1).
70. Zanjani VA, Tabari K, Sheikh-Al-Eslamian SM, et al. Physicochemical properties of experimental nano-hybrid MTA. *Journal of medicine and life*. 2018;11(1):51.
71. Hench LL. The story of Bioglass®. *Journal of materials science: materials in medicine*. 2006;17(11):967-78.
72. Fu Q, Saiz E, Rahaman MN, et al. Bioactive glass scaffolds for bone tissue engineering: state of the art and future perspectives. *Materials Science and Engineering: C*. 2011;31(7):1245-56.
73. El-Fiqi A, Mandakhbayar N, Jo SB, et al. Nanotherapeutics for regeneration of degenerated tissue infected by bacteria through the multiple delivery of bioactive ions and growth factor with antibacterial/angiogenic and osteogenic/odontogenic capacity. *Bioactive materials*. 2021;6(1):123-36.
74. Simila HO, Anselmi C, Cardoso LM, et al. Sol-gel-derived calcium silicate cement incorporating collagen and mesoporous bioglass nanoparticles for dental pulp therapy. *Dental Materials*. 2024;40(11):1832-42.
75. Waltimo T, Brunner T, Vollenweider M, et al. Antimicrobial effect of nanometric bioactive glass 45S5. *Journal of dental research*. 2007;86(8):754-7.
76. Nielsen FH. Update on human health effects of boron. *Journal of Trace Elements in Medicine and Biology*. 2014;28(4):383-7.
77. Hakki SS, Bozkurt BS, Hakki EE. Boron regulates mineralized tissue-associated proteins in osteoblasts (MC3T3-E1). *Journal of Trace Elements in Medicine and Biology*. 2010;24(4):243-50.
78. Wang C, Long Y, Deng Y, et al. Hexagonal boron nitride nanomaterials for biomedical applica-

- tions. *BMEMat.* 2024;2(2):e12068.
79. Weng Q, Wang X, Wang X, et al. Functionalized hexagonal boron nitride nanomaterials: emerging properties and applications. *Chemical Society Reviews.* 2016;45(14):3989-4012.
 80. Darabdhara G, Borthakur P, Boruah PK, et al. Advancements in two-dimensional boron nitride nanostructures: properties, preparation methods, and their biomedical applications. *Journal of Materials Chemistry B.* 2025;13(37):11540-81.
 81. Capasso C, T Supuran C. An overview of the carbonic anhydrases from two pathogens of the oral cavity: *Streptococcus mutans* and *Porphyromonas gingivalis*. *Current topics in medicinal chemistry.* 2016;16(21):2359-68.
 82. Cipreste MF, Andrade GF, da Silva WM, et al. Nanoparticles for Anticancer Therapy. *Nanomaterials and Nanotechnology: Biomedical, Environmental, and Industrial Applications: Springer;* 2021. p. 283-311.
 83. Hakki SS, Malkoc S, Dundar N, et al. Dietary boron does not affect tooth strength, micro-hardness, and density, but affects tooth mineral composition and alveolar bone mineral density in rabbits fed a high-energy diet. *Journal of Trace Elements in Medicine and Biology.* 2015;29:208-15.

BÖLÜM 12

DENS INVAJİNATUS: TANI, SINIFLAMA VE GÜNCEL TEDAVİ YAKLAŞIMLARI

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GİRİŞ

Dens invajinatus (dens in dente), diş gelişimi sırasında mine organının dental papilla içine doğru invajinasyonu ile ortaya çıkan ve dişin içinde mine ile dōşeli bir boşluk oluşumu ile karakterize gelişimsel bir dental anomalidir (1). Radyografide dişin içinde ikinci bir diş varmış izlenimi oluşturması nedeniyle bu şekilde adlandırılmıştır. Görülme sıklığı popülasyona göre değişmekle birlikte en sık maksiller lateral keserlerde saptanır ve çoğu olgu rutin radyografik incelemeler sırasında tesadüfen fark edilir (2). Klinik olarak belirgin bir morfolojik değişiklik göstermese bile, invajinasyonun pulpa dokusuna yakın seyretmesi ve ince mine-dentin bariyeri nedeniyle mikroorganizma penetrasyonuna yatkınlık oluşturması bu anomalinin klinik önemini artırmaktadır (3). Dens invajinatuslu dişlerde çürük varlığı olmaksızın pulpal patoloji ve periapikal lezyon gelişebilmesi ayırt edici bir özelliktir. Invajinasyonun derinliği ve kök kanal sistemi ile ilişkisi olgular arasında büyük farklılıklar gösterebilir (2). Yüzeysel formlar genellikle asemptomatik seyrederken, kök boyunca ilerleyen derin invajinasyonlar erken dönemde pulpal nekroz ve apikal patoloji ile sonuçlanabilir. Bu durum özellikle genç hastalarda, henüz kök gelişimi tamamlanmamış dişlerde klinik yönetimi daha karmaşık hale getirebilir (4).

Tanı ve tedavi planlamasında radyografik değerlendirme temel rol oynamaktadır. Konvansiyonel periapikal radyografiler ilk basamak inceleme yöntemi olmakla birlikte, invajinasyonun üç boyutlu yapısını ve kök kanalı ile ilişkisini ayrıntılı olarak değerlendirmek için konik ışınli bilgisayarlı tomografi (CBCT) giderek daha sık kullanılmaktadır (5). Güncel endodontik yaklaşımlar; dental mikroskop, ultrasonik sistemler ve biyoseramik materyallerin kullanımı ile bu komp-

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dir. Özellikle Tip II ve Tip III vakalarda uzun dönem izlem önem taşımakta olup, olası nüks veya komplikasyonların erken dönemde saptanması tedavi başarısını artırmaktadır. Klinik ve radyolojik değerlendirmelerin birlikte yapılması ve her olguya özgü tedavi planlaması, bu kompleks anatomik varyasyonların başarılı şekilde yönetilmesinde temel yaklaşımı oluşturmaktadır.

KAYNAKLAR

1. Hülsmann M. Dens invaginatus:aetiology, classification, prevalence, diagnosis, and treatment considerations. *Int Endod J.* 1997;30:79–90.
2. Chen YHM, Tseng CC, Harn WM. Dens invaginatus. *Oral Surgery, Oral Med, Oral Pathol, Oral Radiol, and Endod.* 1998;86:347–52.
3. Oehlers FAC. Dens invaginatus (dilated composite odontome). *Oral Surg, Oral Med, Oral Pathol.* 1957;10:1204–18.
4. Stefen H, Splieth C. Conventional Treatment of Dens Invaginatus in Maxillary Lateral Incisor with Sinus Tract: One Year Follow-Up. *J Endod.* 2005;31:130–3.
5. Afkar M, Gholamshahi M, Mohammadi M. Nonsurgical Treatment of Type II Dens Invaginatus in a Maxillary Lateral Incisor Using Cone-Beam Computed Tomography. *Iran Endod J.* 2018;13:132–4.
6. Plotino G, Pameijer C, Mariagrande N, Somma F. Ultrasonics in Endodontics: A Review of the Literature. *J Endod.* 2007;33:81–95.
7. Del Fabbro M, Taschieri S, Lodi G, Banfi G, Weinstein RL. Magnification devices for endodontic therapy. *Cochrane Database of Syst Rev.* 2015;12:CD005969.
8. Kirzioğlu Z, Ceyhan D. The prevalence of anterior teeth with dens invaginatus in the western mediterranean region of Turkey. *Int Endod J.* 2009;42:727–34.
9. Gallacher A, Ali R, Bhakta S. Dens invaginatus: diagnosis and management strategies. *Br Dent J.* 2016;221:383–7.
10. Baruwa AO, Anderson C, Monroe A, Cracel Nogueira F, Corte-Real L, Martins JNR. Dens Invaginatus: A Comprehensive Review of Classification and Clinical Approaches. *Medicina (B Aires).* 2025;61:1281.
11. Alani A, Bishop K. Dens invaginatus. Part 1: classification, prevalence and aetiology. *Int Endod J.* 2008;41:1123–36.
12. Bishop K, Alani A. Dens invaginatus. Part 2: clinical, radiographic features and management options. *Int Endod J.* 2008;41:1137–54.
13. Cohenca N, Berg J. Diagnosis and conservative treatment of dens invaginatus type III using cone beam computed tomography: two case reports. *Pediatr Dent.* 2013;35:E33-7.
14. Uzun İ, Keskin C, Güler B, Özdemir Ö. Management of Dens Invaginatus Type II With Periapical Lesion: A Case Report. *Eur Oral Res.* 2015;49:51–4.
15. Sachdeva GS, Sachdeva LT, Goel M, Bala S. Regenerative endodontic treatment of an immature tooth with a necrotic pulp and apical periodontitis using platelet-rich plasma (PRP) and mineral trioxide aggregate (MTA): a case report. *Int Endod J.* 2015;48:902–10.
16. Zaatari WA, Tarakji M, Ayoubi HR. A Non-Surgical Endodontic Treatment for a Dens in Dente Type II in a Maxillary Lateral Incisor with Chronic Apical Periodontitis: A Case Report. *Front Dent.* 2025;22:25.
17. Vier-Pelisser F V., Pelisser A, Recuero LC, Só MVR, Borba MG, Figueiredo JAP. Use of cone beam computed tomography in the diagnosis, planning and follow up of a type III dens invaginatus case. *Int Endod J.* 2012;45:198–208.
18. Naqibeiranvand M, Nasrabadi N, Jahanshahi N. Minimally Invasive Management of Two Separated Dens Invaginatus Oehler’s Type I and II: A Case Report. *Iran Endod J.* 2025;20:e38.

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19. Candeiro GT de M, de Menezes AST, de Oliveira ACS, Alves FRF. Successful nonsurgical treatment of type II dens invaginatus with 5 root canals using a self-adjusting file: a case report. *Restor Dent Endod.* 2023;48:e17.
20. Fujii R, Asai T, Yamada M, Sako R, Tamiya Y, Furusawa M. Root Canal Treatment of Oehlers Type III Dens Invaginatus in Maxillary Lateral Incisor and Remote Sinus Tract Using Dental Surgical Microscope and Cone-Beam Computed Tomography. *Bull Tokyo Dent Coll.* 2023;64:2022-0032.
21. Kfir A, Telishevsky-Strauss Y, Leitner A, Metzger Z. The diagnosis and conservative treatment of a complex type 3 dens invaginatus using cone beam computed tomography (CBCT) and 3D plastic models. *Int Endod J.* 2013;46:275-88.
22. Diogenes A, Ruparel NB. Regenerative Endodontic Procedures. *Dent Clin North Am.* 2017;61:111-25.
23. Ahmad S, Alam S, Andrabi SMUN, Kumar A. Combined surgical and conservative endodontic management of Oehler's type 3b dens invaginatus aided by guided tissue regeneration. *BMJ Case Rep.* 2023;16:e255546.
24. Patel S, Durack C, Abella F, Shemesh H, Roig M, Lemberg K. Cone beam computed tomography in Endodontics - a review. *Int Endod J.* 2015;48:3-15.
25. Van Der Sluis LWM, Versluis M, Wu MK, Wesselink PR. Passive ultrasonic irrigation of the root canal: a review of the literature. *Int Endod J.* 2007;40:415-26.
26. De Moor RJG, Meire M, Goharkhay K, Moritz A, Vanobbergen J. Efficacy of Ultrasonic versus Laser-activated Irrigation to Remove Artificially Placed Dentin Debris Plugs. *J Endod.* 2010;36:1580-3.
27. Kaya-Büyükbayram I, Özalp Ş, Aytugar E, Aydemir S. Regenerative Endodontic Treatment of an Infected Immature Dens Invaginatus with the Aid of Cone-Beam Computed Tomography. *Case Rep Dent.* 2014;2014:1-5.

BÖLÜM 13

REJENERATİF ENDODONTİ: BİYOLOJİK TEMELLER, KLİNİK PROTOKOLLER VE GÜNCEL YAKLAŞIMLAR

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Rejeneratif endodonti, pulpa nekrozu gelişmiş dişlerde yalnızca enfeksiyonun ortadan kaldırılmasını değil, pulpa-dentin kompleksinin biyolojik olarak yeniden oluşumunu hedefleyen modern bir tedavi yaklaşımıdır. Geleneksel kök kanal tedavileri, özellikle kök gelişimi tamamlanmamış immatür dişlerde yapısal ve biyolojik açıdan bazı sınırlılıklar taşımaktadır. Bu dişlerde kök gelişiminin durması, dentin duvarlarının ince kalması ve kök kırığı riskinin artması, uzun dönem prognozu olumsuz yönde etkileyebilmektedir. Geçmişte uygulanan apeksifikasyon yöntemleri apikal kapanmayı sağlayabilse de kök gelişiminin devamını mümkün kılmamış, bu durum biyolojik temelli tedavi yaklaşımlarına olan ihtiyacı ortaya çıkarmıştır (1, 2).

Rejeneratif endodontik tedaviler, doku mühendisliğinin temel bileşenleri olan kök hücreler, büyüme faktörleri ve skafold yapılar arasındaki etkileşime dayanmaktadır. Bu tedavilerde amaç, kök kanal sisteminde enfeksiyonun kontrol altına alınmasının ardından, kök hücrelerin kanal içerisine göçünü sağlayacak uygun biyolojik ortamın oluşturulmasıdır. Böylece kök uzunluğunun artması, dentin duvarlarının kalınlaşması ve apikal kapanmanın sağlanması mümkün olabilmektedir. Son yıllarda kök hücre biyolojisi ve biyomateryal alanındaki gelişmeler, rejeneratif endodontiyi özellikle immatür dişlerde pulpa nekrozu tedavisinde önemli ve umut verici bir seçenek haline getirmiştir (2, 3).

REJENERATİF ENDODONTİK TEDAVİ

Endodontik tedavinin temel amacı, enfekte/nekrotik pulpa dokusunun uzaklaştırılması, kök kanal sisteminin dezenfekte edilmesi ve biyouyumlu materyallerle

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durum, rejeneratif endodontinin biyolojik mekanizmasının daha iyi anlaşılması gerektiğini ortaya koymaktadır.

Güncel araştırmalar, rejeneratif endodontinin daha öngörülebilir ve fonksiyonel sonuçlar verebilmesi için yeni biyolojik ve teknolojik yaklaşımlar üzerinde yoğunlaşmaktadır. Hücre transplantasyonu, biyomimetik iskelet yapılar, kontrollü büyüme faktörü salınım sistemleri ve üç boyutlu biyobaskı teknolojileri, gelecekte pulpa dokusunun fonksiyonel olarak yeniden oluşturulmasını mümkün kılacak yenilikçi yöntemler arasında yer almaktadır (31).

Sonuç olarak rejeneratif endodonti, biyolojik temelli tedavi yaklaşımlarının klinik endodonti pratiğine entegrasyonunu temsil eden önemli bir gelişmedir. Uygun endikasyonlarda, doğru protokollerle uygulandığında kök gelişiminin devamını sağlayarak dişin uzun dönem prognozunu iyileştirebilmektedir. Bununla birlikte, tedavi protokollerinin standardizasyonu, oluşan dokunun histolojik yapısının daha iyi anlaşılması ve uzun dönem klinik sonuçların değerlendirilmesi için ileri düzey klinik ve deneysel çalışmalara ihtiyaç bulunmaktadır.

KAYNAKLAR

1. Murray PE, Garcia-Godoy F, Hargreaves KM. Regenerative endodontics: a review of current status and a call for action. *Journal of Endodontics*. 2007;33(4):377–390. doi:10.1016/j.joen.2006.09.013
2. Huang GT-J. A paradigm shift in endodontic management of immature teeth: conservation of stem cells for regeneration. *Journal of Dentistry*. 2008;36(6):379–386. doi:10.1016/j.jdent.2008.02.002
3. Hargreaves KM, Diogenes A, Teixeira FB. Treatment options: biological basis of regenerative endodontic procedures. *Pediatric Dentistry*. 2013;35(2):129–140.
4. Andreasen JO, Farik B, Munksgaard EC. Long-term calcium hydroxide as a root canal dressing may increase risk of root fracture. *Dental Traumatology*. 2002;18(3):134–137. doi:10.1034/j.1600-9657.2002.00097.x
5. Cvek M. Prognosis of luxated non-vital maxillary incisors treated with calcium hydroxide and filled with gutta-percha: a retrospective clinical study. *Dental Traumatology*. 1992;8(2):45–55. doi:10.1111/j.1600-9657.1992.tb00228.x
6. Frank AL. Therapy for the divergent pulpless tooth by continued apical formation. *The Journal of the American Dental Association*. 1966;72(1):87–93. doi:10.14219/jada.archive.1966.0038
7. Andreasen JO, Munksgaard EC, Bakland LK. Comparison of fracture resistance in root canals of immature sheep teeth after filling with calcium hydroxide or MTA. *Dental Traumatology*. 2006;22(3):154–156. doi:10.1111/j.1600-9657.2006.00419.x
8. Witherspoon DE. Vital pulp therapy with new materials: new directions and treatment perspectives—permanent teeth. *Pediatric Dentistry*. 2008;30(3):220–224.
9. American Association of Endodontists. AAE clinical considerations for a regenerative procedure. Chicago: American Association of Endodontists; 2016.
10. Bose R, Nummikoski P, Hargreaves K. A retrospective evaluation of radiographic outcomes in immature teeth with necrotic root canal systems treated with regenerative endodontic procedures. *Journal of Endodontics*. 2009;35(10):1343–1349. doi:10.1016/j.joen.2009.06.021
11. Vacanti JB, Langer R. Tissue engineering: the design and fabrication of living replacement devi-

- ces for surgical reconstruction and transplantation. *The Lancet*. 1999;354:S32–S34. doi:10.1016/S0140-6736(99)90247-7
12. Curtis A, Riehle M. Tissue engineering: the biophysical background. *Physics in Medicine and Biology*. 2001;46(4):R47–R65. doi:10.1088/0031-9155/46/4/201
 13. Banchs F, Trope M. Revascularization of immature permanent teeth with apical periodontitis: new treatment protocol? *Journal of Endodontics*. 2004;30(4):196–200. doi:10.1097/00004770-200404000-00003
 14. Galler KM, D’Souza RN, Hartgerink JD, Schmalz G. Scaffolds for dental pulp tissue engineering. *Advances in Dental Research*. 2011;23(3):333–339. doi:10.1177/0022034511405326
 15. Lovelace TW, Henry MA, Hargreaves KM, Diogenes A. Evaluation of the delivery of mesenchymal stem cells into the root canal space of necrotic immature teeth after clinical regenerative endodontic procedure. *Journal of Endodontics*. 2011;37(2):133–138. doi:10.1016/j.joen.2010.10.009
 16. Sonoyama W, Liu Y, Yamaza T, et al. Characterization of the apical papilla and its residing stem cells from human immature permanent teeth: a pilot study. *Journal of Endodontics*. 2008;34(2):166–171. doi:10.1016/j.joen.2007.11.021
 17. Sonoyama W, Liu Y, Fang D, et al. Mesenchymal stem cell-mediated functional tooth regeneration in swine. *PLoS One*. 2006;1(1):e79. doi:10.1371/journal.pone.0000079
 18. Gronthos S, Mankani M, Brahimi J, et al. Postnatal human dental pulp stem cells (DPSCs) in vitro and in vivo. *Proceedings of the National Academy of Sciences of the United States of America*. 2000;97(25):13625–13630. doi:10.1073/pnas.240309797
 19. Iohara K, Zheng L, Ito M, et al. Regeneration of dental pulp after pulpotomy by transplantation of CD31-/CD146-side population cells from a canine tooth. *Regenerative Medicine*. 2009;4(3):377–385. doi:10.2217/rme.09.17
 20. Miura M, Gronthos S, Zhao M, et al. SHED: stem cells from human exfoliated deciduous teeth. *Proceedings of the National Academy of Sciences of the United States of America*. 2003;100(10):5807–5812. doi:10.1073/pnas.0937635100
 21. Seo B-M, Miura M, Gronthos S, et al. Investigation of multipotent postnatal stem cells from human periodontal ligament. *The Lancet*. 2004;364(9429):149–155. doi:10.1016/S0140-6736(04)16627-0
 22. Huang GT-J, Yamaza T, Shea LD, et al. Stem/progenitor cell-mediated de novo regeneration of dental pulp with newly deposited continuous layer of dentin in an in vivo model. *Tissue Engineering Part A*. 2010;16(2):605–615. doi:10.1089/ten.tea.2009.0518
 23. Smith AJ, Scheven BA, Takahashi Y, et al. Dentine as a bioactive extracellular matrix. *Archives of Oral Biology*. 2012;57(2):109–121. doi:10.1016/j.archoralbio.2011.07.008
 24. Galler KM, Widbiller M, Buchalla W, et al. EDTA conditioning of dentine promotes adhesion, migration and differentiation of dental pulp stem cells. *International Endodontic Journal*. 2016;49(6):581–590. doi:10.1111/iej.12469
 25. Roberts-Clark D, Smith AJ. Angiogenic growth factors in human dentine matrix. *Archives of Oral Biology*. 2000;45(11):1013–1016. doi:10.1016/S0003-9969(00)00061-0
 26. Nakashima M, Reddi AH. The application of bone morphogenetic proteins to dental tissue engineering. *Nature Biotechnology*. 2003;21(9):1025–1032. doi:10.1038/nbt864
 27. Zhang W, Walboomers XF, Shi S, et al. Multilineage differentiation potential of stem cells derived from human dental pulp after cryopreservation. *Tissue Engineering*. 2006;12(10):2813–2823. doi:10.1089/ten.2006.12.2813
 28. Marx RE. Platelet-rich plasma: evidence to support its use. *Journal of Oral and Maxillofacial Surgery*. 2004;62(4):489–496. doi:10.1016/j.joms.2003.12.003
 29. Torabinejad M, Turman M. Revitalization of tooth with necrotic pulp and open apex by using platelet-rich plasma: a case report. *Journal of Endodontics*. 2011;37(2):265–268. doi:10.1016/j.joen.2010.11.004
 30. Dohan Ehrenfest DM, Andia I, Zumstein MA, et al. Classification of platelet concentrates (Pla-

- telet-Rich Plasma-PRP, Platelet-Rich Fibrin-PRF) for topical and infiltrative use in orthopedic and sports medicine: current consensus, clinical implications and perspectives. *Muscles, Ligaments and Tendons Journal*. 2014;4(1):3–9. doi:10.11138/mltj/2014.4.1.003
31. Rosa V, Della Bona A, Cavalcanti BN, Nör JE. Tissue engineering: from research to dental clinics. *Dental Materials*. 2012;28(4):341–348. doi:10.1016/j.dental.2012.01.009
 32. Zanjad SR, Justin RM, Patil PN, et al. Comparison of fracture resistance of simulated immature teeth using four different commercially available apexification materials: an in vitro study. *Indian Journal of Dental Research*. 2023;34(1):75–79. doi:10.4103/ijdr.ijdr_656_21
 33. Ruparel N, Ruparel F, Hargreaves K, Diogenes A. Effect of intracanal medicaments on stem cells from apical papilla. *Journal of Endodontics*. 2012;38(3):e25. doi:10.1016/j.joen.2011.12.048
 34. Diogenes A, Ruparel NB. Regenerative endodontic procedures: clinical outcomes. *Dental Clinics of North America*. 2017;61(1):111–125. doi:10.1016/j.cden.2016.08.004
 35. Jeeruphan T, Jantarat J, Yanpiset K, et al. Mahidol study 1: comparison of radiographic and survival outcomes of immature teeth treated with either regenerative endodontic or apexification methods: a retrospective study. *Journal of Endodontics*. 2012;38(10):1330–1336. doi:10.1016/j.joen.2012.06.028
 36. Wang X, Thibodeau B, Trope M, et al. Histologic characterization of regenerated tissues in canal space after the revitalization/revascularization procedure of immature dog teeth with apical periodontitis. *Journal of Endodontics*. 2010;36(1):56–63. doi:10.1016/j.joen.2009.09.039
 37. Kim J-H, Kim Y, Shin S-J, et al. Tooth discoloration of immature permanent incisor associated with triple antibiotic therapy: a case report. *Journal of Endodontics*. 2010;36(6):1086–1091. doi:10.1016/j.joen.2010.03.031
 38. Krastl G, Allgayer N, Lenherr P, et al. Tooth discoloration induced by endodontic materials: a literature review. *Dental Traumatology*. 2013;29(1):2–7. doi:10.1111/j.1600-9657.2012.01140.x
 39. Sheng K, Ding N, Zhao SM, et al. Outcome of regenerative endodontic procedures in delayed replanted immature permanent teeth with apical periodontitis: a retrospective study. *International Journal of Paediatric Dentistry*. 2025;35(3):540–550. doi:10.1111/ipd.13166
 40. Widbiller M, Galler KM. Regenerative endodontics. In: *Vital Pulp Treatment*. 2024:185–200. doi:10.1007/978-3-031-40682-3_11
 41. Athirasala A, Tahayeri A, Thirivikraman G, et al. A dentin-derived hydrogel bioink for 3D bioprinting of cell-laden scaffolds for regenerative dentistry. *Biofabrication*. 2018;10(2):024101. doi:10.1088/1758-5090/aa9d44

BÖLÜM 14

ENDODONTİDE BİYOFİLM DİRENCİ VE KLİNİK BAŞARISIZLIKLARIN MİKROBİYOLOJİK TEMELİ

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GİRİŞ

Endodontik tedavi, enfekte veya geri dönüşümsüz olarak hasarlanmış pulpa dokusunun uzaklaştırılması ve kök kanal sisteminin biyolojik olarak kabul edilebilir bir ortam hâline getirilmesini amaçlayan bir tedavi yaklaşımıdır. Uygun kemomekanik preparasyon ve üç boyutlu obturasyon ile yüksek başarı oranları bildirilmiş olsa da tedavi sonrası apikal periodontitis hâlen klinik pratiğin önemli bir sorunudur (1). Endodontik başarısızlığın başlıca nedeni, kök kanal sistemi içerisinde canlılığını sürdüren mikroorganizmaların varlığıdır (1, 2).

Güncel literatür, bu mikroorganizmaların çoğunlukla organize ve yüzeye bağlı biyofilm yapıları içerisinde bulunduğunu ve bu organizasyonun antimikrobiyal ajanlara karşı belirgin bir tolerans sağladığını göstermektedir (3, 4). Biyofilm formasyonuna geçen bakteriler; düşük metabolik aktivite, ekstraselüler polimerik matriks (EPS) üretimi ve gen ekspresyon değişiklikleri sayesinde çevresel streslere ve dezenfeksiyon prosedürlerine karşı daha dirençli hâle gelmektedir (3). Kök kanal sisteminin apikal deltalar, lateral kanallar ve dentin tübülleri gibi anatomik karmaşıklığı biyofilm gelişimi için uygun mikroçevreler oluşturarak bu direnci artırmaktadır (5, 6).

Persistan ve sekonder enfeksiyonlarda mikrobiyal kompozisyonun değişmesi, tedaviye adapte olabilen ve dirençli fenotipler geliştirebilen türlerin seçim avantajı kazandığını düşündürmektedir (7). Bu nedenle endodontik başarısızlık yalnızca mekanik yetersizliklerle değil, biyofilm temelli mikrobiyal direnç mekanizmalarıyla da yakından ilişkilidir.

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Klinik Açından Öneriler

- Kök kanal sisteminin kompleks anatomisi göz önünde bulundurularak irri-gasyon protokollerinde yeterli hacim, uygun konsantrasyon ve aktivasyon teknikleri birlikte kullanılmalıdır.
- NaOCl ve şelatlayıcı ajanların ardışık kullanımı biyofilm bütünlüğünün bozulması açısından önemlidir.
- Koronal sızdırmazlık, intraradiküler dezenfeksiyon kadar kritik olup mikrosızıntının önlenmesi başarının anahtar unsurlarındandır.
- Persistan vakalarda yalnızca intrakanal patojen varlığı değil, olası ekstraradi-küler biyofilm ve konak yanıtı da değerlendirilmelidir.
- Dirençli ve nükseden olgularda biyofilm hedefli yardımcı yaklaşımlar (akti-vasyon sistemleri, fotodinamik tedavi, yeni antibiyofilm ajanlar) destekleyici seçenekler olarak düşünülmelidir.

Gelecekte moleküler biyoloji yöntemleriyle biyofilm içi gen ekspresyon pro-fillerinin ve adaptif sinyal yollarının daha ayrıntılı olarak tanımlanması, hedefe yönelik antibiyofilm stratejilerin geliştirilmesine katkı sağlayacaktır.

KAYNAKLAR

1. Siqueira JF, Jr. Aetiology of root canal treatment failure: why well-treated teeth can fail. *International Endodontic Journal*. 2001;34(1):1-10. doi: 10.1046/j.1365-2591.2001.00396.x
2. Antunes HS, Rôças IN, Alves FR, et al. Total and Specific Bacterial Levels in the Apical Root Canal System of Teeth with Post-treatment Apical Periodontitis. *Journal of Endodontics*. 2015;41(7):1037-1042. doi: 10.1016/j.joen.2015.03.008
3. Donlan RM. Biofilms: microbial life on surfaces. *Emerging infectious diseases*. 2002;8(9):881-890. doi: 10.3201/eid0809.020063
4. Mah TF, O'Toole GA. Mechanisms of biofilm resistance to antimicrobial agents. *Trends In Microbiology* 2001;9(1):34-39. doi: 10.1016/s0966-842x(00)01913-2
5. Nair PN, Henry S, Cano V, et al. Microbial status of apical root canal system of human mandibular first molars with primary apical periodontitis after "one-visit" endodontic treatment. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, And Endodontics*. 2005;99(2):231-252. doi: 10.1016/j.tripleo.2004.10.005
6. Ricucci D, Siqueira JF, Jr. Fate of the tissue in lateral canals and apical ramifications in response to pathologic conditions and treatment procedures. *Journal of Endodontics*. 2010;36(1):1-15. doi: 10.1016/j.joen.2009.09.038
7. Prada I, Micó-Muñoz P, Giner-Lluesma et al.. Influence of microbiology on endodontic failure. Literature review. *Medicina Oral, Patología Oral Y Cirugía Bucal*. 2019;24(3):e364-e372. doi: 10.4317/medoral.22907
8. Strindberg L. The dependence of the results of pulp therapy on certain factors. *Acta Odontologica Scandinavica*. 1956;14(21):1-175. doi:
9. Orstavik D, Kerekes K, Eriksen HM. The periapical index: a scoring system for radiographic assessment of apical periodontitis. *Endodontics & Dental Traumatology* 1986;2(1):20-34. doi: 10.1111/j.1600-9657.1986.tb00119.x
10. Patel S, Wilson R, Dawood A, et al. The detection of periapical pathosis using periapical ra-

- diography and cone beam computed tomography - part 1: pre-operative status. *International Endodontic Journal*. 2012;45(8):702-710. doi: 10.1111/j.1365-2591.2011.01989.x
11. Friedman S, Mor C. The success of endodontic therapy--healing and functionality. *Journal of the California Dental Association*. 2004;32(6):493-503.
 12. Tabassum S, Khan FR. Failure of endodontic treatment: The usual suspects. *European Journal of Dentistry*. 2016;10(1):144-147. doi: 10.4103/1305-7456.175682
 13. Shanmugam S, PradeepKumar AR, Abbott PV, et al. Coronal Bacterial Penetration after 7 days in class II endodontic access cavities restored with two temporary restorations: A Randomised Clinical Trial. *Australian Endodontic Journal*. 2020;46(3):358-364. doi: 10.1111/aej.12415
 14. Chen P, Chen Z, Teoh YY, Peters OA, Peters CI. Orifice barriers to prevent coronal microleakage after root canal treatment: systematic review and meta-analysis. *Australian Dental Journal*. 2023;68(2):78-91. doi: 10.1111/adj.12951
 15. Carlosama Rodriguez R, Pe Aherrera Manosalvas MS, Pulido C, et al. Effect of Pre-Endodontic Sealing on the Microleakage of Temporary Restorative Materials After Endodontic Treatment: An In Vitro Study. *European Endodontic Journal*. 2025;10(6):525-531. doi:10.14744/ej.2025.58671
 16. Boshnjaku S, Morina J. Coronal Microleakage and Its Impact on the Success of Endodontic Therapy: A Narrative Review. *International Journal of Biomedicine*. 2025;15(2):262-267.
 17. Winkler KC, Van Amerongen J. Bacteriologic results from 4,000 root canal cultures. *Oral Surgery, Oral Medicine, Oral Pathology*. 1959;12(7):857-875. doi: 10.1016/0030-4220(59)90036-2
 18. Byström A, Sundqvist G. Bacteriologic evaluation of the efficacy of mechanical root canal instrumentation in endodontic therapy. *European Journal of Oral Sciences*. 1981;89(4):321-328. doi: 10.1111/j.1600-0722.1981.tb01689.x
 19. Sundqvist GK, Eckerbom MI, Larsson AP, et al. Capacity of anaerobic bacteria from necrotic dental pulps to induce purulent infections. *Infection and immunity*. 1979;25(2):685-693. doi: 10.1128/iai.25.2.685-693.1979
 20. Provenzano JC, Siqueira JF, Jr., Rôças IN, et al. Metaproteome analysis of endodontic infections in association with different clinical conditions. *PLoS One*. 2013;8(10):e76108. doi: 10.1371/journal.pone.0076108
 21. Haapasalo M, Udnæs T, Endal U. Persistent, recurrent, and acquired infection of the root canal system post-treatment. *Endodontic Topics*. 2003;6(1):29-56.
 22. Alves FR, Andrade-Junior CV, Marceliano-Alves MF, et al. Adjunctive Steps for Disinfection of the Mandibular Molar Root Canal System: A Correlative Bacteriologic, Micro-Computed Tomography, and Cryopulverization Approach. *Journal of endodontics*. 2016;42(11):1667-1672. doi: 10.1016/j.joen.2016.08.003
 23. Anderson AC, Hellwig E, Vespermann R, et al. Comprehensive analysis of secondary dental root canal infections: a combination of culture and culture-independent approaches reveals new insights. *PLoS One*. 2012;7(11):e49576. doi: 10.1371/journal.pone.0049576
 24. Lins RX, de Oliveira Andrade A, Hirata Junior R, et al. Antimicrobial resistance and virulence traits of *Enterococcus faecalis* from primary endodontic infections. *Journal of Dentistry* 2013;41(9):779-786. doi: 10.1016/j.jdent.2013.07.004
 25. Ricucci D, Siqueira JF, Jr. Apical actinomycosis as a continuum of intraradicular and extraradicular infection: case report and critical review on its involvement with treatment failure. *Journal of Endodontics*. 2008;34(9):1124-1129. doi: 10.1016/j.joen.2008.06.002
 26. Nair PN. On the causes of persistent apical periodontitis: a review. *International Endodontic Journal*. 2006;39(4):249-281. doi: 10.1111/j.1365-2591.2006.01099.x
 27. Siqueira JF, Jr., Rôças IN. Community as the unit of pathogenicity: an emerging concept as to the microbial pathogenesis of apical periodontitis. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics*. 2009;107(6):870-878. doi: 10.1016/j.tripleo.2009.01.044
 28. Marsh PD. Microbial ecology of dental plaque and its significance in health and disease. *Advances in Dental Research*. 1994;8(2):263-271. doi: 10.1177/08959374940080022001

29. Siqueira JF, Jr., Rôças IN. Diversity of endodontic microbiota revisited. *Journal of Dental Research*. 2009;88(11):969-981. doi: 10.1177/0022034509346549
30. Ran S, He Z, Liang J. Survival of *Enterococcus faecalis* during alkaline stress: changes in morphology, ultrastructure, physiochemical properties of the cell wall and specific gene transcripts. *Archives of Oral Biology* 2013;58(11):1667-1676. doi: 10.1016/j.archoralbio.2013.08.013
31. Love RM. *Enterococcus faecalis*--a mechanism for its role in endodontic failure. *International Endodontic Journal*. 2001;34(5):399-405. doi: 10.1046/j.1365-2591.2001.00437.x
32. Munson MA, Pitt-Ford T, Chong B, et al. Molecular and cultural analysis of the microflora associated with endodontic infections. *Journal of Dental Research*. 2002;81(11):761-766. doi: 10.1177/0810761
33. Nair PN. Pathogenesis of apical periodontitis and the causes of endodontic failures. *Critical Reviews In Oral Biology And Medicine*. 2004;15(6):348-381. doi: 10.1177/154411130401500604
34. Neelakantan P, Romero M, Vera J, et al. Biofilms in Endodontics-Current Status and Future Directions. *International Journal Of Molecular Sciences*. 2017;18(8). doi: 10.3390/ijms18081748
35. Escobar-García DM, Medina-Rosas MG, González-Amaro AM, et al. MTA-Based Cements: Biocompatibility and Effects on the Gene Expression of Collagen Type 1 and TGF- β 1. *BioMed Research International*. 2022;2022(1):2204698. doi: 10.1155/2022/2204698
36. Dunavant TR, Regan JD, Glickman GN, et al. Comparative evaluation of endodontic irrigants against *Enterococcus faecalis* biofilms. *Journal of Endodontics*. 2006;32(6):527-531. doi: 10.1016/j.joen.2005.09.001
37. Pajkos A, Vickery K, Cossart Y. Is biofilm accumulation on endoscope tubing a contributor to the failure of cleaning and decontamination? *The Journal of Hospital Infection*. 2004;58(3):224-9. doi: 10.1016/j.jhin.2004.06.023
38. Portenier I, Waltimo TM, Haapasalo M. *Enterococcus faecalis*--the root canal survivor and 'star' in post-treatment disease. *Endodontic Topics*. 2003;6(1):135-159.
39. Athanassiadis B, Abbott PV, Walsh LJ. The use of calcium hydroxide, antibiotics and biocides as antimicrobial medicaments in endodontics. *Australian Dental Journal*. 2007;52(1 Suppl):S64-82. doi: 10.1111/j.1834-7819.2007.tb00527.x
40. Stewart PS, Costerton JW. Antibiotic resistance of bacteria in biofilms. *Lancet*. 2001;358(9276):135-138. doi: 10.1016/s0140-6736(01)05321-1
41. Lewis K. Persister cells, dormancy and infectious disease. *Nature Reviews. Microbiology*. 2007;5(1):48-56. doi: 10.1038/nrmicro1557
42. Flemming HC, Wingender J. The biofilm matrix. *Nature Reviews. Microbiology*. 2010;8(9):623-363. doi: 10.1038/nrmicro2415
43. Jhajharia K, Parolia A, Shetty KV, et al. Biofilm in endodontics: A review. *International Society of Preventive & Community Dentistry*. 2015;5(1):1-12. doi: 10.4103/2231-0762.151956
44. Narayanan LL, Vaishnavi C. Endodontic microbiology. *Journal Of Conservative Dentistry*. 2010;13(4):233-239. doi: 10.4103/0972-0707.73386
45. Stuart CH, Schwartz SA, Beeson TJ, et al. *Enterococcus faecalis*: its role in root canal treatment failure and current concepts in retreatment. *Journal of Endodontics*. 2006;32(2):93-98. doi: 10.1016/j.joen.2005.10.049
46. Endo MS, Ferraz CCR, Zaia AA, et al. Quantitative and qualitative analysis of microorganisms in root-filled teeth with persistent infection: Monitoring of the endodontic retreatment. *European Journal of Dentistry*. 2013;7(3):302-309. doi: 10.4103/1305-7456.115414
47. Schirrmeyer JF, Liebenow AL, Pelz K, et al. New bacterial compositions in root-filled teeth with periradicular lesions. *Journal of Endodontics*. 2009;35(2):169-174. doi: 10.1016/j.joen.2008.10.024
48. Sunde PT, Olsen I, Göbel UB, et al. Fluorescence in situ hybridization (FISH) for direct visualization of bacteria in periapical lesions of asymptomatic root-filled teeth. *Microbiology (Reading)*. 2003;149(Pt 5):1095-1102. doi: 10.1099/mic.0.26077-0
49. Nóbrega LM, Delboni MG, Martinho FC, et al. *Treponema* diversity in root canals with endo-

- dontic failure. *European Journal of Dentistry*. 2013;7(1):61-68.
50. Ashraf H, Samiee M, Eslami G, et al. Presence of *Candida Albicans* in Root Canal System of Teeth Requiring Endodontic Retreatment with and without Periapical Lesions. *Iranian Endodontic Journal*. 2007;2(1):24-28.
 51. Siqueira JF, Jr., Rôças IN. Polymerase chain reaction-based analysis of microorganisms associated with failed endodontic treatment. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, And Endodontics*. 2004;97(1):85-94. doi: 10.1016/s1079-2104(03)00353-6
 52. Kumar J, Sharma R, Sharma M, et al. Presence of *Candida albicans* in Root Canals of Teeth with Apical Periodontitis and Evaluation of their Possible Role in Failure of Endodontic Treatment. *Journal Of International Oral Health*. 2015;7(2):42-45.
 53. Pereira RS, Rodrigues VAA, Furtado WT, et al. Microbial analysis of root canal and periradicular lesion associated to teeth with endodontic failure. *Anaerobe*. 2017;48:12-18. doi: 10.1016/j.anaerobe.2017.06.016
 54. Rôças IN, Siqueira JF, Jr. Characterization of microbiota of root canal-treated teeth with posttreatment disease. *Journal of Clinical Microbiology*. 2012;50(5):1721-174. doi: 10.1128/jcm.00531-12
 55. Henriques LC, de Brito LC, Tavares WL, et al. Microbial Ecosystem Analysis in Root Canal Infections Refractory to Endodontic Treatment. *Journal of Endodontics*. 2016;42(8):1239-1245. doi: 10.1016/j.joen.2016.05.014
 56. Noguchi N, Noiri Y, Narimatsu M, et al. Identification and localization of extraradicular biofilm-forming bacteria associated with refractory endodontic pathogens. *Applied and Environmental Microbiology*. 2005;71(12):8738-8743. doi: 10.1128/aem.71.12.8738-8743.2005
 57. Pinheiro ET, Gomes BP, Ferraz CC, et al. Evaluation of root canal microorganisms isolated from teeth with endodontic failure and their antimicrobial susceptibility. *Oral microbiology and immunology*. 2003;18(2):100-103. doi: 10.1034/j.1399-302x.2003.00058.x
 58. Siqueira JF, Jr., Antunes HS, Rôças IN, et al. Microbiome in the Apical Root Canal System of Teeth with Post-Treatment Apical Periodontitis. *PLoS One*. 2016;11(9):e0162887. doi: 10.1371/journal.pone.0162887
 59. Siqueira JF, Jr., Alves FR, Rôças IN. Pyrosequencing analysis of the apical root canal microbiota. *Journal of Endodontics*. 2011;37(11):1499-1503. doi: 10.1016/j.joen.2011.08.012
 60. Del Fabbro M, Samaranyake LP, Lolato A, Weinstein T, Taschieri S. Analysis of the secondary endodontic lesions focusing on the extraradicular microorganisms: an overview. *Journal of Investigative and Clinical Dentistry*. 2014;5(4):245-254. doi: 10.1111/jicd.12045
 61. Dudeja PG, Dudeja KK, Srivastava D, et al. Microorganisms in periradicular tissues: Do they exist? A perennial controversy. *Journal of oral and maxillofacial pathology*. 2015;19(3):356-363. doi: 10.4103/0973-029x.174612
 62. Siqueira JF, Jr., Rôças IN. Clinical implications and microbiology of bacterial persistence after treatment procedures. *Journal of Endodontics*. 2008;34(11):1291-1301.e3. doi: 10.1016/j.joen.2008.07.028
 63. Zehnder M. Root canal irrigants. *Journal of Endodontics*. 2006;32(5):389-398. doi: 10.1016/j.joen.2005.09.014
 64. Good M, El KI, Hussey DL. Endodontic 'solutions' part 1: a literature review on the use of endodontic lubricants, irrigants and medicaments. *Dental Update*. 2012;39(4):239-246, 42-4, 46. doi: 10.12968/denu.2012.39.4.239
 65. Haapasalo M, Shen Y, Wang Z, et al. Irrigation in endodontics. *British Dental Journal*. 2014;216(6):299-303. doi: 10.1038/sj.bdj.2014.204
 66. Arias-Moliz MT, Ferrer-Luque CM, Espigares-García M, et al. Enterococcus faecalis biofilms eradication by root canal irrigants. *Journal of Endodontics*. 2009;35(5):711-714. doi: 10.1016/j.joen.2009.01.018
 67. Ordinola-Zapata R, Bramante CM, Aprecio RM, et al. Biofilm removal by 6% sodium hypochlorite activated by different irrigation techniques. *International Endodontic Journal*.

- 2014;47(7):659-666. doi: 10.1111/iej.12202
68. Tartari T, Bachmann L, Maliza AG, et al. Tissue dissolution and modifications in dentin composition by different sodium hypochlorite concentrations. *Journal Of Applied Oral Science*. 2016;24(3):291-298. doi: 10.1590/1678-775720150524
 69. Neelakantan P, Cheng CQ, Mohanraj R, et al. Antibiofilm activity of three irrigation protocols activated by ultrasonic, diode laser or Er:YAG laser in vitro. *Internaitonal Endodontic Journal*. 2015;48(6):602-610. doi: 10.1111/iej.12354
 70. Arias-Moliz MT, Ordinola-Zapata R, Baca P, et al. Antimicrobial activity of Chlorhexidine, Peracetic acid and Sodium hypochlorite/etidronate irrigant solutions against *Enterococcus faecalis* biofilms. *Internaitonal Endodontic Journal*. 2015;48(12):1188-1193. doi: 10.1111/iej.12424
 71. Bukhary S, Balto H. Antibacterial Efficacy of Octenisept, Alexidine, Chlorhexidine, and Sodium Hypochlorite against *Enterococcus faecalis* Biofilms. *Journal of Endodontics*. 2017;43(4):643-647. doi: 10.1016/j.joen.2016.09.013
 72. Chen JE, Nurbakhsh B, Layton G, et al. Irrigation dynamics associated with positive pressure, apical negative pressure and passive ultrasonic irrigations: a computational fluid dynamics analysis. *Australian Endodontic Journal*. 2014;40(2):54-60. doi: 10.1111/aej.12027
 73. Mozo S, Llana C, Forner L. Review of ultrasonic irrigation in endodontics: increasing action of irrigating solutions. *Medicina Oral, Patologia Oral Y Cirugia Bucal*. 2012;17(3):e512-516. doi: 10.4317/medoral.17621
 74. Kishen A, Shi Z, Shrestha A, et al. An investigation on the antibacterial and antibiofilm efficacy of cationic nanoparticles for root canal disinfection. *Journal of Endodontics*. 2008;34(12):1515-1520. doi: 10.1016/j.joen.2008.08.035
 75. Shrestha A, Hamblin MR, Kishen A. Photoactivated rose bengal functionalized chitosan nanoparticles produce antibacterial/biofilm activity and stabilize dentin-collagen. *Nanomedicine : Nanotechnology, Biology, And Medicine*. 2014;10(3):491-501. doi: 10.1016/j.nano.2013.10.010
 76. Persadmehr A, Torneck CD, Cvitkovitch DG, et al. Bioactive chitosan nanoparticles and photodynamic therapy inhibit collagen degradation in vitro. *Journal of Endodontics*. 2014;40(5):703-709. doi: 10.1016/j.joen.2013.11.004
 77. Shrestha A, Hamblin MR, Kishen A. Characterization of a conjugate between Rose Bengal and chitosan for targeted antibiofilm and tissue stabilization effects as a potential treatment of infected dentin. *Antimicrobial Agents and Chemotherapy*. 2012;56(9):4876-4884. doi: 10.1128/aac.00810-12
 78. Ferrari M, Mason PN, Goracci C, et al. Collagen degradation in endodontically treated teeth after clinical function. *Journal of Dental Research*. 2004;83(5):414-419. doi: 10.1177/154405910408300512
 79. Ruenraroengsak P, Cook JM, Florence AT. Nanosystem drug targeting: Facing up to complex realities. *Journal of Control Release*. 2010;141(3):265-276. doi: 10.1016/j.jconrel.2009.10.032
 80. Vertucci FJ. Root canal morphology and its relationship to endodontic procedures. *Endodontic topics*. 2005;10(1):3-29. doi:
 81. Ricucci D, Loghin S, Siqueira Jr JF. Exuberant biofilm infection in a lateral canal as the cause of short-term endodontic treatment failure: report of a case. *Journal of Endodontics*. 2013;39(5):712-718. doi:
 82. Gulabivala K, Ng YL, Gilbertson M, et al. The fluid mechanics of root canal irrigation. *Physiological Measurement*. 2010;31(12):R49-84. doi: 10.1088/0967-3334/31/12/r01
 83. Paqué F, Boessler C, Zehnder M. Accumulated hard tissue debris levels in mesial roots of mandibular molars after sequential irrigation steps. *International Endodontic Journal*. 2011;44(2):148-153. doi: 10.1111/j.1365-2591.2010.01823.x
 84. Paqué F, Laib A, Gautschi H, et al. Hard-tissue debris accumulation analysis by high-resolution computed tomography scans. *Journal of Endodontics*. 2009;35(7):1044-1047. doi:
 85. Haapasalo M, Shen Y, Qian W, et al. Irrigation in endodontics. *Dental Clinics of North America*. 2010;54(2):291-312. doi: 10.1016/j.cden.2009.12.001

86. Vasiliadis L, Darling A, Levers B. The amount and distribution of sclerotic human root dentine. *Archives of Oral Biology*. 1983;28(7):645-649. doi:
87. Vasiliadis L, Darling A, Levers B. The histology of sclerotic human root dentine. *Archives of Oral Biology*. 1983;28(8):693-700. doi:
88. Love R, Jenkinson H. Invasion of dentinal tubules by oral bacteria. *Critical reviews in oral biology & medicine*. 2002;13(2):171-83. doi: 10.1177/154411130201300207
89. Gorni FG, Gagliani MM. The outcome of endodontic retreatment: a 2-yr follow-up. *Journal of Endodontics*. 2004;30(1):1-4. doi: 10.1097/00004770-200401000-00001
90. Boutsoukias C, Kastrinakis E, Lambrianidis T, et al. Formation and removal of apical vapor lock during syringe irrigation: a combined experimental and Computational Fluid Dynamics approach. *International Endodontic Journal*. 2014;47(2):191-201. doi: 10.1111/iej.12133
91. Căpută PE, Retsas A, Kuijk L, et al. Ultrasonic irrigant activation during root canal treatment: a systematic review. *Journal of Endodontics*. 2019;45(1):31-44. e13. doi:
92. van der Sluis LW, Versluis M, Wu MK, et al. Passive ultrasonic irrigation of the root canal: a review of the literature. *International Endodontic Journal*. 2007;40(6):415-426. doi: 10.1111/j.1365-2591.2007.01243.x
93. Gu LS, Kim JR, Ling J, et al. Review of contemporary irrigant agitation techniques and devices. *Journal of Endodontics*. 2009;35(6):791-804. doi: 10.1016/j.joen.2009.03.010
94. Ricucci D, Siqueira JF, Jr. Biofilms and apical periodontitis: study of prevalence and association with clinical and histopathologic findings. *Journal of Endodontics*. 2010;36(8):1277-1288. doi: 10.1016/j.joen.2010.04.007
95. Plotino G, Cortese T, Grande NM, et al. New Technologies to Improve Root Canal Disinfection. *Brazilian Dental Journal*. 2016;27(1):3-8. doi: 10.1590/0103-6440201600726
96. Chow TW. Mechanical effectiveness of root canal irrigation. *Journal of Endodontics*. 1983;9(11):475-479. doi: 10.1016/s0099-2399(83)80162-9
97. Plotino G, Pameijer CH, Grande NM, et al. Ultrasonics in endodontics: a review of the literature. *Journal of Endodontics*. 2007;33(2):81-95. doi: 10.1016/j.joen.2006.10.008
98. Yilmaz A, Yalcin TY, Helvacioğlu-Yigit D. Effectiveness of Various Final Irrigation Techniques on Sealer Penetration in Curved Roots: A Confocal Laser Scanning Microscopy Study. *BioMed Research International*. 2020;2020:8060489. doi: 10.1155/2020/8060489
99. Boutsoukias C, Lambrianidis T, Kastrinakis E, et al. Measurement of pressure and flow rates during irrigation of a root canal ex vivo with three endodontic needles. *International Endodontic Journal*. 2007;40(7):504-513. doi: 10.1111/j.1365-2591.2007.01244.x
100. Generali L, Cavani F, Serena V, et al. Effect of Different Irrigation Systems on Sealer Penetration into Dentinal Tubules. *Journal of Endodontics*. 2017;43(4):652-656. doi: 10.1016/j.joen.2016.12.004
101. Tay FR, Gu LS, Schoeffel GJ, et al. Effect of vapor lock on root canal debridement by using a side-vented needle for positive-pressure irrigant delivery. *Journal of Endodontics*. 2010;36(4):745-750. doi: 10.1016/j.joen.2009.11.022
102. Haapasalo M, Shen Y, Wang Z, et al. Apical pressure created during irrigation with the GentleWave™ system compared to conventional syringe irrigation. *Clinical Oral Investigation*. 2016;20(7):1525-1534. doi: 10.1007/s00784-015-1632-z
103. Huang TY, Gulabivala K, Ng YL. A bio-molecular film ex-vivo model to evaluate the influence of canal dimensions and irrigation variables on the efficacy of irrigation. *International Endodontic Journal*. 2008;41(1):60-71. doi: 10.1111/j.1365-2591.2007.01317.x
104. Virdee SS, Farnell DJJ, Silva MA, et al. The influence of irrigant activation, concentration and contact time on sodium hypochlorite penetration into root dentine: an ex vivo experiment. *International Endodontic Journal*. 2020;53(7):986-997. doi: 10.1111/iej.13290
105. Villalta-Briones N, Baca P, Bravo M, et al. A laboratory study of root canal and isthmus disinfection in extracted teeth using various activation methods with a mixture of sodium hypochlorite and etidronic acid. *International Endodontic Journal*. 2021;54(2):268-278. doi: 10.1111/iej.13417

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106. Mohammadi Z, Shalavi S, Soltani MK, et al. A review of the properties and applications of ozone in endodontics: an update. *Iranian Endodontic Journal*, 2013;8(2):40-43.
107. Walmsley AD. Ultrasound and root canal treatment: the need for scientific evaluation. *International Endodontic Journal*. 1987;20(3):105-111. doi: 10.1111/j.1365-2591.1987.tb00600.x
108. Souza CC, Bueno CE, Kato AS, et al. Efficacy of passive ultrasonic irrigation, continuous ultrasonic irrigation versus irrigation with reciprocating activation device in penetration into main and simulated lateral canals. *Journal of Conservative Dentistry*. 2019;22(2):155-159. doi: 10.4103/jcd.Jcd_387_18
109. Middha M, Sangwan P, Tewari S, et al. Effect of continuous ultrasonic irrigation on postoperative pain in mandibular molars with nonvital pulps: a randomized clinical trial. *International Endodontic Journal*. 2017;50(6):522-530. doi: 10.1111/iej.12666
110. Duque JA, Duarte MA, Canali LC, et al. Comparative Effectiveness of New Mechanical Irrigant Agitating Devices for Debris Removal from the Canal and Isthmus of Mesial Roots of Mandibular Molars. *Journal of Endodontics*. 2017;43(2):326-331. doi: 10.1016/j.joen.2016.10.009
111. Parikh M, Kishan KV, Solanki NP, et al. Efficacy of Removal of Calcium Hydroxide Medicament from Root Canals by Endoactivator and Endovac Irrigation Techniques: A Systematic Review of In vitro Studies. *Contemporary Clinical Dentistry*. 2019;10(1):135-142. doi: 10.4103/ccd.ccd_335_18

BÖLÜM 15

ENDODONTİK TEDAVİDE SEANS YAKLAŞIMLARI

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GİRİŞ

Kök kanal tedavisi (KKT), diş hekimliği pratiğinde pulpal ve periapikal hastalıkların eliminasyonunun temel taşıını oluşturan cerrahi olmayan bir endodontik prosedürdür. Tedavinin başlıca endikasyonları; derin çürük lezyonları, koronal çatlaklar, diş fraktürleri veya travmatik dental yaralanmalar neticesinde gelişen irreversibl pulpitis ve pulpa nekrozudur (1).

Klinik başarı, operasyon sonrası süreçte ağrı, şişlik ve sinüs yolu (fistül) gibi semptomatik belirtilerin tamamen ortadan kalkmasıyla tanımlanır. Radyografik açıdan ise başarının temel göstergesi, periapikal doku bütünlüğünün korunması veya mevcut periapikal lezyonların iyileşmesiyle karakterize edilen normal periodontal ligament aralığının izlenmesidir (2).

Endodontik tedavinin başarısı; dişin preoperatif biyolojik durumu ile kullanılan dezenfeksiyon ve şekillendirme protokolleri gibi bir dizi teknik değişikene sıkı sıkıya bağlıdır (3). Bu bağlamda, kök kanal sisteminin temizlenmesi, şekillendirilmesi ve hemen ardından doldurulmasını (obturasyon) kapsayan tek seanslık yaklaşım ile kanalların dezenfeksiyon amacıyla seanslar arası medikamanla bekletildiği ve obturasyonun sonraki randevuda tamamlandığı çok seanslık yaklaşım, güncel literatürde en yoğun tartışılan klinik stratejiler arasında yer almaktadır.

Geçmişte, endodontik tedavilerin çoğunlukla çok seanslı olarak planlanmasının temel gerekçeleri arasında, kök kanal sisteminin yeterli şekilde dezenfekte edilebilmesi, intrakanal medikamentlerin etkinliğinden yararlanılması ve postoperatif komplikasyonların azaltılması gibi sebepler yer almaktaydı. Özellikle nekrotik pulpal ve apikal periodontitisli dişlerde, çok seanslı yaklaşım uzun yıllar boyunca daha güvenli bir seçenek olarak kabul edilmiştir. Ancak nikel-titanyum

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riapikal durumu, hastanın sistemik ve psikolojik özellikleri, kanal anatomisinin karmaşıklığı ve klinisyenin deneyimi gibi çok sayıda faktörün birlikte değerlendirilmesini gerektirir. Sonuç olarak, kanıta dayalı veriler ile klinik gerçekliğin birlikte değerlendirildiği bir yaklaşım, endodontik tedavide kalıcı biyolojik iyileşme ve uzun dönem fonksiyonel başarı için en güvenilir yolu oluşturmaktadır.

KAYNAKLAR

1. Mergoni G, Ganim M, Lodi G, et al. Single versus multiple visits for endodontic treatment of permanent teeth. *Cochrane Database of Systematic Reviews*. 2022; doi:10.1002/14651858.CD005296.pub4(12).
2. Ørstavik D. Time-course and risk analyses of the development and healing of chronic apical periodontitis in man. *International endodontic journal*. 1996;29(3):150-5. doi: <https://doi.org/10.1111/j.1365-2591.1996.tb01361.x>
3. Endodontology E S o. Quality guidelines for endodontic treatment: consensus report of the European Society of Endodontology. *International endodontic journal*. 2006;39(12):921-30. doi: <https://doi.org/10.1111/j.1365-2591.2006.01180.x>
4. Sathorn C, Parashos P, Messer H. Effectiveness of single-versus multiple-visit endodontic treatment of teeth with apical periodontitis: a systematic review and meta-analysis. *International endodontic journal*. 2005;38(6):347-55. doi: <https://doi.org/10.1111/j.1365-2591.2005.00955.x>
5. Jha S, Jose E C, Chandana N, et al. Single-visit root canal treatment: an efficient clinical approach or merely a time-saving strategy? – A review of the current evidence. *International Journal of Applied Dental Sciences*. 2025;11(3):194-8. doi: <https://www.doi.org/10.22271/oral.2025.v11.i3c.2207>
6. Wong A W, Zhang C, Chu C H. A systematic review of nonsurgical single-visit versus multiple-visit endodontic treatment. *Clinical, cosmetic and investigational dentistry*. 2014;6:45-56. doi: <https://doi.org/10.2147/CCIDE.S61487>
7. Naoum H, Chandler N P. Temporization for endodontics. *International endodontic journal*. 2002;35(12):964-78. doi: <https://doi.org/10.1046/j.1365-2591.2002.00600.x>
8. Nair P N. On the causes of persistent apical periodontitis: a review. *Int Endod J*. 2006;39(4):249-81. doi: <https://doi.org/10.1111/j.1365-2591.2006.01099.x>
9. Choudhari S, Solet P, Jeevanandan G, et al. Single-visit versus multi-visit endodontic retreatment: A systematic review of outcomes in patients with secondary endodontic infection. *Saudi Endodontic Journal*. 2024;14(3):301-11. doi: 10.4103/sej.sej_225_23
10. Schwendicke F, Göstemeyer G. Single-visit or multiple-visit root canal treatment: systematic review, meta-analysis and trial sequential analysis. *BMJ open*. 2017;7(2):e013115. doi: <https://doi.org/10.1136/bmjopen-2016-013115>
11. Vera J, Siqueira J F, Jr., Ricucci D, et al. One- versus Two-visit Endodontic Treatment of Teeth with Apical Periodontitis: A Histobacteriologic Study. *Journal of Endodontics*. 2012;38(8):1040-52. doi: <https://doi.org/10.1016/j.joen.2012.04.010>
12. Ricucci D, Siqueira Jr J F. Biofilms and apical periodontitis: study of prevalence and association with clinical and histopathologic findings. *Journal of endodontics*. 2010;36(8):1277-88. doi: <https://doi.org/10.1016/j.joen.2010.04.007>
13. Ordinola-Zapata R, Noblett W C, Perez-Ron A, et al. Present status and future directions of intracanal medicaments. *Int Endod J*. 2022;55 Suppl 3(Suppl 3):613-36. doi: <https://doi.org/10.1111/iej.13731>
14. Zou X, Zheng X, Liang Y, et al. Expert consensus on irrigation and intracanal medication in root canal therapy. *International journal of oral science*. 2024;16(1):23. doi: <https://doi.org/10.1038/s41368-024-00280-5>

15. Bassam S, El-Ahmar R, Salloum S, et al. Endodontic postoperative flare-up: An update. *The Saudi dental journal*. 2021;33(7):386-94. doi: <https://doi.org/10.1016/j.sdentj.2021.05.005>
16. Siqueira Jr J F, Rôças I N. Clinical implications and microbiology of bacterial persistence after treatment procedures. *Journal of endodontics*. 2008;34(11):1291-301. e3. doi: <https://doi.org/10.1016/j.joen.2008.07.028>
17. Zmener O, Banegas G, Pameijer C H. Coronal microleakage of three temporary restorative materials: an in vitro study. *J Endod*. 2004;30(8):582-4. doi: <https://doi.org/10.1097/01.DON.0000121610.63000.F2>
18. Yassen G H, Vail M M, Chu T G, et al. The effect of medicaments used in endodontic regeneration on root fracture and microhardness of radicular dentine. *Int Endod J*. 2013;46(7):688-95. doi: <https://doi.org/10.1111/iej.12046>
19. Alovisi M, Mirra D, Berutti E, et al. Working length variation during multiple-visit endodontic treatment: An observational study. *Australian Endodontic Journal*. 2023;49(S1):107-12. doi: <https://doi.org/10.1111/aej.12703>
20. Kumar G, Jena S, Manila N, et al. Incidence of postoperative pain after single-visit and multiple-visit root canal therapy: a systematic review. *BMC Oral Health*. 2025;25(1):47. doi: <https://doi.org/10.1186/s12903-024-05412-1>
21. Peters L, Wesselink P. Periapical healing of endodontically treated teeth in one and two visits obturated in the presence or absence of detectable microorganisms. *International endodontic journal*. 2002;35(8):660-7. doi: <https://doi.org/10.1046/j.1365-2591.2002.00541.x>
22. Manfredi M, Figini L, Gagliani M, et al. Single versus multiple visits for endodontic treatment of permanent teeth. *Cochrane Database of Systematic Reviews*. 2016;10.1002/14651858.CD005296.pub3(12). doi: <https://doi.org/10.1002/14651858.CD005296.pub3>
23. Penesis V A, Fitzgerald P I, Fayad M I, et al. Outcome of one-visit and two-visit endodontic treatment of necrotic teeth with apical periodontitis: a randomized controlled trial with one-year evaluation. *Journal of endodontics*. 2008;34(3):251-7. doi: <https://doi.org/10.1016/j.joen.2007.12.015>
24. Kirci H K, Karataslioglu E. Assessment of fractal dimension changes in periapical trabecular patterns following single-visit and multi-visit nonsurgical endodontic treatment with different medicaments: a retrospective study. *Acta Odontologica Scandinavica*. 2025;84:45201. doi: <https://doi.org/10.2340/aos.v84.45201>
25. Mattigatti S, Srinivas S, Metkar C S, et al. Knowledge, Attitude and Beliefs on Single Visit vs Multi-Visit Endodontics of Dental Practitioners. *Int J Cur Res Rev| Vol*. 2021;13(03):75. doi: <https://doi.org/10.31782/IJCRR.2021.13320>
26. Bedene L N R, Leonardi D P, Couto J S, et al. Assessment of Postoperative Pain After Single- or Multiple-Visit Endodontic Therapy and Its Molecular Aspects: A Randomised Controlled Study. *Australian Endodontic Journal*. 2025;51(3):668-76. doi: <https://doi.org/10.1111/aej.12982>
27. Szczurowski P, Gronkiewicz K, Czopik B. Factors Influencing the Healing of Maxillary Sinusitis of Endodontic Origin After Non-Surgical Endodontic Treatment. *Journal of Clinical Medicine*. 2025;14(19):6778. doi: <https://doi.org/10.3390/jcm14196778>
28. Almeida D O, Chaves S C, Souza R A, et al. Outcome of single-vs multiple-visit endodontic therapy of nonvital teeth: a meta-analysis. *J Contemp Dent Pract*. 2017;18(4):330-6. doi: <https://doi.org/10.5005/jp-journals-10024-2041>
29. Su Y, Wang C, Ye L. Healing rate and post-obturation pain of single-versus multiple-visit endodontic treatment for infected root canals: a systematic review. *Journal of endodontics*. 2011;37(2):125-32. doi: <https://doi.org/10.1016/j.joen.2010.09.005>
30. Gill G, Bhuyan A, Kalita C, et al. Single Versus Multi-visit Endodontic Treatment of Teeth with Apical Periodontitis: An In vivo Study with 1-year Evaluation. *Annals of medical and health sciences research*. 2016;6(1):19-26. doi: <https://doi.org/10.4103/2141-9248.180265>
31. Dorasani G, Madhusudhana K, Chinni S K. Clinical and radiographic evaluation of single-visit and multi-visit endodontic treatment of teeth with periapical pathology: An: in vivo:

Güncel Endodonti Çalışmaları X

- study. *Journal of Conservative Dentistry and Endodontics*. 2013;16(6):484-8. doi: 10.4103/0972-0707.120933
32. Drouri S, Laslami K, Dhaim S, et al. Influence of number of visits on the outcome of endodontic treatment. *Journal of Conservative Dentistry and Endodontics*. 2024;27(12):1211-20. doi: 10.4103/JCDE.JCDE_688_24
 33. Karaođlan F, Kiziltaş Gül A, Çalıřkan M K. Postoperative Pain Following Single-Visit Versus Two-Visit Endodontic Retreatment – A Comparison of Inter-Appointment and Post-Obturation Periods: Randomised Clinical Trial. *Australian Endodontic Journal*. 2025;51(3):706-14. doi: <https://doi.org/10.1111/aej.70004>
 34. AL-Omiri M K, Iqbal A, Akbar I. Flare-up rate in molars with periapical radiolucency in one-visit vs two-visit endodontic treatment. *The journal of contemporary dental practice*. 2013;14(3):414-8. doi: 10.5005/jp-journals-10024-1337
 35. Yoldas O, Topuz A, Iřci A S, et al. Postoperative pain after endodontic retreatment: single-versus two-visit treatment. *Oral surgery, oral medicine, oral Pathology, oral Radiology, and endodontology*. 2004;98(4):483-7. doi: <https://doi.org/10.1016/j.tripleo.2004.03.009>
 36. Hepsenoglu Y E, Eyuboglu T F, Özcan M. Postoperative pain intensity after single-versus two-visit nonsurgical endodontic retreatment: a randomized clinical trial. *Journal of endodontics*. 2018;44(9):1339-46. doi: <https://doi.org/10.1016/j.joen.2018.05.017>

BÖLÜM 16

HAMİLELİK VE ENDODONTİ ARASINDAKİ İLİŞKİ

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GİRİŞ

Hamilelik sürecinde, gebelik hormonlarının artan salınımı ve bu hormonların sistemik dolaşıma katılması sonucunda annede çok sayıda fizyolojik ve biyolojik değişiklik meydana gelmektedir (1). Salgılanan hormonlar, ağız boşluğu dokularının fonksiyonlarını etkileyerek, gebelikte anne adayını bazı enfeksiyöz ve inflamatuvar durumlara karşı daha hassas hale getirmektedir (2).

Bu fizyolojik değişimlerin bilinmesi, gebelere uygun ve güvenli ağız sağlığı hizmeti sunulabilmesi açısından temel bir gerekliliktir (3). Ağız hijyeninin ihmal edilmesi; periodontal hastalıkların gelişimine ve oral enfeksiyon riskinin artmasına zemin hazırlayabilmektedir (4, 5). Uluslararası literatürde, gebelerde tedavi edilmemiş çürük prevalansının gebe olmayan kadınlara kıyasla daha yüksek olduğunu gösteren çok sayıda çalışma bulunmaktadır (6-8). Bu artış; bulantı ve kusmaya bağlı asidik ortam değişiklikleri, tükürük pH'ında düşüş, karbonhidratlı, şekerli besin tüketimindeki artış gibi faktörlerle ilişkili olabilmektedir (9). Tedavinin zamanlaması, tercih edilen işlemler ve reçete edilecek ilaçlar açısından bazı düzenlemeler yapılması gerekebilmektedir (10, 11).

Kök kanal tedavisinde, lokal anestezi, irrigasyon, kanal içi medikamentler ile analjezik ve antibiyotik kullanımı gibi aşamalarda hamile hastalarda dikkatli olunmalıdır (11). Dental radyografide ise uygun pozisyonlandırma, abdominal koruma, yüksek hızlı dijital sistemler, kurşun önlük ve tiroid koruyucu kullanımına annenin ve bebeğin sağlığı için dikkat edilmelidir (12-14).

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SONUÇ

Gebelik sürecinde ağız ve diş sağlığının korunması ve gerekli bakımın gecikmeden sağlanması, oral enfeksiyonların önlenmesi açısından büyük önem taşımaktadır. Endodontik tedavi, dişin korunması açısından zorunlu olduğu durumlarda, gebelikte genel olarak güvenli bir girişim olarak kabul edilmektedir. Bununla birlikte, hayati bir gereklilik bulunmadıkça, özellikle organogenez dönemini kapsayan birinci trimesterde bu tür işlemlerin ertelenmesi tercih edilmektedir. Dental uygulamalar sırasında radyografik incelemelerden mümkün olduğunca kaçınılmakta; görüntüleme zorunlu olduğunda ise uygun koruyucu önlemler titizlikle uygulanmaktadır. Tedavi esnasında kullanılan lokal anesteziklerin büyük çoğunluğu gebelikte güvenli kabul edilse de, her hasta için bireysel değerlendirme yapılması ve ilgili sağlık profesyonelleriyle birlikte karar verilmesi önemlidir.

KAYNAK

1. Steinberg BJ, Hilton IV, Iida H, Samelson R. Oral health and dental care during pregnancy. *Dental Clinics*. 2013;57(2):195-210.
2. Ramos-e-Silva M, Martins NR, Kroumpouzou G. Oral and vulvovaginal changes in pregnancy. *Clinics in dermatology*. 2016;34(3):353-8.
3. Ahtari MD, Georgakopoulou EA, Afentoulide N. Dental care throughout pregnancy: what a dentist must know. *Oral Health Dent Manag*. 2012;11(4):169-76.
4. Boggess KA, Edelstein BL. Oral health in women during preconception and pregnancy: implications for birth outcomes and infant oral health. *Maternal and child health journal*. 2006;10(Suppl 1):169-74.
5. Giglio JA, Lanni SM, Laskin DM, Giglio NW. Oral health care for the pregnant patient. *Journal of the Canadian Dental Association*. 2009;75(1).
6. Azofeifa A, Yeung LF, Alverson C, Beltrán-Aguilar E. Dental caries and periodontal disease among US pregnant women and nonpregnant women of reproductive age, National Health and Nutrition Examination Survey, 1999–2004. *Journal of public health dentistry*. 2016;76(4):320-9.
7. Christensen LB, Jeppe-Jensen D, Petersen PE. Self-reported gingival conditions and self-care in the oral health of Danish women during pregnancy. *Journal of clinical periodontology*. 2003;30(11):949-53.
8. Mahmud S, Begum F, Uddin M. Assessment of common oral and dental diseases among pregnant women at Dhaka City in Bangladesh. *Assessment*. 2014;2(2).
9. Cuco G, Fernandez-Ballart J, Sala J, Viladrich C, Iranzo R, Vila J, et al. Dietary patterns and associated lifestyles in preconception, pregnancy and postpartum. *European journal of clinical nutrition*. 2006;60(3):364-71.
10. Cengiz SB. The pregnant patient: considerations for dental management and drug use. *Quintessence International*. 2007;38(3).
11. Ibhawoh L, Enabulele J. Endodontic treatment of the pregnant patient: Knowledge, attitude and practices of dental residents. *Nigerian medical journal*. 2015;56(5):311-6.
12. Fenig E, Mishaeli M, Kalish Y, Lishner M. Pregnancy and radiation. *Cancer treatment reviews*. 2001;27(1):1-7.
13. Kandan PM, Menaga V, Kumar RRR. Oral health in pregnancy (guidelines to gynaecologists, general physicians & oral health care providers). *JPMA-Journal of the Pakistan Medical Asso-*

- ciation. 2011;61(10):1009.
14. Richards AG, Colquitt WN. Reduction in dental x-ray exposures during the past 60 years. *The Journal of the American Dental Association*. 1981;103(5):713-8.
 15. Barak S, Oettinger-Barak O, Oettinger M, Machtei EE, Peled M, Ohel G. Common oral manifestations during pregnancy: a review. *Obstetrical & gynecological survey*. 2003;58(9):624-8.
 16. Harris M, Desai R, Chuang T, Hood A, Mirowski G. Lobular capillary hemangiomas: an epidemiologic report, with emphasis on cutaneous lesions. *Journal of the American Academy of Dermatology*. 2000;42(6):1012-6.
 17. Edgar WM, O'Mullane D, Dawes C. *Saliva and oral health: British Dental Association London*; 2004.
 18. Darveau RP, Tanner A, Page RC. The microbial challenge in periodontitis. *Periodontology* 2000. 1997;14(1):12-32.
 19. Haag D, Peres K, Balasubramanian M, Brennan D. Oral conditions and health-related quality of life: a systematic review. *Journal of dental research*. 2017;96(8):864-74.
 20. Naseem M, Khurshid Z, Khan HA, Niazi F, Zohaib S, Zafar MS. Oral health challenges in pregnant women: Recommendations for dental care professionals. *The Saudi Journal for Dental Research*. 2016;7(2):138-46.
 21. Iida H. Oral health interventions during pregnancy. *Dental Clinics*. 2017;61(3):467-81.
 22. Jiang H, Su Y, Xiong X, Harville E, Wu H, Jiang Z, et al. Prevalence and risk factors of periodontal disease among pre-conception Chinese women. *Reproductive health*. 2016;13(1):141.
 23. Almeida LHS, Pilownic KJ, Tarquínio SBC, Felix AC, Pappen FG, Romano AR. Influence of pregnancy on the inflammatory process following direct pulp capping: a preliminary study in rats. *Brazilian Dental Journal*. 2019;30(1):22-30.
 24. Krüger MS, Lang CA, Almeida LH, Bello-Corrêa FO, Romano AR, Pappen FG. Dental pain and associated factors among pregnant women: an observational study. *Maternal and child health journal*. 2015;19(3):504-10.
 25. Hargreaves KM, Goodis HE, Seltzer S, Bender IB. *Polpa dentária de Seltzer e Bender: Quintessence*; 2009.
 26. Hahn C-L, Liewehr FR. Update on the adaptive immune responses of the dental pulp. *Journal of Endodontics*. 2007;33(7):773-81.
 27. de Andrade ED. *Terapêutica medicamentosa em odontologia: Artes Médicas Editora*; 2014.
 28. Khalighinejad N, Aminoshariae A, Kulild JC, Mickel A. Apical periodontitis, a predictor variable for preeclampsia: a case-control study. *Journal of endodontics*. 2017;43(10):1611-4.
 29. Luppi P. How immune mechanisms are affected by pregnancy. *Vaccine*. 2003;21(24):3352-7.
 30. Abbott P. Are dental radiographs safe? *Australian Dental Journal*. 2000;45(3):208-13.
 31. ARAÚJO LPd, XAVIER SR, HARTWIG AD, AZEVEDO MS, PAPPEN FG, ROMANO AR. Endodontic treatment during pregnancy: case series and literature review. *RGO-Revista Gaúcha de Odontologia*. 2022;70:e20220005.
 32. Hemalatha V, Manigandan T, Sarumathi T, Aarthi Nisha V, Amudhan A. Dental considerations in pregnancy-a critical review on the oral care. *Journal of clinical and diagnostic research: JCDR*. 2013;7(5):948.
 33. Baranwal R, Duggi V, Avinash A, Dubey A, Pagaria S, Munot H. Propolis: a smart supplement for an intracanal medicament. *International journal of clinical pediatric dentistry*. 2017;10(4):324.
 34. Aboalshamat K, Abdulrahman S, Alowadi J, Al-Mutairy N, Fairak M, Alraithi N, et al. Endodontic treatment in pregnancy: knowledge, attitudes, and practices of dentists and interns in Jeddah, Saudi Arabia. *The Open Dentistry Journal*. 2020;14(1).
 35. Gamba TO, Visioli F, Bringmann DR, Rados PV, da Silveira HLD, Flores IL. Impact of dental imaging on pregnant women and recommendations for fetal radiation safety: A systematic review. *Imaging Science in Dentistry*. 2024;54(1):1.
 36. Aliabadi T, Saberi EA, Tabatabaie AM, Tahmasebi E. Antibiotic use in endodontic treat-

- ment during pregnancy: A narrative review. *European Journal of Translational Myology*. 2022;32(4):10813.
37. Hagai A, Diav-Citrin O, Shechtman S, Ornoy A. Pregnancy outcome after in utero exposure to local anesthetics as part of dental treatment: A prospective comparative cohort study. *The Journal of the American Dental Association*. 2015;146(8):572-80.
 38. Xavier HS, Xavier VBC. Cuidados odontológicos com a gestante: Santos; 2004.
 39. Syme MR, Paxton JW, Keelan JA. Drug transfer and metabolism by the human placenta. *Clinical pharmacokinetics*. 2004;43(8):487-514.
 40. Lee JM, Shin TJ. Use of local anesthetics for dental treatment during pregnancy; safety for parturient. *Journal of dental anesthesia and pain medicine*. 2017;17(2):81-90.
 41. Kuzekanani M. Latest concepts in endodontic management of pregnant patients. *International Journal of Dentistry*. 2023;2023(1):9714515.
 42. Markose G, Graham R. Anaesthesia: LA in pregnancy. *British Dental Journal*. 2017;222(1):3-4.
 43. Zhou X, Zhong Y, Pan Z, Zhang J, Pan J. Physiology of pregnancy and oral local anesthesia considerations. *PeerJ*. 2023;11:e15585.
 44. Mendia J, Cuddy MA, Moore PA. Drug therapy for the pregnant dental patient. *Compendium of Continuing Education in Dentistry (15488578)*. 2012;33(8).

BÖLÜM 17

ENDODONTİDE MEZENKİMAL KÖK HÜCRE KAYNAKLI EKSOZOMLARIN BİYOLOJİK VE TERAPÖTİK ROLÜ

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GİRİŞ

Diş pulpası, diş içerisinde yer alan tek yumuşak doku olup mine, dentin ve se-ment gibi mineralize dokularla çevrilidir. Fibroblastlar, odontoblastlar ve immün hücreler başta olmak üzere farklı hücre tiplerinin yanı sıra ekstraselüler matriks bileşenleri, kan damarları ve sınırlardan oluşan kompleks ve dinamik bir yapıya sahiptir. Diş pulpası; diş dokularının beslenmesini sağlamak, primer, sekonder ve tersiyer dentin oluşumuna katkıda bulunmak, duyuşal iletimi gerçekleştirmek ve immün koruma fonksiyonlarını yerine getirmek gibi temel biyolojik görevleri üstlenmektedir (1).

Pulpa dokusunun kaybına sebep olan pulpitis, çoğunlukla bakteriyel enfeksiyon kaynaklı gelişen ve ağızda yaygın olarak görülen inflamatuvar bir hastalıktır. Akut pulpitis, şiddetli diş ağrısı ile karakterize olup hastanın ağız sağlığını önemli ölçüde bozmakta ve genel yaşam kalitesini düşürmektedir. Günümüzde pulpitis tedavisinde tercih edilen klinik yaklaşım, kök kanalındaki enfekte pulpa dokusu ve dentinin tamamen uzaklaştırılmasını ve ardından kök kanal boşluğunun biyolojik olarak inert materyallerle hermetik şekilde doldurulmasını hedefleyen kök kanal tedavisidir (KKT) (2, 3). Bununla birlikte, bu yaklaşım, pulpa-dentin kompleksinin doğal yapısının ve biyolojik fonksiyonlarının geri dönüşümsüz olarak kaybedilmesine yol açmakta; özgül doku mimarisinin rejenerasyonunu ve fonksiyonel rekonstrüksiyonunu sağlayamamaktadır. Sonuç olarak, kök kanal tedavisi sonrası diş canlılığı tamamen ortadan kalkmakta, diş dokusunun kırılabilirliği artmakta ve diş kırılması ya da diş kaybına yatkınlık belirgin şekilde yükselmektedir (4, 5). Yapılan çalışmalarda, kök kanal tedavisi sonrası ön ve premolar dişlerde diş kaybı riskinin 1,8 kat, molar dişlerde ise 7,4 kat arttığı bildirilmiştir (6). Bu nedenle, diş

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tin kompleksinin fonksiyonel ve öngörülebilir rejenerasyonu için klinikte uygulanabilir nanoterapötik ajanlar hâline gelmesi olası görünmektedir.

KAYNAKLAR

1. 1: Hammouda DA, Mansour AM, Saeed MA, et al. Stem cell derived exosomes for dentin-pulp complex regeneration: a mini-review. *Restorative Dentistry & Endodontics*.2023;48(2): 20-33.
2. Han YY, Dal-Fabbro R, Mahmoud AH, et al. GelMA/TCP nanocomposite scaffold for vital pulp therapy. *Acta Biomaterialia*. 2024;173:495–508. doi: <https://doi.org/10.1016/j.actbio.2023.11.005>.
3. Zeng YY, Hu XY, Cai ZB, et al. Photodynamic and nitric oxide therapy-based synergistic antimicrobial nanoplatfrom: an advanced root canal irrigation system for endodontic bacterial infections. *Journal of Nanobiotechnology*. 2024;22(1):213. doi: <https://doi.org/10.1186/s12951-024-02483-8>
4. Liang ZL, Li JD, Lin HK, et al. Understanding the multi-functionality and tissue-specificity of decellularized dental pulp matrix hydrogels for endodontic regeneration. *Acta Biomaterialia*. 2024;181:202–21. doi: <https://doi.org/10.1016/j.actbio.2024.04.040>. Li HX
5. Zhang D, Bao PP, et al. Recent advances in functional hydrogels for treating dental hard tissue and endodontic diseases. *ACS Nano Journal*. 2024;18 (26):16395–412. doi: <https://doi.org/10.1021/acsnano.4c02754>.
6. Sasaki JI, Abe GL, Li AN, et al. Large three-dimensional cell constructs for tissue engineering. *Science and Technology of Advanced Materials* 2021;22(1):571–82. doi: <https://doi.org/10.1080/14686996.2021.1945899>
7. Shi X, Mao J, Liu Y. Pulp stem cells derived from human permanent and deciduous teeth: biological characteristics and therapeutic applications. *Stem Cells Translational Medicine*. 2020;9(4):445–64. doi: <https://doi.org/10.1002/sctm.19-0398>.
8. Chen H, Fu HC, Wu X, et al. Regeneration of pulpo-dentinal-like complex by a group of unique multipotent CD24a+ stem cells. *Science Advances*. 2020;6(15). doi: <https://doi.org/10.1126/sciadv.aay1514>
9. Guo H, Li B, Wu ML, et al. Odontogenesis-related developmental microenvironment facilitates deciduous dental pulp stem cell aggregates to revitalize an avulsed tooth 121223. *Biomaterials*. 2021;279. doi: <https://doi.org/10.1016/j.biomaterials.2021.121223>.
10. Wang DR, Lyu Y, Yang Y, et al. Schwann cell-derived EVs facilitate dental pulp regeneration through endogenous stem cell recruitment via SDF-1/CXCR4 axis *Acta Biomaterials*. 2022;140:610–24.doi:<https://doi.org/10.1016/j.actbio.2021.11.039>.
11. Ding Y, Li Y, Sun Z, et al. Cell-derived extracellular vesicles and membranes for tissue repair. *Journal of Nanobiotechnology*. 2021;19, 368.
12. Zhou T, Yuan Z, Weng J, et al. Challenges and advances in clinical applications of mesenchymal stromal cells. *Journal of Hematology & Oncology*. 2021; 14: 24.
13. de Abreu RC, Fernandes H, da Costa Martins PA, et al. Native and bioengineered extracellular vesicles for cardiovascular therapeutics. *Nature Reviews Cardiology*. 2020; 17:685–697.
14. Murray PE. Review of guidance for the selection of regenerative endodontics, apexogenesis, apexification, pulpotomy, and other endodontic treatments for immature permanent teeth. *International Endodontic journal*. 2023;56(2):188–199. <https://doi.org/10.1111/iej.13809>
15. Ahmad P, Estrin N, Farshidfar N. Mechanistic insights into dental stem cells-derived exosomes in regenerative endodontics. *International Endodontic Journal*. 2025;58:1384–1407. <https://doi.org/10.1111/iej.14269>
16. Ahmad P, Estrin N, Farshidfar N, et al. Isolation methods of exosomes derived from dental stem cells. *International Journal of Oral Sciences*. 2025;17:50<https://doi.org/10.1038/s41368-025-00370-y>

17. Miron RJ, Zhang Y. Understanding exosomes: part 1— characterization, quantification and isolation techniques. *Periodontology 2000*. 2024; 94(1):231– 256.
18. Estrin NE, Farshidfar N, Ahmad P, et al. Exosome-Mediated Alveolar Ridge Augmentation: A First Human Case Report with Histology. *The International journal of periodontics & restorative dentistry*, 2026;46(1):30–41. <https://doi.org/10.11607/prd.7567>
19. Miron RJ, Estrin NE, Sculean A. Understanding exosomes: part 2—emerging leaders in regenerative medicine. *Periodontology 2000*. 2024-1;94(1):257–414
20. Miron RJ, Estrin NE, Sculean A. Understanding exosomes: part 3—therapeutic+ diagnostic potential in dentistry. *Periodontology 2000*. 2024-b;94(1): 415–482.
21. Monje A, Amerio E, Cha JK, et al. Strategies for implant surface decontamination in peri-implantitis therapy. *The International Journal of Oral Implantology*, 2022;15, 213–248.
22. Pan BT, Johnstone RM. Fate of the transferrin receptor during maturation of sheep reticulocytes in vitro: selective externalization of the receptor. *Cell*. 1983;33:967–978.
23. Kowal J, Tkach M, Thery C. (2014). Biogenesis and secretion of exosomes. *Current Opinion in Cell Biology*. 2014;29: 116–125. doi: 10.1016/j.ceb.2014.05.004.
24. van Niel G, D’Angelo G, Raposo G. Shedding light on the cell biology of extracellular vesicles. *Nature Reviews in Molecular and Cell Biology*. 2018;19: 213–228.
25. Tan SS, Yin Y, Lee T, et al. Therapeutic msc exosomes are derived from lipid raft microdomains in the plasma membrane. *Journal of Extracellular Vesicles*. 2013;2:22614. doi: 10.3402/jev.v2i0.22614
26. Skotland T, Hessvik NP, Sandvig K, et al. Exosomal lipid composition and the role of ether lipids and phosphoinositides in exosome biology. *Journal of Lipid Research*. 2019;60:9–18. doi: 10.1194/jlr.R084343.
27. Kowal J, Tkach M, Thery C. Biogenesis and secretion of exosomes. *Current Opinion in Cell Biology*. 2014;29:116–125. doi: 10.1016/j.ceb.2014.05.004.
28. van Balkom BWM, Gremmels H, Giebel B. Proteomic signature of mesenchymal stromal cell-derived small extracellular vesicles. *Proteomics*. 2019;19:e1800163. doi: 10.1002/pmic.201800163.
29. Toh WS, Lai RC, Zhang B. Msc exosome Works through a protein-based mechanism of action. *Biochemical Society Transactions*. 2018-1;46:843–853. doi: 10.1042/BST20180079.
30. Lai RC, Yeo RW, Tan KH, et al. Mesenchymal stem cell exosome ameliorates reperfusion injury through proteomic complementation. *Regenerative Medicine*. 2013;8:197–209. doi: 10.2217/rme.13.4
31. Anderson JD, Johansson HJ, Graham CS, et al. (2016). Comprehensive proteomic analysis of mesenchymal stem cell exosomes reveals modulation of angiogenesis via nuclear factor-kappab signaling. *Stem Cells*. 2016;34:601–613. doi: 10.1002/stem.2298
32. Zhang B, Wang M, Gong A, et al. Hucmscxosome mediated-wnt4 signaling is required for cutaneous wound healing. *Stem Cells*. 2015;33: 2158–2168. doi: 10.1002/stem.1771.
33. Wu JY, Ji AL, Wang ZX, et al. Exosome-mimetic nanovesicles from hepatocytes promote hepatocyte proliferation in vitro and liver regeneration *in vivo*. *Scientific Reports*. 2018; 8:2471. doi: 10.1038/s41598-018-20505-y.
34. Anderson JD, Johansson HJ, Graham CS, et al. (2016). Comprehensive proteomic analysis of mesenchymal stem cell exosomes reveals modulation of angiogenesis via nuclear factor-kappab signaling. *Stem Cells*. 2016;34:601–613. doi: 10.1002/stem.2298.
35. Lai RC, Yeo RW, Lim SK. Mesenchymal stem cell exosomes. *Seminars in Cell Development and Biology*. 2015;40:82–88.
36. Raposo G, Nijman HW, Stoorvogel W, et al. B lymphocytes secrete antigen-presenting vesicles. *Journal of Experimental Medicine*. 1996;183:1161–1172.
37. Zitvogel L, Regnault A, Lozier A, et al. Eradication of established murine tumors using a novel cell-free vaccine: dendritic cell-derived exosomes. *Nature Medicine*. 1998;4:594–600.
38. Raposo G, Stoorvogel W. Extracellular vesicles: exosomes, microvesicles, and friends. *Journal of*

- Cellular Biology*. 2013;200:373–383. doi: 10.1083/jcb.201211138.
39. Valadi H, Ekstrom K, Bossios A, et al. Exosome-mediated transfer of mRNAs and microRNAs is a novel mechanism of genetic exchange between cells. *Nature Cell Biology*. 2007;9:654–659.
 40. Tomasoni S, Longaretti L, Rota C, et al. Transfer of growth factor receptor mRNA via exosomes unravels the regenerative effect of mesenchymal stem cells. *Stem Cells and Development*. 2013;22:772–780. doi: 10.1089/scd.2012.0266.
 41. Guo SC, Tao SC, Yin WJ, et al. Exosomes derived from platelet-rich plasma promote the re-epithelization of chronic cutaneous wounds via activation of YAP in a diabetic rat model. *Theranostics* 2017;7:81–96. doi: 10.7150/thno.16803.
 42. Shanmuganathan M, Vughs J, Noseda M, et al. Exosomes: basic biology and technological advancements suggesting their potential as ischemic heart disease therapeutics. *Frontiers in Physiology*. 2018;9:1159. doi: 10.3389/fphys.2018.01159.
 43. Zamani P, Fereydouni N, Butler AE, et al. The therapeutic and diagnostic role of exosomes in cardiovascular diseases. *Trends in Cardiovascular Medicine*. 2018;29:313–323. doi: 10.1016/j.tcm.2018.10.010.
 44. Mead B, Tomarev S. Bone marrow-derived mesenchymal stem cell-derived exosomes promote survival of retinal ganglion cells through mirna-dependent mechanisms. *Stem Cells in Translational Medicine*. 2017;6:1273–1285. doi: 10.1002/sctm.16-0428.
 45. Chen J, Ren S, Duscher D, et al. Exosomes from human adipose-derived stem cells promote sciatic nerve regeneration via optimizing Schwann cell function. *Journal of Cellular Physiology*. 2019;234:23097–23110. doi:10.1002/jcp.28873.
 46. Nakamura Y, Miyaki S, Ishitobi H, et al. Mesenchymal-stem-cell-derived exosomes accelerate skeletal muscle regeneration. *FEBS Letters*. 2015;589:1257–1265. doi: 10.1016/j.febslet.2015.03.031.
 47. Qing L, Chen H, Tang J, et al. (2018). Exosomes and their microRNA cargo: new players in peripheral nerve regeneration. *Neurorehabilitation and Neural Repair*. 2018;32:765–776. doi: 10.1177/1545968318798955.
 48. Park KM, Gerecht S. Harnessing developmental processes for vascular engineering and regeneration. *Development*. 2014;141:2760–2769. doi: 10.1242/dev.102194.
 49. Watt SM, Gullo F, van der Garde M, et al. The angiogenic properties of mesenchymal stem/stromal cells and their therapeutic potential. *British Medical Bulletin*. 2013;108:25–53. doi: 10.1093/bmb/ldt031.
 50. Gong M, Yu B, Wang J, et al. Mesenchymal stem cells release exosomes that transfer miRNAs to endothelial cells and promote angiogenesis. *Oncotarget: Peer-reviewed Oncology & Cancer Research Journal*. 2017;8:45200–45212. doi: 10.18632/oncotarget.16778.
 51. Alcayaga-Miranda F, Varas-Godoy M, Khoury M. Harnessing the angiogenic potential of stem cell-derived exosomes for vascular regeneration. *Stem Cells International*. 2016:3409169. doi: 10.1155/2016/3409169.
 52. Bartholomew A, Sturgeon C, Siatskas M, Ferrer K, et al. Mesenchymal stem cells suppress lymphocyte proliferation *in vitro* and prolong skin graft survival *in vivo*. *Experimental Hematology*. 2002;30:42–48.
 53. Di Nicola M, Carlo-Stella C, Magni M, et al. Human bone marrow stromal cells suppress T-lymphocyte proliferation induced by cellular or nonspecific mitogenic stimuli. *Blood*. 2002;99:3838–3843.
 54. Assoni A, Coatti G, Valadares MC, et al. Different Donors Mesenchymal Stromal Cells Secretomes Reveal Heterogeneous Profile of Relevance for Therapeutic Use. *Stem Cells and Development*. 2017;26:206–214.
 55. Yu S, Zhao Y, Ma Y, et al. Profiling the Secretome of Human Stem Cells from Dental Apical Papilla. *Stem Cells and Development*. 2016;25:499–508.
 56. Caseiro AR, Santos Pedrosa S, Ivanova G, et al. Mesenchymal Stem/Stromal Cells metabolomic and bioactive factors profiles: A comparative analysis on the umbilical cord and dental pulp

- derived Stem/ Stromal Cells secretome. *PLoS ONE*. **2019**;14: e0221378.
57. Murakami M, Hayashi Y, Iohara K, et al. Trophic Effects and Regenerative Potential of Mobilized Mesenchymal Stem Cells from Bone Marrow and Adipose Tissue as Alternative Cell Sources for Pulp/Dentin Regeneration. *Cell Transplantation*. 2015;24:1753–1765.
 58. Joo KH, Song JS, Kim S, et al. Cytokine Expression of Stem Cells Originating from the Apical Complex and Coronal Pulp of Immature Teeth. *Journal of Endodontics*. **2018**;44:87–92.e81.
 59. Nagata M, Iwasaki K, Akazawa K, et al. Conditioned Medium from Periodontal Ligament Stem Cells Enhances Periodontal Regeneration. *Tissue Engineering Part A*. 2017;23:367–377.
 60. Kumar A, Kumar V, Rattan V. Secretome proteins regulate comparative osteogenic and adipogenic potential in bone marrow and dental stem cells. *Biochimie*. 2018;155: 129–139.
 61. Konala VBR, Bhonde R, Pal R. Secretome studies of mesenchymal stromal cells (MSCs) isolated from three tissue sources reveal subtle differences in potency. *In Vitro Cellular and Developmental Biology Animal*. 2020;56: 689–700.
 62. Kim K, Jeon M, Lee HS, et al. Comparative analysis of secretory factors from permanent- and deciduous-teeth periodontal ligament cells. *Archives of Oral Biology*. 2016;71: 65–79.
 63. Ishizaka R, Hayashi Y, Iohara K, et al. Stimulation of angiogenesis, neurogenesis and regeneration by side population cells from dental pulp. *Biomaterials*. 2013;34:1888–1897.
 64. Ji L, Bao L, Gu Z, et al. Comparison of immunomodulatory properties of exosomes derived from bone marrow mesenchymal stem cells and dental pulp stem cells. *Immunology Research*. 2019;67:432–442.
 65. Silvestro S, Chiricosta L, Gugliandolo A, et al. Extracellular Vesicles Derived from Human Gingival Mesenchymal Stem Cells: A Transcriptomic Analysis. *Genes*. 2020;11:118.
 66. Chiricosta L, Silvestro S, Gugliandolo A, et al. Extracellular Vesicles of Human Periodontal Ligament Stem Cells Contain MicroRNAs Associated to Proto-Oncogenes: Implications in Cytokinesis. *Frontiers in Genetics*. 2020;11:582.
 67. Cui S, Cheng Z, Qin W, et al. Exosomes as a Liquid Biopsy for Lung Cancer. *Lung Cancer*. 2018;16, 46–54. doi:10.1016/j.lungcan.2017.12.012.
 68. Li G, Tang W, Yang F. Cancer Liquid Biopsy Using Integrated Microfluidic Exosome Analysis Platforms. *Biotechnology Journal*. 2020;15:1900225. doi:10.1002/biot.201900225.
 69. Paolini L, Zendrini A, Noto GD, et al. Residual Matrix from Different Separation Techniques Impacts Exosome Biological Activity. *Scientific Reports*. 2016;6:23550. doi:10.1038/srep23550.
 70. Johnstone RM. The Jeanne Manery-Fisher Memorial Lecture 1991. Maturation of reticulocytes: formation of exosomes as a mechanism for shedding membrane proteins. *Biochemistry and Cell Biology*. 1992;70(3–4):179–190.
 71. Clotilde Théry AS, Raposo G, Amigorena S, et al. Isolation and characterization of exosomes from cell culture supernatants and biological fluids. *Current Protocols in Stem Cell Biology*. 2006;30(1) doi:10.1139/o92-028.
 72. Livshits MA, Khomyakova E, Evtushenko EG, et al. Isolation of exosomes by differential centrifugation: theoretical analysis of a commonly used protocol. *Scientific Reports*. 2015;5(1):17319. doi:10.1038/srep17319.
 73. Cvjetkovic A, Lotvall J, Lasser C. The influence of rotor type and centrifugation time on the yield and purity of extracellular vesicles. *Journal of Extracellular Vesicles*. 2014;3(1):23111. doi:10.3402/jev.v3.23111.
 74. Boing AN, van der Pol E, Grootemaat AE, et al. Single-step isolation of extracellular vesicles by size-exclusion chromatography. *Journal of Extracellular Vesicles*. 2014;3 (1):23430. doi:10.3402/jev.v3.23430.
 75. Cantin R, Diou J, Belanger D, et al. Discrimination between exosomes and HIV-1: purification of both vesicles from cell-free supernatants. *Journal of Immunological Methods*. 2008;338(1–2):21–30. doi:10.1016/j.jim.2008.07.007.
 76. Ford T, Graham J, Rickwood D. Iodixanol: a nonionic iso-osmotic centrifugation medium for the formation of self-generated gradients. *Analytical Biochemistry*. 1994;220(2):360–366.

- doi:10.1006/ abio.1994.1350.
77. Oh DK, Hyun CK, Kim JH, et al. Production of penicillin in a fluidized-bed bioreactor: control of cell growth and penicillin production by phosphate limitation. *Biotechnology and Bioengineering*. 1988;32 (4):569–573. doi:10.1002/bit.260320421.
 78. Rider MA, Hurwitz SN, Meckes DG Jr. ExtraPEG: a polyethylene glycol-based method for enrichment of extracellular vesicles. *Scientific Reports*. 2016;6(1):23978. doi:10.1038/srep23978.
 79. Consortium E-T, Van Deun J, Mestdagh P, et al. EV-TRACK: transparent reporting and centralizing knowledge in extracellular vesicle research. *Nature Methods*. 2017;14(3):228–232. doi:10.1038/nmeth.4185.
 80. Vergauwen G, Dhondt B, Van Deun J, et al. Confounding factors of ultrafiltration and protein analysis in extracellular vesicle research. *Scientific Reports*. 2017;7(1):2704. doi:10.1038/s41598-017-02599-y.
 81. Tschuschke M, Kocherova I, Bryja A, et al. Inclusion biogenesis, methods of isolation and clinical application of human cellular exosomes. *Journal of Clinical Medicine*. 2020;9(2):436. doi:10.3390/jcm902043617.
 82. Fitzgerald J, Leonard P, Darcy E, et al. Immunoaffinity chromatography: concepts and applications. *Methods in Molecular Biology*. 2017;1485:27–51.59.
 83. Li P, Kaslan M, Lee SH, et al. Progress in exosome isolation techniques. *Theranostics*. 2017;7(3):789–804. doi:10.7150/thno.1813360.
 84. Zarovni N, Corrado A, Guazzi P, et al. Integrated isolation and quantitative analysis of exosome shuttled proteins and nucleic acids using immunocapture approaches. *Methods*. 2015;87:46–58. doi:10.1016/j.ymeth.2015.05.028.
 85. Han S, Xu Y, Sun J, et al. Isolation and analysis of extracellular vesicles in a Morpho butterfly wing-integrated microvortex biochip. *Biosensors & bioelectronics*, 2020;154:112073. <https://doi.org/10.1016/j.bios.2020.112073>.
 86. Wang Z, Li F, Rufo J, et al. Acoustofluidic salivary exosome isolation: a liquid biopsy compatible approach for human papillomavirus-associated oropharyngeal cancer detection. *Journal of Molecular Diagnostics*. 2020;22(1):50–59. doi:10.1016/j.jmoldx.2019.08.004.
 87. Heinemann ML, Ilmer M, Silva LP, et al. Benchtop isolation and characterization of functional exosomes by sequential filtration. *Journal of Chromatography A*. 2014;1371:125–135. doi:10.1016/j.chroma.2014.10.026.
 88. Yang JS, Lee JC, Byeon SK, et al. Size dependent lipidomic analysis of urinary exosomes from patients with prostate cancer by flow field-flow fractionation and nanoflow liquid chromatography-tandem mass spectrometry. *Analytical Chemistry Journal*. 2017;89 (4):2488–2496. doi:10.1021/acs.analchem.6b04634.
 89. Wunsch BH, Smith JT, Gifford SM, et al. Nanoscale lateral displacement arrays for the separation of exosomes and colloids down to 20 nm. *Nature, Nanotechnology*. 2016;11(11):936–940. doi:10.1038/nnano.2016.134.
 90. Mathivanan S, Lim JW, Tauro BJ, et al. Proteomics analysis of A33 immunoaffinity-purified exosomes released from the human colon tumor cell line LIM1215 reveals a tissue-specific protein signature. *Molecular and Cellular Proteomics*. 2010;9 (2):197–208. doi:10.1074/mcp.M900152-MCP200.
 91. Ryu KJ, Lee JY, Park C, et al. Isolation of small extracellular vesicles from human serum using a combination of ultracentrifugation with polymer-based precipitation. *Annals of Laboratory Medicine*. 2020;40(3):253–258. doi:10.3343/alm.2020.40.3.253.
 92. Koh YQ, Almughlliq FB, Vaswani K, et al. Exosome enrichment by ultracentrifugation and size exclusion chromatography. *Frontiers in Bioscience-Landmark*. 2018;23(3):865– 874. doi:10.2741/462169.
 93. Thery C, Witwer KW, Aikawa E, et al. Minimal information for studies of extracellular vesicles 2018 (MISEV2018): a position statement of the International Society for Extracellular Vesicles and update of the MISEV2014 guidelines. *Journal of Extracellular Vesicles*. 2018;7(1):1535750.

94. Islam MK, Syed P, Lehtinen L, et al. A nanoparticle-based approach for the detection of extracellular vesicles. *Scientific Reports*. 2019;9(1):10038. doi:10.1038/s41598-019-46395-2.
95. Record M, Carayon K, Poirot M, et al. Exosomes as new vesicular lipid transporters involved in cell-cell communication and various pathophysiologicals. *Biochimica et Biophysica Acta*. 2014;1841(1):108–120. doi:10.1016/j.bbali.2013.10.004.
96. Skotland T, Sandvig K, Llorente A. Lipids in exosomes: current knowledge and the way forward. *Progress in Lipid Research*. 2017;66:30–41. doi:10.1016/j.plipres.2017.03.001.
97. Bahr MM, Amer MS, Abo-El-Sooud K, et al. Preservation techniques of stem cells extracellular vesicles: a gate for manufacturing of clinical grade therapeutic extracellular vesicles and long-term clinical trials. *International Journal of Veterinary Science Medicine*. 2020;8 (1):1–8. doi:10.1080/23144599.2019.1704992.
98. Jeyaram A, Jay SM. Preservation and storage stability of extracellular vesicles for therapeutic applications. *AAPS Journal*. 2017;20 (1):1. doi:10.1208/s12248-017-0160-y.
99. Kusuma GD, Barabadi M, Tan JL, et al. Protect and to preserve: novel preservation strategies for extracellular vesicles. *Frontiers in Pharmacology*. 2018;9:1199.
100. Wu Y, Deng W, Klinke D. Exosomes: improved methods to characterize their morphology, RNA content, and surface protein biomarkers. *Analyst*. 2015;140(19):6631–6642. doi:10.1039/C5AN00688K.
101. Abdelwahed W, Degobert G, Stainmesse S, et al. Freeze-drying of nanoparticles: formulation, process and storage considerations. *Advanced Drug Delivery Reviews*. 2006;58(15):1688–1713. doi:10.1016/j.addr.2006.09.017.
102. Bosch S, de Beaurepaire L, Allard M, et al. Trehalose prevents aggregation of exosomes and cryodamage. *Scientific Reports*. 2016;6 (1):36162. doi:10.1038/srep36162.
103. Charoenviriyakul C, Takahashi Y, Nishikawa M, et al. Preservation of exosomes at room temperature using lyophilization. *International Journal of Pharmacology*. 2018;553(1–2):1–7. doi:10.1016/j.ijpharm.2018.10.032.
104. Maroto R, Zhao Y, Jamaluddin M, et al. Effects of storage temperature on airway exosome integrity for diagnostic and functional analyses. *Journal of Extracellular Vesicles*. 2017;6(1):1359478. doi:10.1080/20013078.2017.1359478.
105. Lorincz AM, Timar CI, Marosvari KA, et al. Effect of storage on physical and functional properties of extracellular vesicles derived from neutrophilic granulocytes. *Journal of Extracellular Vesicles*. 2014;3(1):25465. doi:10.3402/jev.v3.25465.
106. Agrawal AK, Aqil F, Jeyabalan J, et al. Milk-derived exosomes for oral delivery of paclitaxel. *Nanomedicine*. 2017;13(5):1627–1636. doi:10.1016/j.nano.2017.03.001.
107. D’Acunzo P, Kim Y, Ungania JM, et al. Isolation of mitochondria-derived mitovesicles and subpopulations of microvesicles and exosomes from brain tissues. *Nature Protocols* 2022;17(11):2517–49. doi: https://doi.org/10.1038/s41596-022-00719-1.
108. Li M, Fang F, Sun M, et al. Extracellular vesicles as bioactive nanotherapeutics: An emerging paradigm for regenerative medicine. *Theranostics* 2022;12(11):4879–903. doi: https://doi.org/10.7150/thno.72812.
109. Lu B, Ku J, Flojo R, et al. Exosome- and extracellular vesicle-based approaches for the treatment of lysosomal storage disorders. *Advanced Drug Delivery Reviews*. 2022;188. doi: https://doi.org/10.1016/j.addr.2022.114465114465.
110. Shi X, Jiang N, Mao J, et al. Mesenchymal stem cell-derived exosomes for organ development and cell-free therapy. *Nano Select*. 2021;2:1291–325. doi: https://doi.org/10.1002/nano.202000286.
111. Li C, Qin S, Wen Y, et al. Overcoming the blood-brain barrier: Exosomes as theranostic nanocarriers for precision neuroimaging. *Journal of Control Release*. 2022;349:902–16. doi: https://doi.org/10.1016/j.jconrel.2022.08.002.
112. Khan FH, Reza MJ, Shao YF, et al. Role of exosomes in lung cancer: A comprehensive insight from immunomodulation to theragnostic applications. *Biochimica et Biophysica Acta Reviewss-Cancer* 2022;1877(5):. doi: https://doi.org/10.1016/j.bbcan.2022.188776188776.

113. Wu Y, Li J, Zeng Y, et al. Exosomes rewire the cartilage microenvironment in osteoarthritis: from intercellular communication to therapeutic strategies. *International Journal of Oral Sciences*. 2022;14(1):40. doi: <https://doi.org/10.1038/s41368-022-00187-z>.
114. Fujita Y. Extracellular vesicles in idiopathic pulmonary fibrosis: Pathogenesis and therapeutics. *Inflammation and Regeneration*. 2022;42(1):23. doi: <https://doi.org/10.1186/s41232-022-00210-0>.
115. D'Acunzo P, Kim Y, Ungania JM, et al. Isolation of mitochondria-derived mitovesicles and subpopulations of microvesicles and exosomes from brain tissues. *Nature Protocols*. 2022;17(11):2517–49. doi: <https://doi.org/10.1038/s41596-022-00719-1>.
116. Jiang N, Xiang L, He L, et al. Exosomes mediate epithelium-mesenchyme crosstalk in organ development. *ACS Nanotechnology*. 2017;11(8):7736–46. doi: <https://doi.org/10.1021/acsnano.7b01087>.
117. Zhang S, Yang Y, Jia S, et al. Exosome-like vesicles derived from Hertwig's epithelial root sheath cells promote the regeneration of dentin-pulp tissue. *Theranostics* 2020;10(13):5914–31. doi: <https://doi.org/10.7150/thno.43156>.
118. Wang HS, Yang FH, Wang YJ, et al. Odontoblastic exosomes attenuate apoptosis in neighboring cells. *Journal of Dental Research*. 2019;98(11):1271–8. doi: <https://doi.org/10.1177/0022034519869580>.
119. Swanson WB, Gong T, Zhang Z, et al. Controlled release of odontogenic exosomes from a biodegradable vehicle mediates dentinogenesis as a novel biomimetic pulp capping therapy. *Journal of Controlled Release*. 2020;324:679–94. doi: <https://doi.org/10.1016/j.jconrel.2020.06.006>.
120. Li M, Fang F, Sun M, et al. Extracellular vesicles as bioactive nanotherapeutics: An emerging paradigm for regenerative medicine. *Theranostics*. 2022;12(11):4879–903. doi: <https://doi.org/10.7150/thno.72812>.
121. Zhang S, Thiebes AL, Kreimendahl F, et al. Extracellular vesicles-loaded fibrin gel supports rapid neovascularization for dental pulp regeneration. *International Journal of Molecular Sciences*. 2020;21(12):4226. doi: <https://doi.org/10.3390/ijms21124226>.
122. Zhou H, Li X, Yin Y, et al. The proangiogenic effects of extracellular vesicles secreted by dental pulp stem cells derived from periodontally compromised teeth. *Stem Cell Research and Therapy*. 2020;11(1):110. doi: <https://doi.org/10.1186/s13287-020-01614-w>.
123. Bian S, Zhang L, Duan L, et al. Extracellular vesicles derived from human bone marrow mesenchymal stem cells promote angiogenesis in a rat myocardial infarction model. *Journal of Molecular Medicine (Berl)*. 2014;92(4):387–97. doi: <https://doi.org/10.1007/s00109-013-1110-5>.
124. Zhang B, Wu X, Zhang X, et al. Human umbilical cord mesenchymal stem cell exosomes enhance angiogenesis through the Wnt4/b-catenin pathway. *Stem Cells in Translational Medicine*. 2015;4(5):513–22. doi: <https://doi.org/10.5966/sctm.2014-0267>.
125. Ren S, Chen J, Duscher D, et al. Microvesicles from human adipose stem cells promote wound healing by optimizing cellular functions via AKT and ERK signaling pathways. *Stem Cells in Research Therapy*. 2019;10(1):47. doi: <https://doi.org/10.1186/s13287-019-1152-x>.
126. Baruah J, Wary KK. Exosomes in the regulation of vascular endothelial cell regeneration. *Frontiers in Cell Development Biology*. 2020;7:353. doi: <https://doi.org/10.3389/fcell.2019.00353>.
127. Yu M, Liu W, Li J, et al. Exosomes derived from atorvastatin-pretreated MSC accelerate diabetic wound repair by enhancing angiogenesis via AKT/eNOS pathway. *Stem Cell Research and Therapy*. 2020;11(1):350. doi: <https://doi.org/10.1186/s13287-020-01824-2>.
128. Xian X, Gong Q, Li C, et al. Exosomes with highly angiogenic potential for possible use in pulp regeneration. *Journal of Endodontics*. 2018;44(5):751–8. doi: <https://doi.org/10.1016/j.joen.2017.12.024>.
129. Liang X, Zhang L, Wang S, et al. Exosomes secreted by mesenchymal stem cells promote endothelial cell angiogenesis by transferring miR-125a. *Journal of Cell Science*. 2016;129(11):2182–9. doi: <https://doi.org/10.1242/jcs.170373>.
130. Kir D, Schnettler E, Modi S, et al. Regulation of angiogenesis by microRNAs in cardiovascular

- diseases. *Angiogenesis*. 2018;21(4):699–710. doi: <https://doi.org/10.1007/s10456-018-9632-7>.
131. Wu M, Liu X, Li Z, et al. SHED aggregate exosomes shuttled miR-26a promote angiogenesis in pulp regeneration via TGF- β /SMAD2/3 signalling. *Cell Proliferation*. 2021;54(7):e13074.
 132. Huang CC, Narayanan R, Alapati S, et al. Exosomes as biomimetic tools for stem cell differentiation: Applications in dental pulp tissue regeneration. *Biomaterials*. 2016;111:103–15. doi: <https://doi.org/10.1016/j.biomaterials.2016.09.029>.
 133. Hu X, Zhong Y, Kong Y, et al. Lineage-specific exosomes promote the odontogenic differentiation of human dental pulp stem cells (DPSCs) through TGF β 1/smads signaling pathway via transfer of microRNAs. *Stem Cell Research Therapy*. 2019;10(1):170. doi: <https://doi.org/10.1186/s13287-019-1278-x>.
 134. Zhuang X, Ji L, Jiang H, et al. Exosomes derived from stem cells from the apical papilla promote dentine-pulp complex regeneration by inducing specific dentinogenesis. *Stem Cells International*. 2020;2020:5816723. doi: <https://doi.org/10.1155/2020/5816723>.
 135. Yu H, Cheng J, Shi W, et al. Bone marrow mesenchymal stem cell-derived exosomes promote tendon regeneration by facilitating the proliferation and migration of endogenous tendon stem/progenitor cells. *Acta Biomaterial*. 2020;106:328–41. doi: <https://doi.org/10.1016/j.actbio.2020.01.051>.
 136. Ivica A, Ghayor C, Zehnder M, et al. Pulp-derived exosomes in a fibrin-based regenerative root filling material. *Journal of Clinical Medicine*. 2020;9(2):491. doi:<https://doi.org/10.3390/jcm9020491>.
 137. Chen Y, Ma Y, Yang X, et al. The application of pulp tissue derived-exosomes in pulp regeneration: A novel cell-homing approach. *International Journal of Nanomedicine*. 2022;17:465–76. doi: <https://doi.org/10.2147/IJN.S342685>.
 138. Yu S, Chen H, Gao B. Potential therapeutic effects of exosomes in regenerative endodontics. *Archives of Oral Biology*. 2020;120:. doi: <https://doi.org/10.1016/j.archoralbio.2020.104946>.
 139. Li Z, Liang Y, Pan K, et al. Schwann cells secrete extracellular vesicles to promote and maintain the proliferation and multipotency of hDPCs. *Cell Proliferation*. 2017;50(4):e12353.
 140. Chen WJ, Xie J, Lin X, et al. The role of small extracellular vesicles derived from lipopolysaccharide-preconditioned human dental pulp stem cells in dental pulp regeneration. *Journal of Endodontics*. 2021;47(6):961–9. doi: <https://doi.org/10.1016/j.joen.2021.03.010>.
 141. Zhou H, Li X, Wu RX, et al. Periodontitis-compromised dental pulp stem cells secrete extracellular vesicles carrying miRNA-378a promote local angiogenesis by targeting Sufu to activate the Hedgehog/Gli1 signalling. *Cell Proliferation*. 2021;54(5):e13026.
 142. He W, Wang Z, Luo Z, et al. LPS promote the odontoblastic differentiation of human dental pulp stem cells via MAPK signaling pathway. *Journal of Cell Physiology*. 2015;230(3):554–61. doi: <https://doi.org/10.1002/jcp.24732>.
 143. Yang G, Ju Y, Liu S, Zhao S. Lipopolysaccharide upregulates the proliferation, migration, and odontoblastic differentiation of NG2+ cells from human dental pulp in vitro. *Cellular Biology International*. 2019;43(11):1276–85. doi: <https://doi.org/10.1002/cbin.11127>.
 144. Kisch T, Weber C, Rapoport DH, et al. LPS-stimulated human skin-derived stem cells enhance neo-vascularization during dermal regeneration. *PLoSOne* 2015;10(11):e0142907.
 145. Liu Z, Wang J, Xing W, et al. LPS binding to HMGB1 promotes angiogenic behavior of endothelial cells through inhibition of p120 and CD31 via ERK/P38/Src signaling. *European Journal of Cellular Biology*. 2017;96(7):695–704. doi: <https://doi.org/10.1016/j.ejcb.2017.07.004>.
 146. Huang X, Qiu W, Pan Y, et al. Exosomes from LPS-stimulated hdpSCs activated the angiogenic potential of huveCs in vitro. *Stem Cells Int* 2021;2021:6685307. doi: <https://doi.org/10.1155/2021/6685307>.
 147. Li J, Ju Y, Liu S, et al. Exosomes derived from lipopolysaccharidepreconditioned human dental pulp stem cells regulate Schwann cell migration and differentiation. *Connective Tissue Research*. 2021;62(3):277–86. doi:<https://doi.org/10.1080/03008207.2019.1694010>.
 148. Ko KW, Park SY, Lee EH, et al. Integrated bioactive scaffold with polydeoxyribonucleoti-

- de and stem-cell-derived extracellular vesicles for kidney regeneration. *ACS Nano Journal*. 2021;15(4):7575–85. doi: <https://doi.org/10.1021/acsnano.1c01098>.
149. Rombouts C, Giraud T, Jeanneau C, et al. Pulp vascularization during tooth development, regeneration, and therapy. *Journal of Dental Research*. 2017;96(2):137–44. doi:<https://doi.org/10.1177/0022034516671688>.
150. Zhu J, Lu K, Zhang N, et al. Myocardial reparative functions of exosomes from mesenchymal stem cells are enhanced by hypoxia treatment of the cells via transferring microRNA-210 in an nSMase2-dependent way. *Artificial Cells Nanomedicine Biotechnology*. 2018;46(8):1659–70. doi: <https://doi.org/10.1080/21691401.2017.1388249>.
151. Han Y, Ren J, Bai Y, et al. Exosomes from hypoxia-treated human adipose-derived mesenchymal stem cells enhance angiogenesis through VEGF/VEGF-R. *International Journal of Biochemistry and Cell Biology*. 2019;109:59–68. doi: <https://doi.org/10.1016/j.biocel.2019.01.017>.
152. Liu W, Li L, Rong Y, et al. Hypoxic mesenchymal stem cell-derived exosomes promote bone fracture healing by the transfer of miR-126. *Acta Biomaterials*. 2020;103:196–212. doi: <https://doi.org/10.1016/j.actbio.2019.12.020>.
153. Gao W, He R, Ren J, et al. Exosomal HMGB1 derived from hypoxiaconditioned bone marrow mesenchymal stem cells increases angiogenesis via the JNK/HIF-1 α pathway. *FEBS Open Biology*. 2021;11(5):1364–73. doi:<https://doi.org/10.1002/2211-5463.13142>.
154. Liu P, Qin L, Liu C, et al. Exosomes derived from hypoxia-conditioned stem cells of human deciduous exfoliated teeth enhance angiogenesis via the transfer of let-7f-5p and miR-210-3p. *Frontiers in Cell Development and Biology*. 2022;10:. doi:<https://doi.org/10.3389/fcell.2022.87987787987>.
155. Li B, Xian X, Lin X, et al. Hypoxia alters the proteome profile and enhances the angiogenic potential of dental pulp stem cell-derived exosomes. *Biomolecules*. 2022;12(4):575. doi: <https://doi.org/10.3390/biom12040575>.
156. Dou L, Yan Q, Liang P, et al. iTRAQ-based proteomic analysis exploring the influence of hypoxia on the proteome of dental pulp stem cells under 3d culture. *Proteomics* 2018;18(3–4):10.1002/pmic.201700215. doi:<https://doi.org/10.1002/pmic.201700215>.
157. Gonzalez-King H, Garcia NA, Ontoria-Oviedo I, et al. Hypoxia inducible factor-1 α potentiates jagged 1-mediated angiogenesis by mesenchymal stem cell-derived exosomes. *Stem Cells*. 2017;35(7):1747–59. doi: <https://doi.org/10.1002/stem.2618>.
158. Pan Z, Sun W, Chen Y, et al. Extracellular vesicles in tissue engineering:biology and engineered strategy. *Advanced Healthcare Materials*. 2022;11(21):e2201384.
159. Ju Y, Hu Y, Yang P, et al. Extracellular vesicle-loaded hydrogels for tissue repair and regeneration. *Materials Today Bio*. 2022;18:. doi: <https://doi.org/10.1016/j.mtbio.2022.100522100522>.
160. Mendt M, Kamerkar S, Sugimoto H, et al. Generation and testing of clinicalgrade exosomes for pancreatic cancer. *JCI Insight*. 2018;3(8). doi: <https://doi.org/10.1172/jci.insight.99263>. e99263.
161. Witwer KW, Buzás EI, Bemis LT, et al. Standardization of sample collection, isolation and analysis methods in extracellular vesicle research 10.3402/jev.v2i0.20360. *Journal of Extracellular Vesicles*. 2013;2. doi: <https://doi.org/10.3402/jev.v2i0.20360>.
162. Pan Z, Sun W, Chen Y, et al. Extracellular vesicles in tissue engineering:biology and engineered strategy. *Adv Healthc Mater* 2022;11(21):e2201384

BÖLÜM 18

KASITLI REİMPLANTASYON

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GİRİŞ

Endodontik tedavinin temel amacı, pulpa ve periapikal dokularda mevcut patolojik durumların ortadan kaldırılarak dişin sağlıklı, asemptomatik ve fonksiyonel bir şekilde ağızda tutulmasının sağlanmasıdır (1). Güncel literatür, primer cerrahi olmayan kök kanal tedavisinin başarı oranının %90'ın üzerinde olduğunu ortaya koymaktadır (2-4). Bununla birlikte, bazı olgularda persistan veya tekrarlayan periapikal lezyonların varlığı ek tedavi yaklaşımlarını zorunlu kılabilir.

Bu tür durumlarda, olgunun klinik ve radyografik özellikleri doğrultusunda cerrahi olmayan yeniden tedavi veya endodontik mikrocerrahi ilk basamak tedavi seçenekleri olarak değerlendirilmekte; her iki yaklaşımın da güncel kanıtlara göre yüksek başarı oranlarına ulaştığı bildirilmektedir (5, 6). Ancak endodontik mikrocerrahinin başarı oranı yüksek olmakla birlikte, inferior alveoler kanal, mental foramen veya maksiller sinüs gibi kritik anatomik oluşumlara yakın dişlerde uygulanması zorlaşabilmekte veya kontrendike hâle gelebilmektedir.

Dişin prognozunun çekim ve implant yönünde olumsuz seyrettiği ya da cerrahi olmayan ve cerrahi endodontik tedavilerin riskli veya uygulanamaz olduğu seçilmiş olgularda, kasıtlı reimplantasyon doğal dişin ağızda tutulmasını amaçlayan koruyucu bir tedavi alternatifi olarak gündeme gelmektedir (7).

Kasıtlı reimplantasyon; dişin kontrollü ve atravmatik bir şekilde çekilmesini takiben kök yüzeyinin değerlendirilmesi ve gerekli endodontik işlemler veya onarımlar gerçekleştirildikten sonra, dişin kendi alveol soketine yeniden yerleştiril-

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yaller ve atravmatik cerrahi yaklaşımlar, bu yöntemin klinik başarısını belirgin şekilde artırmış ve modern endodonti pratiğinde yeniden önem kazanmasını sağlamıştır. Bununla birlikte, tedavinin başarısı yalnızca teknik yeterlilikle değil; doğru hasta seçimi, kapsamlı bir şekilde hastanın bilgilendirilmesi ve klinisyenin prosedürün riskleri ile işlemin sınırlılıklarına hâkimiyetiyle doğrudan ilişkilidir. Bu yönleriyle kasıtlı reimplantasyon, diş çekimine alternatif olarak, doğal dişin mümkün olan en uzun süre ağzıda tutulmasını hedefleyen biyolojik temelli bir yaklaşım olarak değerlendirilmelidir.

KAYNAKLAR

1. Karamifar K, Tondari A, Saghiri MA. Endodontic periapical lesion: an overview on the etiology, diagnosis and current treatment modalities. *European Endodontic Journal*. 2020;5(2):54. doi: 10.14744/ej.2020.42714
2. Paredes-Vieyra J, Enriquez FJJ. Success rate of single-versus two-visit root canal treatment of teeth with apical periodontitis: a randomized controlled trial. *Journal Of Endodontics*. 2012;38(9): 1164-1169. doi: 10.1016/j.joen.2012.05.021
3. Ng YL, Mann V, Rahbaran S, et al. Outcome of primary root canal treatment: systematic review of the literature—part 1. Effects of study characteristics on probability of success. *International Endodontic Journal*. 2007;40(12):921-939. doi: 10.1111/j.1365-2591.2007.01322.x
4. Gomes BPFdA, Herrera DR. Etiologic role of root canal infection in apical periodontitis and its relationship with clinical symptomatology. *Brazilian Oral Research*. 2018;32(suppl 1):e69. doi: 10.1590/1807-3107bor-2018.vol32.0069
5. Sabeti M, Chung Y, Aghamohammadi N, et al. Outcome of contemporary nonsurgical endodontic retreatment: a systematic review of randomized controlled trials and cohort studies. *Journal Of Endodontics*. 2024;50(4):414-433. doi: 10.1016/j.joen.2024.01.013
6. Ko MJ, Park JH, Lee NR, et al. Success rates comparison of endodontic microsurgery and single implants with comprehensive and explicit criteria: a systematic review and meta-analysis. *Restorative Dentistry & Endodontics*. 2025;50(1): e8. doi: 10.5395/rde.2025.50.e8
7. Torabinejad M, Dinsbach NA, Turman M, et al. Survival of intentionally replanted teeth and implant-supported single crowns: a systematic review. *Journal of Endodontics*. 2015;41(7): 992-998. doi: 10.1016/j.joen.2015.01.004
8. Lin Z, Huang D, Huang S, et al. Expert consensus on intentional tooth replantation. *International Journal of Oral Science*. 2025;17(1):16. doi: 10.1038/s41368-024-00337-5
9. Moffat MA, Smart CM, Fung DE, Welbury RR. Intentional surgical repositioning of an ankylosed permanent maxillary incisor. *Dental Traumatology*. 2002;18(4): 222-226. doi: 10.1034/j.1600-9657.2002.00113.x
10. Friedlander LT, Chandler NP, Drummond BK. Avulsion and replantation of a primary incisor tooth. *Dental Traumatology*. 2013;29(6): 494-497. doi: 10.1111/j.1600-9657.2012.01168.x
11. Pisano M, Di Spirito F, Martina S, et al. Intentional replantation of single-rooted and multi-rooted teeth: a systematic review. *Healthcare*. 2022;11(1):11. doi:10.3390/healthcare11010011
12. Plotino G, Abella Sans F, Duggal MS, et al. Present status and future directions: Surgical extrusion, intentional replantation and tooth autotransplantation. *International Endodontic Journal*. 2022;55:827-842. doi: 10.1111/iej.13723
13. Clark D, Levin L. In the dental implant era, why do we still bother saving teeth? *Journal Of Endodontics*. 2019;45(12):S57-S65. doi: 10.1016/j.joen.2019.05.014
14. Thaore S, Desai N, Srinidhi S, Balsaraf O. Intentional replantation of an endodontically treated tooth with separated instrument: A case report. *Saudi Journal of Oral and Dental Research*.

- 2017;2:59-62. doi: 10.21276/sjodr.2017.2.3.1
15. Grossman LI. Intentional replantation of teeth: a clinical evaluation. *The Journal of the American Dental Association*. 1982;104(5):633-639. doi: 10.14219/jada.archive.1982.0252
 16. Plotino G, Abella Sans F, Bastos JV, Nagendrababu V. Effectiveness of intentional replantation in managing teeth with apical periodontitis: A systematic review. *International Endodontic Journal*. 2023;56:499-509. doi: 10.1111/iej.13727
 17. Cho S-Y, Lee Y, Shin S-J, et al. Retention and healing outcomes after intentional replantation. *Journal of Endodontics*. 2016;42(6): 909-915. doi: 10.1016/j.joen.2016.03.006
 18. Dorow C, Krstin N, Sander F-G. Experiments to determine the material properties of the periodontal ligament. *Journal of Orofacial Orthopedics/Fortschritte der Kieferorthopädie*. 2002;63(2):94-104. doi: 10.1007/s00056-002-0107-4
 19. De Angelis P, De Rosa G, Manicone PF, et al. Hard and soft tissue evaluation of alveolar ridge preservation compared to spontaneous healing: a retrospective clinical and volumetric analysis. *International Journal of Implant Dentistry*. 2022;8(1):62. doi: 10.1186/s40729-022-00456-w
 20. Bhatnagar VM, Karani JT, Khanna A, et al. Osseoperception: an implant mediated sensory motor control-a review. *Journal of Clinical and Diagnostic Research: JCDR*. 2015;9(9):ZE18. doi: 10.7860/JCDR/2015/14349.6532
 21. Berzaghi A, Testori T, Scaini R, Bortolini S. Occlusion and Biomechanical Risk Factors in Implant-Supported Full-Arch Fixed Dental Prosthesis—Narrative Review. *Journal of Personalized Medicine*. 2025;15(2):65. doi: 10.3390/jpm15020065
 22. Andreasen JO. Relationship between cell damage in the periodontal ligament after replantation and subsequent development of root resorption: a time-related study in monkeys. *Acta Odontologica Scandinavica*. 1981;39(1):15-25. doi: 10.3109/00016358109162254
 23. Sans FA, Plotino G. Intentional replantation. *Clinical Dentistry Reviewed*. 2021;5(1):19. doi: 10.1007/s41894-021-00106-1
 24. Mainkar A. A systematic review of the survival of teeth intentionally replanted with a modern technique and cost-effectiveness compared with single-tooth implants. *Journal of Endodontics*. 2017;43(12): 1963-1968. doi: 10.1016/j.joen.2017.08.019
 25. Wang L, Jiang H, Bai Y, et al. Clinical outcomes after intentional replantation of permanent teeth: A systematic review. *Bosnian Journal Of Basic Medical Sciences*. 2020;20(1):13. doi: 10.17305/bjbms.2019.3937
 26. Becker BD. Intentional replantation techniques: a critical review. *Journal of Endodontics*. 2018;44(1):14-21. doi: 10.1016/j.joen.2017.08.002
 27. Lee S-M, Marmo M. Intentional Replantation: No Longer a Last Resort for Saving a Natural Tooth. *Compendium of Continuing Education in Dentistry*. 2024;45(3):134-139.
 28. Bağış N, Arpak N. Periodontal açıdan umutsuz dişlerin estetik amaçla bilinçli replantasyonu–2 olgu sunumu. *European Annals of Dental Sciences*. 2013;40(3): 127-132.
 29. Peer M. Intentional replantation—a ‘last resort’ treatment or a conventional treatment procedure? Nine case reports. *Dental Traumatology*. 2004;20(1):48-55. doi: 10.1046/j.1600-4469.2003.00218.x
 30. Agrawal PK, Jibhkate NG, Redij SA. Intentional Replantation of Failed Root Canal Treated Tooth. *Journal of Interdisciplinary Dentistry*. 2024;14(2):128-130. doi: 10.4103/jid.jid_57_23
 31. Asgary S, Marvasti LA, Kolahdouzan A. Indications and case series of intentional replantation of teeth. *Iranian Endodontic Journal*. 2013;9(1):71-75. doi: 10.22037/iej.v9i1.4020
 32. Grossman LI. Intentional replantation of teeth. *The Journal of the American Dental Association*. 1966;72(5):1111-1118. doi: 10.14219/jada.archive.1966.0125
 33. Jafarzadeh H, Rouhani A, Javidi B, Habibi M. Intentional replantation: a procedure as a last resort. *The Journal of Contemporary Dental Practice*. 2012;12(6):486-492. doi: 10.5005/jp-journals-10024-1081
 34. Ward J. Intentional replantation of a lower premolar. *Australian Endodontic Journal*. 2004;30(3):99-102. doi: 10.1111/j.1747-4477.2004.tb00420.x

35. Wilke IP, Marques EF, Silva Kd. Intentional replantation as a last resort in the treatment of endodontic failures: Literature Review. *International Journal of Advanced Engineering Research and Science*. 2021;8(7):451-455. doi: 10.22161/ijaers.87.50
36. Peñarrocha M, García B, Martí E, et al. Intentional replantation for the management of maxillary sinusitis. *International Endodontic Journal*. 2007;40(11): 891-899. doi: 10.1111/j.1365-2591.2007.01278.x
37. Madison S. Intentional replantation. *Oral Surgery, Oral Medicine, Oral Pathology*. 1986;62(6):707-709. doi: 10.1016/0030-4220(86)90268-9
38. Aji Y, Yao Q-t, Wu Y-h, Li S-h. Intentional replantation as the treatment of left mandibular second premolar refractory periapical periodontitis: A case report. *The Open Dentistry Journal*. 2024;18: e18742106283909. doi: 10.2174/0118742106283909240111113544
39. OCAK MS, ÇANKAYA G. Endodontide Kasıtlı Replantasyon: Genel Bir Bakış. *Firat Üniversitesi Sağlık Bilimleri Tip Dergisi*. 2024;38(1).
40. Nosonowitz DM, Stanley HR. Intentional replantation to prevent predictable endodontic failures. *Oral Surgery, Oral Medicine, Oral Pathology*. 1984;57(4):423-432. doi: 10.1016/0030-4220(84)90163-4
41. American Association of Endodontists. Treatment of the avulsed permanent tooth. Recommended guidelines of the American Association of Endodontists. *Dental Clinics of North America*. 1995;39(1):221-225.
42. Kratchman S. Intentional replantation. *Dental Clinics of North America*. 1997;41(3):603-617.
43. Deeb E. Reimplantation of luxated teeth in humans. *Journal of the California Dental Association*. 1965;28:194-206.
44. Demiralp B, Nohutçu RM, Tepe DI, et al. Intentional replantation for periodontally involved hopeless teeth. *Dental Traumatology*. 2003;19(1):45-51. doi: 10.1034/j.1600-9657.2003.00084.x
45. Filippi A, Pohl Y, Von Arx T. Treatment of replacement resorption with Emdogain®- a prospective clinical study. *Dental Traumatology*. 2002;18(3): 138-143. doi: 10.1034/j.1600-9657.2002.00078.x
46. Plotino G, Abella Sans F, Duggal M, et al. European Society of Endodontology position statement: Surgical extrusion, intentional replantation and tooth autotransplantation. *International Endodontic Journal*. 2021;54(5):655-659. doi: 10.1111/iej.13456
47. Krug R, Soliman S, Krastl G. Intentional replantation with an atraumatic extraction system in teeth with extensive cervical resorption. *Journal of Endodontics*. 2019;45(11):1390-1396. doi: 10.1016/j.joen.2019.07.012
48. Hupp J, Mesaros S, Aukhil I, et al. Periodontal ligament vitality and histologic healing of teeth stored for extended periods before transplantation. *Dental Traumatology*. 1998;14(2):79-83. doi: 10.1111/j.1600-9657.1998.tb00815.x
49. Huang D, Li J, Xu X. Clinical management of the intentional tooth replantation. *Zhonghua Kou Qiang yi xue za zhi= Zhonghua Kouqiang Yixue Zazhi= Chinese Journal of Stomatology*. 2018;53(6):392-397. doi: 10.3760/cma.j.issn.1002-0098.2018.06.006
50. Han-Yi Z, Zheng-Wei H. Clinical considerations for intentional replantation of teeth. *Chinese Journal of Practical Stomatology*. 2021;14:275-281.
51. Plotino G, Abella Sans F, Duggal M, et al. Clinical procedures and outcome of surgical extrusion, intentional replantation and tooth autotransplantation—a narrative review. *International Endodontic Journal*. 2020;53(12):1636-1652. doi: 10.1111/iej.13396
52. Emmertsen E, Andreasen J. Replantation of extracted molars. A radiographic and histological study. *Acta Odontologica Scandinavica*. 1966;24(3): 327-346. doi: 10.3109/00016356609028225
53. Wang L, Shen H, Zheng W, et al. Characterization of stem cells from alveolar periodontal ligament. *Tissue Engineering Part A*. 2011;17(7-8):1015-1026. doi: 10.1089/ten.tea.2010.0140
54. Dryden JA, Arens DE. Intentional replantation. A viable alternative for selected cases. *Dental Clinics of North America*. 1994;38(2):325-353.
55. Guy SC, Goerig AC. Intentional replantation: technique and rationale. *Quintessence Internatio-*

- nal. 1984;15(6):471-475.
56. Sherman P Jr. Intentional replantation of teeth in dogs and monkeys. *Journal of Dental Research*. 1968;47(6):1066-1071. doi: 10.1177/00220345680470061101
 57. Deotale SP, Shewale AH, Gattani DR, et al. Reliability of two different protocols used for intentional re-implantation of periodontally hopeless teeth. *Journal of Indian Society of Periodontology*. 2018;22(4):353-359. doi: 10.4103/jisp.jisp_170_18
 58. Jang Y, Lee S-J, Yoon T-C, et al. Survival rate of teeth with a C-shaped canal after intentional replantation: a study of 41 cases for up to 11 years. *Journal of Endodontics*. 2016;42(9): 1320-1325. doi: 10.1016/j.joen.2016.05.010
 59. Niemczyk S. Re-inventing intentional replantation: a modification of the technique. *Practical Procedures & Aesthetic Dentistry: PPAD*. 2001;13(6):433-439.
 60. Fegan S, Steiman H. Intentional replantation. *The Journal of the Michigan Dental Association*. 1991;73(6):22-24.
 61. Roudsari RV, Jawad S, Taylor C, et al. Modern endodontic principles part 8: The future of endodontics. *Dental Update*. 2016;43(5): 430-441. doi: 10.12968/denu.2016.43.5.430
 62. Bender I, Rossman LE. Intentional replantation of endodontically treated teeth. *Oral Surgery, Oral Medicine, Oral Pathology*. 1993;76(5): 623-630. doi: 10.1016/0030-4220(93)90073-d
 63. Rajasekharan S, Martens L, Cauwels R, Anthonappa RP. Biodentine™ material characteristics and clinical applications: a 3 year literature review and update. *European Archives of Paediatric Dentistry*. 2018;19(1):1-22. doi: 10.1007/s40368-018-0328-x
 64. Chung WC, Tu YK, Lin YH, et al. Outcomes of autotransplanted teeth with complete root formation: a systematic review and meta-analysis. *Journal of Clinical Periodontology*. 2014;41(4): 412-423. doi: 10.1111/jcpe.12228
 65. Hirooka H. The biologic concept for the use of enamel matrix protein: true periodontal regeneration. *Quintessence International*. 1998;29(10):621-630.
 66. Zeichner-David M. Is there more to enamel matrix proteins than biomineralization? *Matrix Biology*. 2001;20(5-6): 307-316. doi: 10.1016/s0945-053x(01)00155-x
 67. Miron RJ, Sculean A, Cochran DL, et al. Twenty years of enamel matrix derivative: the past, the present and the future. *Journal of Clinical Periodontology*. 2016;43(8):668-683. doi: 10.1111/jcpe.12546
 68. Wang HH, Sarmast ND, Shadmehr E, et al. Application of enamel matrix derivative (Emdogain) in endodontic therapy: A comprehensive literature review. *Journal of Endodontics*. 2018;44(7):1066-1079. doi: 10.1016/j.joen.2018.02.012
 69. Li Q, Pan S, Dangaria SJ, et al. Platelet-rich fibrin promotes periodontal regeneration and enhances alveolar bone augmentation. *BioMed Research International*. 2013;2013(1):638043. doi: 10.1155/2013/638043
 70. Tözüm TF, Keçeli HG, Serper A, Tuncel B. Intentional replantation for a periodontally involved hopeless incisor by using autologous platelet-rich plasma. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*. 2006;101(6):e119-e124. doi: 10.1016/j.tripleo.2005.10.043
 71. Madi M, Elakel AM. The clinical implications of platelet-rich fibrin on periodontal regeneration: A systematic review. *The Saudi Dental Journal*. 2021;33(2):55-62. doi: 10.1016/j.sdentj.2020.12.002
 72. Aydın H, Er K. The effect of orthodontic tooth movement of endodontically treated teeth. *Journal of Restorative Dentistry*. 2016;4(2):51-56.
 73. Abbott P. Prevention and management of external inflammatory resorption following trauma to teeth. *Australian Dental Journal*. 2016;61:82-94. doi: 10.1111/adj.12400
 74. Souza BDM, Dutra KL, Kuntze MM, et al. Incidence of root resorption after the replantation of avulsed teeth: a meta-analysis. *Journal of Endodontics*. 2018;44(8):1216-1227. doi: 10.1016/j.joen.2018.03.002

BÖLÜM 19

REHBERLİ ENDODONTİ: KAVRAMSAL GELİŞİM, DİJİTAL İŞ AKIŞI VE KLİNİK UYGULAMALAR

Furkan YILMAZ ¹
Esma DİNGER ²

GİRİŞ

Pulpa kanalı obliterasyonu (PCO) bulunan dişlerde kök kanal tedavisi, kalsifiye kanalın bulunmasının güçlüğü ve artmış perforasyon riski nedeniyle klinik açıdan önemli bir zorluk oluşturmaktadır. PCO, özellikle dental travma sonrası sık görülen geç dönem bir bulgu olup luksasyon yaralanmalarından sonra %15–40 oranında ortaya çıkmaktadır (1, 2). Bunun yanında çürük, pulpotomi, restoratif işlemler (3, 4), ortodontik tedavi (5) ve yaşa bağlı dentin birikimi (6) sonucunda da gelişebilmektedir.

Kalsifikasyon süreci genellikle asemptomatik olup çoğunlukla radyografik inceleme sırasında veya dişte sarımsı renk değişikliği ile fark edilir. Dentin birikimi, sıklıkla duyarlılık testlerine olumsuz yanıt alınmasına rağmen pulpanın dolaylı bir canlılık göstergesi olarak kabul edilmektedir. Klinik ve radyolojik patoloji bulunmadıkça kök kanal tedavisi önerilmemektedir(7, 8).

Bununla birlikte uzun dönem takiplerde PCO bulunan dişlerin yaklaşık %27'sinde apikal periodontitis gelişebileceği bildirilmiştir (9). Bu durumlarda tedavi teknik açıdan zor olup perforasyon, kanalın bulunamaması ve alet kırılması gibi komplikasyonlar daha sık görülmektedir(10). Günümüzde gelişmiş ekipmanlar ve mikroskobik büyütme tedavi başarısını artırmış olsa da, modern tekniklerin etkinliğini destekleyen kanıtlar sınırlıdır. Operasyon mikroskobu kullanılarak yapılan bir çalışmada, vakaların %90'ında çalışma boyuna ulaşılmış ve üç yıl sonunda %80 başarı oranı bildirilmiştir (11). Ancak işlem süresinin uzunluğu ve özellikle servikal bölgede oluşabilecek aşırı doku kaybı, kök kırığı riskini artırabilmektedir (11).

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KAYNAKLAR

1. Andreasen FM, Zhjie Y, Thomsen BL, Andersen PK. Occurrence of pulp canal obliteration after luxation injuries in the permanent dentition. *Dental Traumatology*. 1987;3(3):103-15.
2. Nikoui M, Kenny DJ, Barrett EJ. Clinical outcomes for permanent incisor luxations in a pediatric population. III. Lateral luxations. *Dental Traumatology*. 2003;19(5):280-5.
3. Mass E, Zilberman U. Long-term radiologic pulp evaluation after partial pulpotomy in young permanent molars. *Quintessence International*. 2011;42(7).
4. Fleig S, Attin T, Jungbluth H. Narrowing of the radicular pulp space in coronally restored teeth. *Clinical oral investigations*. 2017;21(4):1251-7.
5. Delivanis HP, Sauer GJ. Incidence of canal calcification in the orthodontic patient. *American Journal of Orthodontics*. 1982;82(1):58-61.
6. Carvalho TS, Lussi A. Age-related morphological, histological and functional changes in teeth. *Journal of oral rehabilitation*. 2017;44(4):291-8.
7. by: ESoEd, Krastl G, Weiger R, Filippi A, Van Waes H, Ebeleseder K, et al. European Society of Endodontology position statement: endodontic management of traumatized permanent teeth. *International Endodontic Journal*. 2021;54(9):1473-81.
8. Krastl G, Weiger R, Filippi A, Van Waes H, Ebeleseder K, Ree M, et al. Endodontic management of traumatized permanent teeth: a comprehensive review. *International Endodontic Journal*. 2021;54(8):1221-45.
9. Oginni AO, Adekoya-Sofowora CA, Kolawole KA. Evaluation of radiographs, clinical signs and symptoms associated with pulp canal obliteration: an aid to treatment decision. *Dental Traumatology*. 2009;25(6):620-5.
10. Cvek M, Granath L, Lundberg M. Failures and healing in endodontically treated non-vital anterior teeth with posttraumatically reduced pulpal lumen. *Acta Odontologica Scandinavica*. 1982;40(4):223-8.
11. Kiefner P, Connert T, ElAyouti A, Weiger R. Treatment of calcified root canals in elderly people: a clinical study about the accessibility, the time needed and the outcome with a three-year follow-up. *Gerodontology*. 2017;34(2):164-70.
12. Krastl G, Zehnder MS, Connert T, Weiger R, Kühl S. Guided endodontics: a novel treatment approach for teeth with pulp canal calcification and apical pathology. *Dental traumatology*. 2016;32(3):240-6.
13. Zehnder M, Connert T, Weiger R, Krastl G, Kühl S. Guided endodontics: accuracy of a novel method for guided access cavity preparation and root canal location. *International endodontic journal*. 2016;49(10):966-72.
14. Buchgreitz J, Buchgreitz M, Mortensen D, Bjørndal L. Guided access cavity preparation using cone-beam computed tomography and optical surface scans—an ex vivo study. *International endodontic journal*. 2016;49(8):790-5.
15. Van Der Meer WJ, Vissink A, Ng YL, Gulabivala K. 3D Computer aided treatment planning in endodontics. *Journal of dentistry*. 2016;45:67-72.
16. Wei X, Du Y, Zhou X, Yue L, Yu Q, Hou B, et al. Expert consensus on digital guided therapy for endodontic diseases. *International Journal of Oral Science*. 2023;15(1):54.
17. Bun San Chong B, Manpreet Dhessi B, Makkissi J, RCR D. Computer-aided dynamic navigation: a novel method for guided endodontics. *Quintessence International*. 2019;50(3):196-202.
18. Dianat O, Gupta S, Price JB, Mostoufi B. Guided endodontic access in a maxillary molar using a dynamic navigation system. *Journal of endodontics*. 2021;47(4):658-62.
19. Chen C, Zhang R, Zhang W, Wang F, Wang Z, Qin L, et al. Analysis of the accuracy of a dynamic navigation system in endodontic microsurgery: a prospective case series study. *Journal of Dentistry*. 2023;134:104534.
20. Haarmann B, Leontiev W, Magni E, Kühl S, Dagassan-Berndt D, Weiger R, et al. Accuracy of guided endodontics in posterior teeth. *Applied Sciences*. 2023;13(4):2321.

21. Jung RE, Schneider D, Ganeles J, Wismeijer D, Zwahlen M, Hammerle C, et al. Computer technology applications in surgical implant dentistry: a systematic review. Database of Abstracts of Reviews of Effects (DARE): Quality-assessed Reviews [Internet]. 2009.
22. Kühl S, Payer M, Zitzmann NU, Lambrecht JT, Filippi A. Technical Accuracy of Printed Surgical Templates for Guided Implant Surgery with the co D iagnosti X TM Software. *Clinical implant dentistry and related research*. 2015;17:e177-e82.
23. Krug R, Reich S, Connert T, Kess S, Soliman S, Reymus M, et al. Guided endodontics: a comparative in vitro study on the accuracy and effort of two different planning workflows. *Int J Comput Dent*. 2020;23(2):119-28.
24. Marquardt P, Witkowski S, Strub J. Three-dimensional navigation in implant dentistry. *European Journal of Esthetic Dentistry*. 2007;2(1).
25. Block MS, Emery RW, Lank K, Ryan J. Implant Placement Accuracy Using Dynamic Navigation. *International Journal of Oral & Maxillofacial Implants*. 2017;32(1).
26. Connert T, Weiger R, Krastl G. Present status and future directions—Guided endodontics. *International endodontic journal*. 2022;55:995-1002.
27. LARA-MENDES STdO, Barbosa CdF, Machado VC, Santa-Rosa C. Guided endodontics as an alternative for the treatment of severely calcified root canals. *Dental Press Endodontics*. 2019;9(1):15-20.
28. Connert T, Walter E, Benz L, Schwendicke F, Leontiev W. Guided Endodontics—Potential and Limitations. *Australian Dental Journal*. 2025.
29. Connert T, Zehnder M, Amato M, Weiger R, Kühl S, Krastl G. Microguided Endodontics: a method to achieve minimally invasive access cavity preparation and root canal location in mandibular incisors using a novel computer-guided technique. *International endodontic journal*. 2018;51(2):247-55.
30. Connert T, Zehnder MS, Weiger R, Kühl S, Krastl G. Microguided endodontics: accuracy of a miniaturized technique for apically extended access cavity preparation in anterior teeth. *Journal of endodontics*. 2017;43(5):787-90.
31. Connert T, Krug R, Eggmann F, Emsermann I, ElAyouti A, Weiger R, et al. Guided endodontics versus conventional access cavity preparation: a comparative study on substance loss using 3-dimensional—printed teeth. *Journal of endodontics*. 2019;45(3):327-31.
32. Zhang T, Chen D, Miao L-Y, Xie S-J, Tang X-N. Guided endodontic access of calcified root canal by laser melting templates. *Hua xi kou Qiang yi xue za zhi= Huaxi Kouqiang Yixue Zazhi= West China Journal of Stomatology*. 2020;38(5):525-31.
33. Torres A, Lerut K, Lambrechts P, Jacobs R. Guided endodontics: use of a sleeveless guide system on an upper premolar with pulp canal obliteration and apical periodontitis. *Journal of Endodontics*. 2021;47(1):133-9.
34. Buchgreitz J, Buchgreitz M, Bjørndal L. Guided root canal preparation using cone beam computed tomography and optical surface scans—an observational study of pulp space obliteration and drill path depth in 50 patients. *International Endodontic Journal*. 2019;52(5):559-68.
35. Moreno-Rabié C, Torres A, Lambrechts P, Jacobs R. Clinical applications, accuracy and limitations of guided endodontics: a systematic review. *International endodontic journal*. 2020;53(2).
36. Zubizarreta-Macho Á, Valle Castaño S, Montiel-Company JM, Mena-Álvarez J. Effect of computer-aided navigation techniques on the accuracy of endodontic access cavities: a systematic review and meta-analysis. *Biology*. 2021;10(3):212.
37. Zubizarreta-Macho Á, de Pedro Muñoz A, Riad Deglow E, Agustín-Panadero R, Mena Álvarez J. Accuracy of computer-aided dynamic navigation compared to computer-aided static procedure for endodontic access cavities: an in vitro study. *Journal of clinical medicine*. 2020;9(1):129.
38. Jain SD, Carrico CK, Bermanis I. 3-Dimensional accuracy of dynamic navigation technology in locating calcified canals. *Journal of Endodontics*. 2020;46(6):839-45.
39. Gambarini G, Galli M, Morese A, Stefanelli LV, Abduljabbar F, Giovarruscio M, et al. Precision

- of dynamic navigation to perform endodontic ultraconservative access cavities: a preliminary in vitro analysis. *Journal of endodontics*. 2020;46(9):1286-90.
40. Dianat O, Nosrat A, Tordik PA, Aldahmash SA, Romberg E, Price JB, et al. Accuracy and efficiency of a dynamic navigation system for locating calcified canals. *Journal of endodontics*. 2020;46(11):1719-25.
 41. Jain SD, Saunders MW, Carrico CK, Jadhav A, Deeb JG, Myers GL. Dynamically navigated versus freehand access cavity preparation: a comparative study on substance loss using simulated calcified canals. *Journal of endodontics*. 2020;46(11):1745-51.
 42. Connert T, Leontiev W, Dagassan-Berndt D, Kühl S, ElAyouti A, Krug R, et al. Real-time guided endodontics with a miniaturized dynamic navigation system versus conventional freehand endodontic access cavity preparation: substance loss and procedure time. *Journal of Endodontics*. 2021;47(10):1651-6.
 43. Janabi A, Tordik PA, Griffin IL, Mostoufi B, Price JB, Chand P, et al. Accuracy and efficiency of 3-dimensional dynamic navigation system for removal of fiber post from root canal-treated teeth. *Journal of endodontics*. 2021;47(9):1453-60.

BÖLÜM 20

KÖK KANAL DEZENFEKSİYONUNDA NANOMALZEMELERİN ROLÜ

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Etimolojik kökeni Yunanca “cüce” (nannos) kelimesine dayanan nanoteknoloji; materyallerin atomik ve moleküler düzeyde manipüle edilmesine olanak tanıyarak diş hekimliğinde devrim niteliğinde gelişmelere yol açmıştır.

Avrupa Komisyonu tarafından doğal, tesadüfi veya üretim yoluyla elde edilen; parçacıkların serbest, agrega veya aglomera formunda bulunduğu malzemeler olarak tanımlanan nanomateryaller, günümüzde dental uygulamalarda giderek artan bir kullanım yelpazesine sahiptir[2,3,5].

Nanoteknoloji kavramı ilk olarak 1959’da **Dr. Richard Feynman** tarafından açıklanmıştır. 1991 yılında **Dr. Sumio Lijima** nanotüp kavramını tanıtmıştır. “**Nano Diş Hekimliği**” terimi ise 2000 yılında **Dr. Freitas Jr.** tarafından türetilmiştir. Freitas; nanomalzemeler ve nanorobotlar geliştirmiş, diş yapısının rejenerasyonuna yardımcı olmuş ve diş macunları içindeki robotlar olan “dentifrobotları” geliştirmiştir. Başlangıçta imkansız görünen ve “bilimkurgu” olarak nitelendirilen bu fikirler, günümüzde klinisyenler tarafından nihayet kabul görmektedir[6].

Nanomalzemeler; Şekil 1’de gösterildiği üzere **boyutlarına, yapısal konfigürasyonuna ve kökenlerine** göre sınıflandırılmaktadır.

Nanopartiküller genel olarak bileşimlerine göre **doğal** ve **yapay** olmak üzere sınıflandırılabilir. Doğal nanopartiküller kendi içerisinde **inorganik** ve **organik** olarak ayrılmaktadır. Şekillerine göre ise nanopartiküller; küresel, tübüler, çubuk şeklinde ve tabakalı (plak benzeri) yapılar olarak sınıflandırılabilir. Ayrıca, **fonksiyonelleştirilmiş nanopartiküller** de ayrı bir grup oluşturmaktadır. Bu tür

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yumluluk verilerinin yetersizliği ve yüksek kaliteli klinik kanıtların sınırlı olması nedeniyle henüz kısıtlıdır. Bu nedenle, gelecekteki araştırmaların; nanomalzeme-lerin güvenliğini, etkinliğini ve uzun dönem klinik performansını doğrulamak amacıyla, sağlam in vivo modeller ve randomize kontrollü klinik çalışmaları içeren iyi tasarlanmış translasyonel çalışmalara odaklanması gerekmektedir.

KAYNAKLAR

1. Dipali Dinkar Deshpande, Varsha Pandit, Dhananjay Gunawat & Gauri Sanpurkar. *Biomedical Informatics* (2025) May 31, 2025 [DOI: 10.6026/973206300211239]
2. Dağlıoğlu Y, Yavuz MC. Dişhekimiğinde nanoteknoloji ve uygulamaları. *EÜ Dişhek Fak Derg* 2020;41:149-60. [DOI: 10.5505/eudfd.2020.14725]
3. Kaehler T. Nanotechnology: basic concepts and definitions. *Clin Chem* 1994;40:1797-9. [DOI: 10.1093/clinchem/40.9.1797b]
4. Özdemir O, Kopac T. Recent Progress on the Applications of Nanomaterials and Nano-Characterization Techniques in Endodontics: A Review. *Materials* 2022;15:5109. [DOI: 10.3390/ma15155109]
5. European Commission. Commission recommendation of 18 October 2011 on the definition of nanomaterial. *J Eur Union* 2011;275:38-40.
6. Aeran H, Kumar V, Uniyal S, Tanwer P. Nanodentistry: Is just a fiction or future. *J Oral Biol Craniofac Res.* 2015;5(3):207-11. [DOI: 10.1016/j.jobcr.2015.06.012]
7. Jhajharia, K.; Mehta, L.; Parolia, A.; Shetty, K. Biofilm in endodontics: A review. *J. Int. Soc. Prev. Community Dent.* 2015, 5, 1. [DOI: 10.4103/2231-0762.151956]
8. Wojciech Zakrzewski, Maciej Dobrzyński, Anna Zawadzka-Knefel ve ark. *Materials* 2021, 14, 5296. [DOI: 10.3390/ma14185296]
9. Şadihan Kurt Koç, Mügem Gürel Ekici, Bağdagül Helvacıoğlu Kıvanç. *Acta Odontol Turc* 2025;42(2):101-108. [DOI: 10.17214/gaziaot.1298937]
10. Roduner E. Size matters: why nanomaterials are different. *Chem Soc Rev.* 2006;35(7):583-92. [DOI: 10.1039/B502142C]
11. Bhushan J, Maini C. Nanoparticles: a promising novel adjunct for dentistry. *Indian J Dent* 2019;11:167-73. [DOI: 10.4103/ijd.ijd_325_18]
12. Kim YH, Lee DK, Cha HG ve ark. Preparation and characterization of the antibacterial Cu nanoparticle formed on the surface of SiO₂ nanoparticles. *J Phys Chem B* 2006;110:24923-8. [DOI: 10.1021/jp0633716]
13. Wang D, Lin Z, Wang T ve ark. Where does the toxicity of metal oxide nanoparticles come from: the nanoparticles, the ions, or a combination of both? *J Hazard Mater* 2016;308:328-34. [DOI: 10.1016/j.jhazmat.2016.01.013]
14. Nel A, Xia T, Madler L, Li N. Toxic potential of materials at the nanolevel. *Science* 2006;311:622-7. [DOI: 10.1126/science.1114397]
15. Lynch I, Dawson KA. Protein-nanoparticle interactions. *Nano Today* 2008;3:40-7. [DOI: 10.1016/S1748-0132(08)70014-8]
16. Aggarwal P, Hall JB, McLeland CB, Dobrovolskaia MA, McNeil SE. Nanoparticle interaction with plasma proteins as it relates to particle biodistribution, biocompatibility and therapeutic efficacy. *Adv Drug Deliv Rev* 2009;61:428-37. [DOI: 10.1016/j.addr.2009.03.003]
17. Giannousi K, Lafazanis K, Arvanitidis J, Pantazaki A, Dendrinou-Samara C. Hydrothermal synthesis of copper based nanoparticles: Antimicrobial screening and interaction with DNA. *J Inorg Biochem* 2014;133:24-32. [DOI: 10.1016/j.jinorgbio.2014.01.001]
18. Arakha M, Pal S, Samantarrai D, Panigrahi TK, Mallick BC, Pramanik K, et al. Antimicrobial activity of iron oxide nanoparticle upon modulation of nanoparticle-bacteria interface. *Sci Rep*

- 2015;5:14813. [DOI: 10.1038/srep14813]
19. Kirstein J, Turgay K. A new tyrosine phosphorylation mechanism involved in signal transduction in *Bacillus subtilis*. *J Mol Microbiol Biotechnol* 2005;9:182-8. [DOI: 10.1159/000089645]
 20. Shrivastava S, Bera T, Roy A ve ark. Characterization of enhanced antibacterial effects of novel silver nanoparticles. *Nanotechnology* 2007;18:225103. [DOI: 10.1088/0957-4484/18/22/225103]
 21. Chen WJ, Chen YC. Fe₃O₄/TiO₂ core/shell magnetic nanoparticle-based photokilling of pathogenic bacteria. *Nanomedicine (Lond)* 2010;5:1585-93. [DOI: 10.2217/nnm.10.126]
 22. Carpio IE, Santos CM, Wei X, Rodrigues DF. Toxicity of a polymer-graphene oxide composite against bacterial planktonic cells, biofilms, and mammalian cells. *Nanoscale* 2012;4(15):4746-56. [DOI: 10.1039/C2NR30774J]
 23. Hu W, Peng C, Lv M, Li X, Zhang Y, Chen N, Fan C, Huang Q. Protein corona-mediated mitigation of cytotoxicity of graphene oxide. *ACS Nano* 2011;5(5):3693-700. [DOI: 10.1021/nn200021j]
 24. Dubey, N.; Rajan, S.S.; Bello, Y.D.; Min, K.S.; Rosa, V. Graphene Nanosheets to Improve Physico-Mechanical Properties of Bioactive Calcium Silicate Cements. *Materials* 2017, 10, 606. [DOI: 10.3390/ma10060606]
 25. Rago I, Bregnocchi A, Zanni E, ve ark. Antimicrobial activity of graphene nanoplatelets against *Streptococcus mutans*. *2015 IEEE 15th International Conference on Nanotechnology (IEEE-NANO)*. [DOI: 10.1109/NANO.2015.7388897]
 26. Virlan, M.J.R.; Miricescu, D.; Radulescu, R.; ve ark. Organic Nanomaterials and Their Applications in the Treatment of Oral Diseases. *Molecules* 2016, 21, 207. [DOI: 10.3390/molecules21020207]
 27. Shrestha, A.; Kishen, A. Antibacterial Nanoparticles in Endodontics: A Review. *J. Endod.* 2016, 42, 1417-1426. [DOI: 10.1016/j.joen.2016.05.021]
 28. Del Carpio-Perochena A, Bramante CM, Duarte MA, ve ark. Chelating and antibacterial properties of chitosan nanoparticles on dentin. *Restor Dent Endod.* 2015;40(3):195-201. [DOI: 10.5395/rde.2015.40.3.195]
 29. Ionescu A, Harris D, Selvaganapathy PR, Kishen A. Electrokinetic transport and distribution of antibacterial nanoparticles for endodontic disinfection. *Int Endod J.* 2020;53 (8):1120-1130. [DOI: 10.1111/iej.13321]
 30. Shrestha A, Shi Z, Neoh KG, Kishen A. Nanoparticulates for antibiofilm treatment and effect of aging on its antibacterial activity. *J Endod.* 2010;36(6):1030-1035. [DOI: 10.1016/j.joen.2010.02.008]
 31. Upadya M, Shrestha A, Kishen A. Role of efflux pump inhibitors on the antibiofilm efficacy of calcium hydroxide, chitosan nanoparticles, and light-activated disinfection. *J Endod.* 2011;37(10):1422-1426. [DOI: 10.1016/j.joen.2011.06.017]
 32. Shrestha A, Kishen A. The effect of tissue inhibitors on the antibacterial activity of chitosan nanoparticles and photodynamic therapy. *J Endod.* 2012;38(9):1275-1278. [DOI: 10.1016/j.joen.2012.05.006]
 33. Savitha A, SriRekha A, Vijay R, ve ark. An in vivo comparative evaluation of antimicrobial efficacy of chitosan, chlorhexidine gluconate gel and their combination... *Saudi Dent J* 2019;31:360-6. [DOI: 10.1016/j.sdentj.2019.03.009]
 34. Silva PV, Guedes DF, Nakadi FV, Pecora JD, Cruz-Filho AM. Chitosan: a new solution for removal of smear layer after root canal instrumentation. *Int Endod J.* 2013;46(4):332-338. [DOI: 10.1111/j.1365-2591.2012.02119.x]
 35. Hashmi A, Sodhi RNS, Kishen A. Interfacial characterization of dentin conditioned with chitosan hydroxyapatite precursor nanocomplexes... *J Endod.* 2019;45(12):1513-1521. [DOI: 10.1016/j.joen.2019.08.011]
 36. Kishen A, Shrestha S, Shrestha A, Cheng C, Goh C. Characterizing the collagen stabilizing effect of crosslinked chitosan nanoparticles against collagenase degradation. *Dent Mater.* 2016;32(8):968-977. [DOI: 10.1016/j.dental.2016.05.005]

37. Aydın ZU, Özyürek T, Keskin B, Baran T. Effect of chitosan nanoparticle, QMix, and EDTA on TotalFill BC sealers' dentinal tubule penetration... *Odontology*. 2019;107(1):64–71. [DOI: 10.1007/s10266-018-0359-0]
38. Ratih DN, Sari NI, Santosa P, Kaswati NMN. Time-dependent effect of chitosan nanoparticles as final irrigation on the apical sealing ability... *Int J Dent*. 2020;2020:1–6. [DOI: 10.1155/2020/8887593]
39. Guerreiro-Tanomaru JM, ve ark. Effect of zirconium oxide and zinc oxide nanoparticles on physicochemical properties... *Sci World J*. 2014;975213. [DOI: 10.1155/2014/975213]
40. Nicoletta Capuano, Alessandra Amato, Federica Dell'Annunziata ve ark. *Antibiotics* 2023, 12, 1690. [DOI: 10.3390/antibiotics12121690]
41. Pagonis, T.C.; ve ark. Nanoparticle-Based Endodontic Antimicrobial Photodynamic Therapy. *J. Endod*. 2010, 36, 322–328. [DOI: 10.1016/j.joen.2009.11.006]
42. Razumova, S.; ve ark. The Application of Nano Silver Argitos as a Final Root Canal Irrigation... *Nanomaterials* 2022, 12, 248. [DOI: 10.3390/nano12020248]
43. Moazami, F; Sahebi, S.; Ahzan, S. Tooth Discoloration Induced by Imidazolium Based Silver Nanoparticles... *J. Dent*. 2018, 19, 280–286. [PMID: 30542316]
44. Waltimo T, ve ark. Fine-tuning of bioactive glass for root canal disinfection. *J Dent Res*. 2009;88(3):235–8. [DOI: 10.1177/0022034508330315]
45. Correia, B.L.; ve ark. New and Efficient Bioactive Glass Compositions for Controlling Endodontic Pathogens. *Nanomaterials* 2022, 12, 1577. [DOI: 10.3390/nano12091577]
46. Wu C, Chang J, Fan W. Bioactive mesoporous calcium–silicate nanoparticles... *J Mater Chem*. 2012; 22(33):16801–9. [DOI: 10.1039/C2JM32435K]
47. Huang, C.-Y.; ve ark. Mesoporous Calcium Silicate Nanoparticles with Drug Delivery and Odontogenesis Properties. *J. Endod*. 2017, 43, 69–76. [DOI: 10.1016/j.joen.2016.09.012]
48. Zhu, J.; ve ark. Effects of Nanosilver and Nanozinc Incorporated Mesoporous Calcium-Silicate Nanoparticles... *PLoS ONE* 2017, 12, e0182583. [DOI: 10.1371/journal.pone.0182583]
49. Xing, Y.; ve ark. Chitosan-Based Coating with Antimicrobial Agents... *Int. J. Polym. Sci*. 2016, 2016, 4851730. [DOI: 10.1155/2016/4851730]
50. Hamad, A.; Khashan, K.S.; Hadi, A. Silver nanoparticles and silver ions as potential antibacterial agents. *J. Inorg. Organomet. Polym. Mater*. 2020, 30, 4811–4828. [DOI: 10.1007/s10904-020-01744-x]
51. Mohamed, D.S.; ve ark. Antimicrobial Activity of Silver-Treated Bacteria against other Multi-Drug Resistant Pathogens... *Antibiotics* 2020, 9, 181. [DOI: 10.3390/antibiotics9040181]
52. Xu, Z.; Zhang, C.; Wang, X.; Liu, D. Release strategies of silver ions from materials for bacterial killing. *ACS Appl. Bio Mater*. 2021, 4, 3985–3999. [DOI: 10.1021/acsabm.1c00028]
53. Chávez-Andrade, G.M.; ve ark. Antimicrobial and biofilm anti-adhesion activities of silver nanoparticles and farnesol... *Arch. Oral. Biol*. 2019, 107, 104482. [DOI: 10.1016/j.archoral-bio.2019.104482]
54. Ozdemir, H.O.; ve ark. Effect of EDTA and NaOCl irrigation on *Enterococcus faecalis* biofilm colonization... *J. Endod*. 2010, 36, 842–846. [DOI: 10.1016/j.joen.2010.02.001]
55. Wu, D.; ve ark. Evaluation of the antibacterial efficacy of silver nanoparticles against *Enterococcus faecalis* biofilm. *J. Endod*. 2014, 40, 285–290. [DOI: 10.1016/j.joen.2013.08.022]
56. Firouzmandi, M.; Mohaghegh, M.; Jafarpisheh, M. Effect of silver diamine fluoride on the bond durability of normal and carious dentin. *J. Clin. Exp. Dent*. 2020, 12, e468. [DOI: 10.4317/jced.56588]
57. Topala F, ve ark. En-face optical coherence tomography analysis of gold and silver nanoparticles... *Exp. Ther. Med*. 2021;22(3):992. [DOI: 10.3892/etm.2021.10424]
58. Razumova S, ve ark. The application of nano silver argitos as a final root canal irrigation... *Nanomaterials*. 2022;12(2):248. [DOI: 10.3390/nano12020248]
59. Umeda Suzuki TY, ve ark. Influence of silver nanoparticle solution on the mechanical properties... *PLOS ONE*. 2019;14(6):e0217750. [DOI: 10.1371/journal.pone.0217750]

60. Suzuki TYU, ve ark. Do irrigation solutions influence the bond interface between glass fiber posts and dentin? *Braz. Dent. J.* 2019;30(2):106–116. [DOI: 10.1590/0103-6440201902404]
61. Beyth N, ve ark. Alternative antimicrobial approach: nano-antimicrobial materials. *Evid Based Complement Alternat Med.* 2015;2015:246012. [DOI: 10.1155/2015/246012]
62. Shrestha A, Shi Z, Neoh KG, Kishen A. Nanoparticulates for antibiofilm treatment... *J Endod.* 2010;36(6):1030–1035. [DOI: 10.1016/j.joen.2010.02.008]
63. Samiei M, ve ark. Antibacterial efficacy of polymer containing nanoparticles in comparison with sodium hypochlorite... *Minerva Stomatol.* 2015;64(6):275–281. [PMID: 26343543]
64. de Almeida J, ve ark. Effectiveness of nanoparticles solutions and conventional endodontic irrigants... *Indian J Dent Res.* 2018;29(3):347–351. [DOI: 10.4103/ijdr.IJDR_634_15]
65. Jowkar Z, ve ark. The effect of silver, zinc oxide, and titanium dioxide nanoparticles used as final irrigation... *Clin Cosmet Investig Dent.* 2020;12:141–148. [DOI: 10.2147/CCIDE.S253251]
66. Raura N, Garg A, Arora A, Roma M. Nanoparticle technology and its implications in endodontics: a review. *Biomater Res* 2020;24:21. [DOI: 10.1186/s40824-020-00198-z]
67. Kishen A, Shi Z, Shrestha A, Neoh KG. An Investigation on the Antibacterial and Antibiofilm Efficacy of Cationic Nanoparticulates... *J Endod* 2008;34:1515-20. [DOI: 10.1016/j.joen.2008.08.035]
68. Monzavi A, Eshraghi S, Hashemian R, Momen-Heravi F. In vitro and ex vivo antimicrobial efficacy of nano-MgO... *Clin Oral Investig* 2015;19:349-56. [DOI: 10.1007/s00784-014-1253-y]
69. Deshpande DD, Pandit V, Gunawat D, Sanpurkar G. *Bioinformation* 2025; 21(5): 1239-1244. [DOI: 10.6026/973206300211239]
70. Ramar K & Vivek N. *International Journal of Clinical Pediatric Dentistry.* 2022, 15:S57. [DOI: 10.5005/jp-journals-10005-2121]
71. Raura N et al. *Biomaterials Research.* 2020 24:21. [DOI: 10.1186/s40824-020-00198-z]
72. AlKahtani, R.N. The Implications and Applications of Nanotechnology in Dentistry: A Review. *Saudi Dent. J.* 2018, 30, 107–116. [DOI: 10.1016/j.sdentj.2018.01.002]
73. Sharma, S.; Parveen, R.; Chatterji, B.P. Toxicology of Nanoparticles in Drug Delivery. *Curr. Pathobiol. Rep.* 2021, 9, 133–144. [DOI: 10.1007/s40139-021-00227-z]
74. Yusuf, A.; ve ark. Nanoparticles as Drug Delivery Systems: A Review... *Polymers* 2023, 15, 1596. [DOI: 10.3390/polym15071596]

BÖLÜM 21

MODERN ENDODONTİDE YAPAY ZEKA TABANLI KARAR DESTEK SİSTEMLERİ

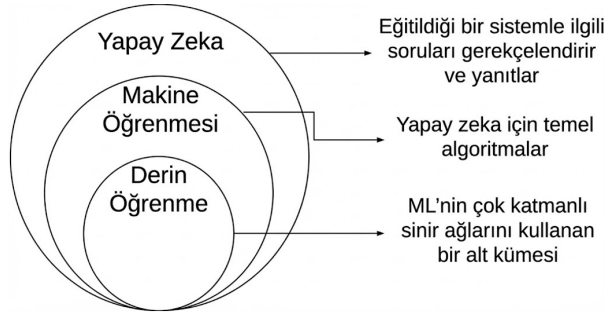
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GİRİŞ VE TEMEL KAVRAMLAR

Yapay Zeka, Makine Öğrenmesi ve Derin Öğrenme: Terminolojik Çerçeve

Yapay zeka; problem çözme, akıl yürütme ve öğrenme gibi insani zeka fonksiyonlarını modelleyen sistemleri kapsayan geniş bir disiplin olarak tanımlanır(1). Yapay zekanın kökenleri Alan Turing'in meşhur sorgulamasına uzanmakta olup ismi 1956 Dartmouth Konferansı'nda konulmuştur(2). Sonrasında ise 21. Yüzyılda özellikle işlemci hızlarının artması ve büyük verinin işlenebilir hale gelmesiyle tıp ve diş hekimliğinde bu teknolojide devrim yaşanmıştır(2).

Literatürde metodolojinin doğru anlaşılması açısından, Yapay zeka (YZ), Makine Öğrenmesi (Machine Learning – ML) ve Derin Öğrenme (Deep Learning – DL) kavramları arasındaki hiyerarşik ilişkinin netleştirilmesi gerekmektedir. Bu kavramlar, **Şekil 1**'de gösterildiği üzere iç içe geçmiş kümeler şeklinde ele alınabilir:



Şekil 1: Yapay Zeka, Makine Öğrenmesi ve Derin Öğrenme arasındaki hiyerarşik ilişki(3).

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Sonuç olarak, yapay zekanın gelecekte endodonti pratiğini hesaplama gücü ile hekimin klinik yargısının mükemmel bir uyumu üzerinde yeniden inşa edeceği öngörülmektedir. Ancak bu hedefe ulaşmak için daha fazla prospektif çok merkezli klinik çalışmaya ve sağlam etik çerçevelere ihtiyaç vardır (19, 37, 43, 44).

KAYNAKLAR

1. Russell SJN, Peter. Artificial Intelligence: A Modern Approach. 3rd ed. Upper Saddle River, NJ: Pearson; 2010.
2. Kaul V, Enslin S, Gross SA. History of artificial intelligence in medicine. *Gastrointest Endosc* 2020;92(4):807-812.doi:10.1016/j.gie.2020.06.040
3. Kuntz D, Wilson AK. Machine learning, artificial intelligence, and chemistry: How smart algorithms are reshaping simulation and the laboratory. *Pure and Applied Chemistry* 2022;94(8):1019-1054.doi: 10.1515/pac-2022-0402
4. Obermeyer Z, Emanuel EJ. Predicting the Future - Big Data, Machine Learning, and Clinical Medicine. *N Engl J Med* 2016;375(13):1216-1219.doi:10.1056/NEJMP1606181
5. Schwendicke F, Samek W, Krois J. Artificial Intelligence in Dentistry: Chances and Challenges. *J Dent Res* 2020;99(7):769-774.doi: 10.1177/0022034520915714
6. Goldman M, Pearson AH, Darzenta N. Endodontic success—who's reading the radiograph? *Oral Surgery, Oral Medicine, Oral Pathology* 1972;33(3):432-437.doi:10.1016/0030-4220(72)90473-2
7. Sprawls P. Physical Principles of Medical Imaging. 2nd ed. Madison, WI: Medical Physics Publishing; 1995.
8. Orhan K, Bayrakdar IS, Ezhov M, Kravtsov A, Ozyurek T. Evaluation of artificial intelligence for detecting periapical pathosis on cone-beam computed tomography scans. *Int Endod J* 2020;53(5):680-689.doi:10.1111/iej.13265
9. Aminoshariae A, Kulild J, Nagendrababu V. Artificial Intelligence in Endodontics: Current Applications and Future Directions. *J Endod* 2021;47(9):1352-1357.doi:10.1016/j.joen.2021.06.003
10. Grischke J, Johannsmeier L, Eich L, Griga L, Haddadin S. Dentronics: Towards robotics and artificial intelligence in dentistry. *Dent Mater* 2020;36(6):765-778.doi:10.1016/j.dental.2020.03.021
11. Aminoshariae A, Kulild JC, Syed A. Cone-beam Computed Tomography Compared with Intraoral Radiographic Lesions in Endodontic Outcome Studies: A Systematic Review. *J Endod* 2018;44(11):1626-1631.doi:10.1016/j.joen.2018.08.006
12. Krois J, Ekert T, Meinhold L, Golla T, Kharbot B, Wittemeier A, et al. Deep Learning for the Radiographic Detection of Periodontal Bone Loss. *Sci Rep* 2019;9(1):8495.doi:10.1038/s41598-019-44839-3
13. Hiraiwa T, Arijji Y, Fukuda M, Kise Y, Nakata K, Katsumata A, et al. A deep-learning artificial intelligence system for assessment of root morphology of the mandibular first molar on panoramic radiography. *Dentomaxillofac Radiol* 2019;48(3):20180218.doi:10.1259/dmfr.20180218
14. Endres MG, Hillen F, Salloumis M, Sedaghat AR, Niehues SM, Quatela O, et al. Development of a Deep Learning Algorithm for Periapical Disease Detection in Dental Radiographs. *Diagnostics* 2020;10(6):430.doi:10.3390/diagnostics10060430
15. Akalin F, Özkan Y. Deep Learning-Based Hybrid Scenario for Classification of Periapical Lesions in Cone Beam Computed Tomography. *Symmetry* 2025;17(9):1392.doi:10.3390/sym17091392
16. Hassan W, Mehta V, Singdha NT, Karobari MI. AI in Root Canal Morphology: A Detailed Bibliometric Analysis of Research Trends and Global Contributions. *Clin Exp Dent Res* 2025;11(6):e70269.doi:10.1002/cre2.70269
17. Ahmed HMA, Versiani MA, De-Deus G, Dummer PMH. A new system for classifying root and root canal morphology. *Int Endod J* 2017;50(8):761-770.doi:10.1111/iej.12685

18. Santos-Junior AO, Fontenele RC, Neves FS, Tanomaru-Filho M, Jacobs R. A novel artificial intelligence-powered tool for automated root canal segmentation in single-rooted teeth on cone-beam computed tomography. *Int Endod J* 2025;58(4):658-671.doi:10.1111/iej.14200
19. Kun K, GonzÁlez NA, Malla G. Artificial Intelligence in The Diagnosis, Treatment, and Prognostication in Endodontics: A Comprehensive Literature Review. *Eur Endod J* 2025;10(6):466-478.doi:10.14744/eej.2025.83788
20. Fatima A, Shafi I, Afzal H, Díez IT, Lourdes DRM, Breñosa J, et al. Advancements in Dentistry with Artificial Intelligence: Current Clinical Applications and Future Perspectives. *Healthcare (Basel)* 2022;10(11).doi:10.3390/healthcare10112188
21. Abdelazim R, Fouad EM. Artificial intelligent-driven decision-making for automating root fracture detection in periapical radiographs. *BDJ Open* 2024;10(1):76.doi:10.1038/s41405-024-00260-1
22. Yang P, Guo X, Mu C, Qi S, Li G. Detection of vertical root fractures by cone-beam computed tomography based on deep learning. *Dentomaxillofac Radiol* 2023;52(3):20220345.doi:10.1259/dmfr.20220345
23. Fukuda M, Inamoto K, Shibata N, Arijji Y, Yanashita Y, Kutsuna S, et al. Evaluation of an artificial intelligence system for detecting vertical root fracture on panoramic radiography. *Oral Radiol* 2020;36(4):337-343.doi:10.1007/s11282-019-00409-x
24. Ahmed ZH, Almuharib AM, Abdulkarim AA, Alhassoon AH, Alanazi AF, Alhaqbani MA, et al. Artificial Intelligence and Its Application in Endodontics: A Review. *J Contemp Dent Pract* 2023;24(11):912-917.doi:10.5005/jp-journals-10024-3593
25. Qu Y, Wen Y, Chen M, Guo K, Huang X, Gu L. Predicting case difficulty in endodontic microsurgery using machine learning algorithms. *Journal of Dentistry* 2023;133:104522.doi:10.1016/j.jdent.2023.104522
26. Zeng X, Ding J, Yuan K, Zhan J, He C, Wu H, et al. Joint detection of dental diseases with panoramic imaging system via multi-task context integration network. *Optics & Laser Technology* 2025;192:113394.doi:10.1016/j.optlastec.2025.113394
27. Latke VN, Vaibhav. Measuring Endodontic Working Length Using Artificial Intelligence. *Frontiers in Health Informatics* 2024;13(2):83-96.
28. Saghiri MA, Garcia-Godoy F, Gutmann JL, Lotfi M, Asgar K. The reliability of artificial neural network in locating minor apical foramen: a cadaver study. *J Endod* 2012;38(8):1130-1134.doi:10.1016/j.joen.2012.05.004
29. Ardila CM, Pineda-Velez E, Vivares-Builes AM. Artificial Intelligence in Endodontic Education: A Systematic Review with Frequentist and Bayesian Meta-Analysis of Student-Based Evidence. *Dent J (Basel)* 2025;13(11).doi:10.3390/dj13110489
30. Gao X, Xin X, Li Z, Zhang W. Predicting postoperative pain following root canal treatment by using artificial neural network evaluation. *Sci Rep* 2021;11(1):17243.doi:10.1038/s41598-021-96777-8
31. Bannasar C, Garcia I, Gonzalez-Cid Y, Perez F, Jimenez J. Second Opinion for Non-Surgical Root Canal Treatment Prognosis Using Machine Learning Models. *Diagnostics (Basel)* 2023;13(17).doi:10.3390/diagnostics13172742
32. Mohammad-Rahimi H, Sohrabniya F, Ourang SA, Dianat O, Aminoshariae A, Nagendrababu V, et al. Artificial intelligence in endodontics: Data preparation, clinical applications, ethical considerations, limitations, and future directions. *Int Endod J* 2024;57(11):1566-1595. doi:10.1111/iej.14128
33. Campo L, Aliaga IJ, De Paz JF, Garcia AE, Bajo J, Villarubia G, et al. Retreatment Predictions in Odontology by means of CBR Systems. *Comput Intell Neurosci* 2016;2016:7485250. doi:10.1155/2016/7485250
34. Zhou X. Predicting Non-Surgical Root Canal Therapy Outcomes Using Machine Learning. 2025.

35. Keskin NB, Gunec HG, Uslu G, Tezer EO. Using artificial intelligence in the evaluation of periapical, caries, and restoration status: a new methodological and technological study. *BMC Med Imaging* 2025;25(1):466.doi:10.1186/s12880-025-02019-y
36. Doumani M, Almaqboul F, Alduwaysan SSS, Alzahrani MA, Al Ghamdi SA, Alzahrani MN, et al. Effectiveness of Artificial Intelligence in Endodontic Diagnosis and Treatment Evaluation: A Systematic Review. *Cureus* 2025;17(11).doi:10.7759/cureus.96091
37. Sunar AT, Çağan; Sır, Eda; Polater, Hülya; Bağhoğlu, Nihal. Diş Hekimliğinde Yapay Zeka Uygulamaları (Artificial Intelligence Applications In Dentistry). *Journal of Kocaeli Health and Technology University (JOKOHTU)* 2024;2(3):41-57.
38. Yamaguchi S, Lee C, Karaer O, Ban S, Mine A, Imazato S. Predicting the Debonding of CAD/CAM Composite Resin Crowns with AI. *J Dent Res* 2019;98(11):1234-1238. doi:10.1177/0022034519867641
39. Suárez A, Adanero A, Díaz-Flores García V, Freire Y, Algar J. Using a Virtual Patient via an Artificial Intelligence Chatbot to Develop Dental Students' Diagnostic Skills. *Int J Environ Res Public Health* 2022;19(14).doi:10.3390/ijerph19148735
40. Agrawal P, Nikhade P. Artificial Intelligence in Dentistry: Past, Present, and Future. *Cureus* 2022;14(7):e27405.doi:10.7759/cureus.27405
41. Ardila CM, Yadalam PK. AI and dental education. *Br Dent J* 2025;238(5):294.doi:10.1038/s41415-025-8514-9
42. Suresh AN, Shyamala Nagendran; Inginshtetty, Vaishnavi. ENDO AI: A Novel Artificial Intelligence Framework for Predicting Treatment Outcomes in Endodontic Therapy. *Quest Journals: Journal of Medical and Dental Science Research* 2025;12(2):12-19.doi:10.35629/076X-12021219
43. Asgary S. Artificial Intelligence in Endodontics: A Scoping Review. *Iran Endod J* 2024;19(2):85-98.doi:10.22037/iej.v19i2.44842
44. Alaqla A, Khanagar SB, Albelaihi AI, Singh OG, Alfadley A. Application and performance of artificial intelligence-based models in the detection, segmentation and classification of periapical lesions: a systematic review. *Front Dent Med* 2025;6:1717343.doi:10.3389/fdmed.2025.1717343
45. Sadr S, Rokhshad R, Daghighi Y, Golkar M, Toloie Kheybari F, Gorjinejad F, et al. Deep learning for tooth identification and numbering on dental radiography: a systematic review and meta-analysis. *Dentomaxillofac Radiol* 2024;53(1):5-21.doi:10.1093/dmfr/twad001
46. Mangat PC, Bhaviya. Biomarkers in endodontics and conservative dentistry: An editorial overview with latest literature and future perspectives. *IP Indian Journal of Conservative and Endodontics (IJCE)* 2025;10(2):71-73.doi:10.18231/j.ijce.2025.013
47. Ossowska A, Kusiak A, Swietlik D. Artificial Intelligence in Dentistry-Narrative Review. *Int J Environ Res Public Health* 2022;19(6).doi:10.3390/ijerph19063449
48. Nayyar N, Ojcius DM, Dugoni AA. The Role of Medicine and Technology in Shaping the Future of Oral Health. *J Calif Dent Assoc* 2020;48(3):127-130.
49. Hung KF, Yeung AWK, Bornstein MM, Schwendicke F. Personalized dental medicine, artificial intelligence, and their relevance for dentomaxillofacial imaging. *Dentomaxillofac Radiol* 2023;52(1):20220335.doi:10.1259/dmfr.20220335

BÖLÜM 22

DENTAL TRAVMADA KULLANILAN SPLİNTLER

Duygu POLAT¹
Tuğrul ASLAN²

GİRİŞ

Travmatik dental yaralanmalar (TDY) sıklıkla birden fazla dokuyu etkileyen ve karmaşık bir klinik tabloyla seyreden yaralanmalardır. Bu nedenle doğru ve kapsamlı bir tanının konulması, etkili bir tedavi planının oluşturulmasında kritik bir rol oynar. Çoğu travmatik olgu, etkilenen anatomik yapılara göre daha küçük alt yaralanmalara ayrılarak değerlendirilebilir. Bu yapılar dişin sert dokuları, pulpa dokusu, alveol kemiği ve gingival dokuları kapsamaktadır (1-3). Uluslararası Dental Travmatoloji Derneği (International Association of Dental Traumatology – IADT) tarafından yakın dönemde güncellenen kılavuzlar, travmatik dental yaralanmaların acil ve gecikmeden uygulanması gereken tedavilerine ilişkin açık ve yol gösterici öneriler sunmaktadır (4-6).

Tanısal süreç; ayrıntılı ekstraoral ve intraoral klinik muayene, pulpa vitalite testleri, dişin mobilite durumu veya pozisyon değişikliklerinin incelenmesi ile radyografik analizleri kapsar. Bunun yanı sıra, klinik olarak elde edilen nitelikli fotoğraflar yalnızca başlangıç tanısının desteklenmesi açısından değil, aynı zamanda olası komplikasyonların travmatik olaya bağlı geliştiğinin belgelenmesi amacıyla adli diş hekimliği açısından da önemli bir yere sahiptir (7).

TDY restoratif, endodontik ve cerrahi yaklaşımların bir arada ve bütüncül bir bakış açısıyla değerlendirilmelidir. TDY olgularında hekimin vakaya zaman kaybetmeden müdahale etmesi, tedavi sürecinin başarısı açısından büyük önem taşımaktadır. Diş hekiminin dental travma konusunda bilgi ve farkındalığa sahip olması, hastanın muayene ve tedavi basamaklarının daha etkin ve hızlı bir şekilde tamamlanmasına olanak sağlar (8).

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KAYNAKLAR

1. Filippi A, Tschan J, Pohl Y, Berthold H, Ebeleseder K. A retrospective classification of tooth injuries using a new scoring system. *Clinical Oral Investigations*. 2000;4(3):173-175. doi:10.1007/s007840000056.
2. Ebeleseder K. A suggestion of a new classification system of traumatic dental injuries. *Endodontics & Dental Traumatology*. 1994;10(1):39-42.
3. Andreasen JO, Andreasen FM, Andersson L. *Textbook and color atlas of traumatic injuries to the teeth*. John Wiley & Sons; 2018.
4. Levin L, Day PF, Hicks L, O'Connell A, Fouad AF, Bourguignon C, et al. International Association of Dental Traumatology guidelines for the management of traumatic dental injuries: General introduction. *Dental Traumatology*. 2020;36(4):309-313. doi:10.1111/edt.12574.
5. Fouad AF, Abbott PV, Tsilingaridis G, Cohenca N, Lauridsen E, Bourguignon C, et al. International Association of Dental Traumatology guidelines for the management of traumatic dental injuries: 2. Avulsion of permanent teeth. *Dental Traumatology*. 2020;36(4):331-342. doi:10.1111/edt.12573.
6. Bourguignon C, Cohenca N, Lauridsen E, Flores MT, O'Connell AC, Day PF, et al. International Association of Dental Traumatology guidelines for the management of traumatic dental injuries: 1. Fractures and luxations. *Dental Traumatology*. 2020;36(4):314-330. doi:10.1111/edt.12578.
7. Andreasen FM, Andreasen JO. Diagnosis of luxation injuries: the importance of standardized clinical, radiographic and photographic techniques in clinical investigations. *Dental Traumatology*. 1985;1(5):160-169.
8. Day PF, Flores MT, O'Connell AC, Abbott PV, Tsilingaridis G, Fouad AF, et al. International Association of Dental Traumatology guidelines for the management of traumatic dental injuries: 3. Injuries in the primary dentition. *Dental Traumatology*. 2020;36(4):343-359. doi:10.1111/edt.12576.
9. von Arx T. Splinting of traumatized teeth with focus on adhesive techniques. *Journal of the California Dental Association*. 2005;33(5):409-416.
10. Ayhan E. Ön bölge dental travmalar ve tedavilerinde kullanılan fiksasyon yöntemlerinin klinik araştırması [Doktora tezi]. İzmir: Ege Üniversitesi Sağlık Bilimleri Enstitüsü; 1999.
11. Malmgren B, Andreasen JO, Flores MT, Robertson A, DiAngelis AJ, Andersson L, et al. International Association of Dental Traumatology guidelines for the management of traumatic dental injuries: 3. Injuries in the primary dentition. *Dental Traumatology*. 2012;28(3):174-182. doi:10.1111/j.1600-9657.2012.01146.x.
12. Trope M. Avulsion of permanent teeth: theory to practice. *Dental Traumatology*. 2011;27(4):281-294. doi:10.1111/j.1600-9657.2011.01003.x.
13. Andersson L, Andreasen JO, Day P, Heithersay G, Trope M, DiAngelis AJ, et al. International Association of Dental Traumatology guidelines for the management of traumatic dental injuries: 2. Avulsion of permanent teeth. *Dental Traumatology*. 2012;28(2):88-96. doi:10.1111/j.1600-9657.2012.01125.x.
14. Andreasen JO, Bakland LK, Flores MT, Andreasen FM, Andersson L. *Travmatik dental yaralanmalar el kitabı*. İstanbul: Elma Basım; 2014.
15. Pozzobon MH, de Sousa Vieira R, Alves AMH, Reyes-Carmona J, Teixeira CS, de Souza BDM, et al. Assessment of pulp blood flow in primary and permanent teeth using pulse oximetry. *Dental Traumatology*. 2011;27(3):184-188. doi:10.1111/j.1600-9657.2011.00976.x.
16. Andreasen JO, Lauridsen E, Gerds TA, Ahrensburg SS. Dental Trauma Guide: a source of evidence-based treatment guidelines for dental trauma. *Dental Traumatology*. 2012;28(5):345-350. doi:10.1111/j.1600-9657.2011.01059.x.
17. Robertson A, Andreasen FM, Andreasen JO, Noren JG. Long-term prognosis of crown-fractured permanent incisors: the effect of stage of root development and associated luxation

- injury. *International Journal of Paediatric Dentistry*. 2000;10(3):191-199. doi:10.1046/j.1365-263x.2000.00191.x.
18. Flores MT, Andersson L, Andreasen JO, Bakland LK, Malmgren B, Barnett F, et al. Guidelines for the management of traumatic dental injuries. I. Fractures and luxations of permanent teeth. *Endodontic Topics*. 2006;14(1):102-110. doi:10.1111/j.1600-9657.2007.00592.x.
 19. Keçeci AD. Sporcularda dental travma. *Egzersiz*. 2007;1(1):6-15.
 20. Andreasen JO. *Traumatic injuries of the teeth*. Copenhagen: Munksgaard; 1972.
 21. Kahler B, Hu JY, Marriot-Smith C, Heithersay G. Splinting of teeth following trauma: a review and a new splinting recommendation. *Australian Dental Journal*. 2016;61(Suppl1):59-73. doi:10.1111/adj.12398.
 22. Sevinç D. Çocuk diş hekimliğinde travma hastalarında kullanılan splint tipleri [Bitirme tezi]. İstanbul: İstanbul Üniversitesi; 2020.
 23. Altan H, Coşgun A. Çocuk diş hekimliğinde travma hastalarında kullanılan splint tipleri. *Atatürk Üniversitesi Diş Hekimliği Fakültesi Dergisi*. 2016;26(4):82-87.
 24. Filippi A, von Arx T, Lussi A. Comfort and discomfort of dental trauma splints: a comparison of a new device (TTS) with three commonly used splinting techniques. *Dental Traumatology*. 2002;18(5):275-280.
 25. Garg N, Garg A. *Textbook of endodontics*. Boydell & Brewer Ltd; 2010.
 26. Andreasen JO, Andreasen FM, Mejare I, Cvek M. Healing of 400 intra-alveolar root fractures. 2. Effect of treatment factors such as treatment delay, repositioning, splinting type and period and antibiotics. *Dental Traumatology*. 2004;20(4):203-211.
 27. Özbaş H, Öztürk E, Kocaelli H. Travmatik diş yaralanmalarında splint uygulamaları. *Journal of Istanbul University Faculty of Dentistry*. 41(4):45-50.
 28. Oikarinen K. Comparison of the flexibility of various splinting methods for tooth fixation. *International Journal of Oral and Maxillofacial Surgery*. 1988;17(2):125-127. doi:10.1016/S0901-5027(88)80166-8.
 29. King BJ, Christensen BJ. Hybrid arch bars reduce placement time and glove perforations compared with Erich arch bars during the application of intermaxillary fixation: a randomized controlled trial. *Journal of Oral and Maxillofacial Surgery*. 2019;77(6):1228.e1-1228.e8. doi:10.1016/j.joms.2019.01.030.
 30. Bathla S. *Periodontics revisited*. JP Medical Ltd; 2011.
 31. Zaim SB, Kahvecioğlu F. Evaluation of dental trauma splints in early permanent dentition through finite element analysis. *Applied Sciences*. 2025;15(19):10307. doi:10.3390/app151910307.
 32. Rao A, Rao A, Shenoy R. Splinting – when and how? *Dental Update*. 2011;38(5):341-346. doi:10.12968/denu.2011.38.5.341.
 33. Jacob J, Nandlal B. Bond strength of wire-composite resin interface of dental splints using different wire surface treatments: an in vitro study. *Endodontology*. 2003;15(1):2-6. doi:10.4103/0970-7212.351405.

BÖLÜM 23

ENDODONTİDE KÖK KANAL ANATOMİSİNİN HARİTASI:GELİŞİM, SINIFLANDIRMA VE KLİNİK VARYASYONLAR

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GİRİŞ

Endodontik tedavilerin prognozu, kök kanal sisteminin anatomik özelliklerinin doğru tanınması ve bu bilginin klinik uygulamaya etkin şekilde yansıtılmasına bağlıdır (1, 2). Kök kanal sistemi; kanal sayısı, konfigürasyonu ve apikal bölgedeki varyasyonlar açısından belirgin bir değişkenlik gösterir (1, 3).

Bu anatomik çeşitlilik, kanalın tespit edilememesi veya yetersiz temizlenmesi durumunda tedavi başarısızlığına yol açabilir; dolayısıyla kök kanal anatomisinin klinik olarak doğru değerlendirilmesi uzun dönem prognoz açısından kritik öneme sahiptir (3-5).

Kök kanal anatomisine ilişkin bilgiler uzun yıllar klasik radyografik yöntemler ve klinik gözlemler temelinde şekillenmiştir. Vertucci'nin tanımladığı kanal konfigürasyonları, morfolojinin sistematik olarak değerlendirilmesinde temel bir referans oluşturmuştur (1). Ancak iki boyutlu görüntüleme yöntemlerinin sınırlılıkları, kanal sisteminin üç boyutlu yapısını tam olarak ortaya koymayı güçleştirmiştir. Son yıllarda ileri görüntüleme yöntemlerinin kullanımının yaygınlaşmasıyla, kök kanal anatomisinin beklenenden daha karmaşık olduğu anlaşılmıştır (5, 6).

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KAYNAKLAR

1. Vertucci FJ. Root canal anatomy of the human permanent teeth. *Oral surgery, oral medicine, oral pathology*. 1984;58(5):589-99.
2. Hargreaves KM, Berman LH. *Cohen's Pathways of the Pulp*. 12th ed. St. Louis: Elsevier; 2021.
3. Vertucci FJ. Root canal morphology and its relationship to endodontic procedures. *Endodontic topics*. 2005;10(1):3-29.
4. Ng YL, Mann V, Rahbaran S, Lewsey J, Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature - part 1. Effects of study characteristics on probability of success. *Int Endod J*. 2007;40(12):921-39.
5. Patel S, Durack C, Abella F, Shemesh H, Roig M, Lemberg K. Cone beam computed tomography in endodontics—a review. *International endodontic journal*. 2015;48(1):3-15.
6. Versiani M, Pécora JD, Sousa-Neto MD. Microcomputed tomography analysis of the root canal morphology of single-rooted mandibular canines. *International Endodontic Journal*. 2013;46(9):800-7.
7. A N. Ten Cate's *Oral Histology: Development, Structure, and Function*. 9 ed. St. Louis: Elsevier; 2017.
8. Berkovitz BK, Holland GR, Moxham BJ. *Oral Anatomy, Histology and Embryology-E-Book*: Elsevier Health Sciences; 2024.
9. Ohshima H. Overview: developmental biology of Hertwig's epithelial root sheath (HERS) and tooth root formation. *Journal of oral biosciences*. 2008;50(3):147-53.
10. Zeichner-David M, Oishi K, Su Z, Zakartchenko V, Chen LS, Arzate H, et al. Role of Hertwig's epithelial root sheath cells in tooth root development. *Developmental dynamics: an official publication of the American Association of Anatomists*. 2003;228(4):651-63.
11. Karobari MI, Parveen A, Mirza MB, Makandar SD, Nik Abdul Ghani NR, Noorani TY, et al. Root and root canal morphology classification systems. *International Journal of Dentistry*. 2021;2021(1):6682189.
12. Weine FS, Healey HJ, Gerstein H, Evanson L. Canal configuration in the mesiobuccal root of the maxillary first molar and its endodontic significance. *Oral Surgery, Oral Medicine, Oral Pathology*. 1969;28(3):419-25.
13. Vertucci F, Seelig A, Gillis R. Root canal morphology of the human maxillary second premolar. *Oral Surgery, Oral Medicine, Oral Pathology*. 1974;38(3):456-64.
14. Ahmed H, Versiani M, De-Deus G, Dummer P. A new system for classifying root and root canal morphology. *International endodontic journal*. 2017;50(8):761-70.
15. Usha G, Muddappa SC, Venkitachalam R, Singh VPP, Rajan RR, Ravi AB. Variations in root canal morphology of permanent incisors and canines among Asian population: A systematic review and meta-analysis. *J Oral Biosci*. 2021;63(4):337-50.
16. Altunsoy M, Ok E, Nur BG, Aglarci OS, Gungor E, Colak M. A cone-beam computed tomography study of the root canal morphology of anterior teeth in a Turkish population. *Eur J Dent*. 2014;8(3):302-6.
17. Hülsmann M. Dens invaginatus: aetiology, classification, prevalence, diagnosis, and treatment considerations. *International endodontic journal*. 1997;30(2):79-90.
18. Al-kinani A, Al-Shameri B, Al-Hamzi MA, Al-kholani A, Alnesairy AM. Root and canal morphology of permanent maxillary and mandibular canines in a sample of Yemeni population using cone beam computed tomography. *J Clinical Research and Reports*. 2024;16(5):2690-1919.
19. Baybars SC, Yalçın D. Investigation of root canal morphologies of anterior and premolar teeth using cone beam computed tomography. *Ege Journal of Medicine*. 2024;63(2).
20. BÜYÜKBAYRAM İK, ELÇİN MA, AYDEMİR S, ÖZKALE C. Türk Popülasyonunda Üst ve Alt Kanin Dişlerinin Kök Kanal Morfolojilerinin Konik Işınlı Bilgisayarlı Tomografi ile İncelenmesi. *Türkiye Klinikleri Endodontics-Special Topics*. 2015;1(3):40-6.

21. Erkan E, Olcay K, Eyüboğlu TF, Şener E, Gündoğar M. Assessment of the canal anatomy of the premolar teeth in a selected Turkish population: a cone-beam computed tomography study. *BMC Oral Health*. 2023;23(1):403.
22. Watanabe S, Yabumoto S, Okiji T. Evaluation of root and root canal morphology in maxillary premolar teeth: A cone-beam computed tomography study using two classification systems in a Japanese population. *Journal of Dental Sciences*. 2025;20(2):927-35.
23. Chourasia HR, Odabi AI, Owis AA, Dahas ZA, Bokhari AM, Mashyakh M, et al. Evaluation of Root Canal Morphology of Maxillary Second Premolars and Its Relation to Maxillary Sinus in a Saudi Arabian Population. *J Contemp Dent Pract*. 2023;24(1):35-41.
24. Xu M, Ren H, Liu C, Zhao X, Li X. Systematic review and meta-analysis of root morphology and canal configuration of permanent premolars using cone-beam computed tomography. *BMC Oral Health*. 2024;24(1):656.
25. Cleghorn BM, Christie WH, Dong CC. Root and root canal morphology of the human permanent maxillary first molar: a literature review. *Journal of endodontics*. 2006;32(9):813-21.
26. Erkan E, Olcay K, Eyüboğlu TF, Şener E, Gündoğar M. Evaluation of root canal configuration of permanent maxillary molar teeth in a Turkish subpopulation: A cone-beam computed tomographic study. *Online Turkish Journal of Health Sciences*. 2023;8(1):89-95.
27. Altunsoy M, Ok E, Nur BG, Aglarci OS, Gungor E, Colak M. Root canal morphology analysis of maxillary permanent first and second molars in a southeastern Turkish population using cone-beam computed tomography. *Journal of Dental Sciences*. 2015;10(4):401-7.
28. Martins JNR, Marques D, Silva E, Caramês J, Mata A, Versiani MA. Second mesiobuccal root canal in maxillary molars-A systematic review and meta-analysis of prevalence studies using cone beam computed tomography. *Arch Oral Biol*. 2020;113:104589.
29. Razumova S, Brago A, Khaskhanova L, Barakat H, Howijeh A. Evaluation of anatomy and root canal morphology of the maxillary first molar using the cone-beam computed tomography among residents of the Moscow region. *Contemporary clinical dentistry*. 2018;9(Supp 1):S133-S6.
30. Asaad RT, Hamasaeed NH. Assessing The Prevalence of Anatomical Variations in Root Canals of Maxillary Molars and Premolars Using Cone Beam Computed Tomography in Erbil City: Retrospective CBCT Study. *Erbil Dental Journal (EDJ)*. 2025;8(2):119-27.
31. Kanyılmaz ANÇ, Okumuş Ö, Sunay H. Assessment of root canal anatomy of mandibular incisors using cone-beam computed tomography in a Turkish subpopulation: Root Canal Anatomy of Mandibular Incisors Using CBCT. *International Dental Research*. 2021;11(1):46-53.
32. Morphological evaluation of maxillary and mandibular canines using cone-beam computed tomography in Turkish population. *Annals of Medical Research*. 2021;26(10):2312-9.
33. Magat G, Uzun S. Evaluation of root and root canal morphology of mandibular and maxillary canine teeth in Turkish subpopulation by cone beam computed tomography with using two classification systems. *BMC Oral Health*. 2024;24(1):1499.
34. YİĞİT DH, CORA S, SİNANOĞLU A, GÜR C. Alt Çene Ön Grup Dişlerde Kök Kanal Morfolojisi ve Simetrisinin Konik Işınlı Bilgisayarlı Tomografi ile İncelenmesi: Retrospektif Bir Çalışma. *Türkiye Klinikleri Endodontics-Special Topics*. 2015;1(3):53-8.
35. Uğur Z, Akpınar KE, Altunbaş D. İKİ KÖK VE İKİ KANALA SAHİP MANDİBULAR KANİN: İKİ OLGU RAPORU. *Atatürk Üniversitesi Diş Hekimliği Fakültesi Dergisi*. 2018;28(2):245-8.
36. Ezentaş N, Özyürek EU. Root canal morphology of mandibular first and second premolars using cone-beam computed tomography in a selected Turkish-population and literature review. *Selcuk Dental Journal*. 2022;9(2):540-6.
37. Cleghorn BM, Christie WH, Dong CC. The root and root canal morphology of the human mandibular first premolar: a literature review. *Journal of endodontics*. 2007;33(5):509-16.
38. Kottoor J, Albuquerque D, Velmurugan N, Kuruvilla J. Root anatomy and root canal configuration of human permanent mandibular premolars: a systematic review. *Anatomy research international*. 2013;2013(1):254250.

39. Yu X, Guo B, Li K-Z, Zhang R, Tian Y-Y, Wang H. Cone-beam computed tomography study of root and canal morphology of mandibular premolars in a western Chinese population. *BMC medical imaging*. 2012;12(1):18.
40. Alghamdi FT, Khalil WA. Root canal morphology and symmetry of mandibular second premolars using cone-beam computed tomography. *Oral Radiology*. 2022;38(1):126-38.
41. Thanaruengrong P, Kulvitit S, Navachinda M, Charoenlarp P. Prevalence of complex root canal morphology in the mandibular first and second premolars in Thai population: CBCT analysis. *BMC oral health*. 2021;21(1):449.
42. Brea G, Gomez F, Gomez-Sosa JF. Cone-beam computed tomography evaluation of C-shaped root and canal morphology of mandibular premolars. *BMC Oral Health*. 2021;21(1):236.
43. Alazemi HS, Al-Nazhan SA, Aldosimani MA. Root and root canal morphology of permanent mandibular first and second molars in a Kuwaiti population: A retrospective cone-beam computed tomography study. *The Saudi Dental Journal*. 2023;35(4):345-53.
44. Wang D, Wang R, Xu H, Zhang Q, Guo Y. Prevalence and morphology of middle mesial canals in mandibular first molars and their relationship with anatomical aspects of the mesial root: a CBCT analysis. *BMC Oral Health*. 2025;25(1):147.
45. Pan JYY, Parolia A, Chuah SR, Bhatia S, Mutalik S, Pau A. Root canal morphology of permanent teeth in a Malaysian subpopulation using cone-beam computed tomography. *BMC oral health*. 2019;19(1):14.
46. Hargreaves KM BL. *Cohen's Pathways of the Pulp*. 12th ed. St. Louis: Elsevier; 2021.
47. Şendişçi Gök R, Tercanlı H, Ekinci A. Evaluation of root and canal morphology of mandibular molar teeth by cone beam computed tomography: cross-sectional study. *BMC Oral Health*. 2025;25(1):798.
48. Steinfort K, Chalub M, Gloria Mora C, Zaror C, Monardes H, Abarca J. Prevalence and Morphology of Extra-Roots in Mandibular Molars: A Cone-Beam Computed Tomography Study. *International Journal of Morphology*. 2024;42(6).
49. Al-Alawi H, Al-Nazhan S, Al-Maflehi N, Aldosimani MA, Zahid MN, Shihabi GN. The prevalence of radix molaris in the mandibular first molars of a Saudi subpopulation based on cone-beam computed tomography. *Restorative Dentistry & Endodontics*. 2019;45(1):e1-e.
50. Sella Tunis T, Sarne O, Hershkovitz I, Finkelstein T, Pavlidi AM, Shapira Y, et al. Dental anomalies' characteristics. *Diagnostics*. 2021;11(7):1161.
51. Park H, Hosomichi K, Kim Y-I, Hikita Y, Tajima A, Yamaguchi T. Comprehensive genetic exploration of fused teeth by whole exome sequencing. *Applied Sciences*. 2022;12(23):11899.
52. Özdemir A, Ocak MS. Determination of the Incidence and Types of Tooth Development Anomalies Using Cone Beam Computed Tomography. *Current Research in Dental Sciences*. 2025;35(4):295-9.
53. Jafarzadeh H, Azarpazhooh A, Mayhall J. Taurodontism: a review of the condition and endodontic treatment challenges. *International endodontic journal*. 2008;41(5):375-88.
54. Dineshshankar J, Sivakumar M, Balasubramaniam AM, Kesavan G, Karthikeyan M, Prasad VS. Taurodontism. *J Pharm Bioallied Sci*. 2014;6(Suppl 1):S13-5.
55. EYMİRLİ PS, KARAHAN S, ÖZYÜREK EU. Bir Grup Türk Çocuğunda Dental Anomalilerin Sıklığının Değerlendirilmesi: Retrospektif Çalışma. *Bezmialem Science*. 2025.

BÖLÜM 24

ENDODONTİK TEDAVİDE KULLANILAN AKTİVASYON YÖNTEMLERİ

Merve MUTLU ¹

1. MANUEL İRRİGASYON AKTİVASYON YÖNTEMLERİ

1.1. Geleneksel İğne İrrigasyonu (Gii)

İrrigasyon solüsyonunun, özel irrigasyon iğneleri vasıtasıyla kök kanal sistemine ulaştırıldığı bu dezenfeksiyon metodolojisinde; kanül kanal içerisine konumlandırılarak solüsyonun kontrollü bir biçimde zerk edilmesi esastır. Uygulama sırasında iğneye kazandırılan dikey (aşağı-yukarı) hareketler, solüsyonun kanal anatomisinde daha homojen bir dağılım sergilemesine olanak tanır (1). Bu dinamik manevra, iğnenin kanal içerisinde sıkışma (kilitlenme) riskini minimize ederek irrigantın apikal dokulara kontrolsüz taşmasını engeller; böylelikle kanal içi hidrodinamik aktivasyon süreci optimize edilir (2).

Yöntemin Klinik Parametreleri:

- Avantajlar:
 - Kanal içerisine sevk edilen solüsyon miktarının (hacminin) hassas bir şekilde tayin edilebilmesi.
 - İğne ucunun kanal içindeki penetrasyon derinliğinin klinisyen tarafından kolaylıkla denetim altında tutulabilmesi (3).
- Dezavantajlar:
 - İrrigasyon solüsyonunu aktive etme kapasitesinin sınırlı olması nedeniyle, debris ve mikroorganizmaların kanaldan tamamen uzaklaştırılmaması (3,4).
 - Solüsyonun, iğne ucunun ulaştığı noktadan itibaren yalnızca yaklaşık 1 mm ileriye penetre olabilmesi (5).

Endodontik irrigasyonda kullanılan iğneler, uç veya yan yüzeylerinde bulunan delik konfigürasyonlarına göre yapısal farklılıklar sergilemektedir (1). Literatür-

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oluşturan bu ikincil kabarcıklar dentinyüzeyine ulaştığında, yeni mikro kabarcıklar üreterek süpersonik hızlarda yayılım göstermeye devam etmektedir (43,44).

Erbium Yttrium Aluminium Garnet (Er:YAG, 2940 nm) ve Erbiyum, Krom: Yittriyum-Selenyum-Galyum-Garnet (Er,Cr:YSGG, 2780 nm) lazer sistemleri, su molekülleri tarafından en yüksek düzeyde absorbe edilme kapasitesine ve hidroksiapatit kristallerine karşı maksimum afiniteye (ilgiye) sahiptir. Sahip oldukları bu özgün optik özellikler neticesinde, söz konusu lazer türleri kök kanallarındaki irrigasyon solüsyonlarının aktivasyonunda yaygın bir kullanım alanına sahiptir (45).

GENTLEWAVE SİSTEMİ (SONENDO INC, LAGUNA HILLS, CA)

Kök kanal dezenfeksiyonu protokollerine 2014 yılında dahil edilen GentleWave sistemi, Amerika Birleşik Devletleri merkezli olarak literatüre tanıtılmıştır (46). Bu teknolojinin temel avantajı, cihaz ucunun doğrudan kök kanal girişine konumlandırılmasına gerek duyulmaksızın; yüksek akış hızları ve şiddetli kesme kuvvetleri aracılığıyla irrigasyon solüsyonunun tüm kanal sistemine efektif bir biçimde iletilmesini sağlamasıdır. Sistemin operasyonel mekanizması, multisonik aktivasyon ve bu süreci takip eden kavitasyon fenomenine dayanmaktadır. Meydana gelen kavitasyon, irrigasyon solüsyonu içerisinde akustik dalgaların oluşumunu tetikleyerek kanal anatomisinin derinlemesine temizlenmesine imkan tanır.

GentleWave sistemi, negatif basınçlı irrigasyon prensibiyle çalışarak solüsyonun apikal foramenden periapikal dokulara taşma (ekstrüzyon) riskini minimize etmektedir. Uygulama sırasında solüsyon 45 ml/dk'lık bir hızla dağıtılırken, eş zamanlı olarak fazla miktardaki irrigant sistemden uzaklaştırılmaktadır (47). Oluşan güçlü akustik akım, solüsyonun kök kanal sisteminin en karmaşık bölgelerine dahi nüfuz etmesini sağlar; bu sayede kanaldaki organik doku artıkları ve mikroorganizmalar yüksek etkinlikte elimine edilir (48).

KAYNAKLAR

1. Kahn FH, Rosenberg PA, Gliksberg J, 1995. An in vitro evaluation of the irrigating characteristics of ultrasonic and subsonic handpieces and irrigating needles and probes. J. Endod., 21, 5, 277-280.
2. Mamootil K ve Messer H, 2007. Penetration of dentinal tubules by endodontic sealer cements in extracted teeth and in vivo. Int. Endod. J., 40, 11, 873-881.
3. Van der Sluis L, Gambarini G, Wu M, Wesselink P, 2006. The influence of volume, type of irrigant and flushing method on removing artificially placed dentine debris from the apical root canal during passive ultrasonic irrigation. Int. Endod. J., 39, 6, 472-476.
3. Wu MK, Dummer P, Wesselink P, 2006. Consequences of and strategies to deal with residual

- post-treatment root canal infection. *Int. Endod. J.*, 39, 5, 343-356.
4. Wu MK ve Wesselink P, 2001. A primary observation on the preparation and obturation of oval canals. *Int. Endod. J.*, 34, 2, 137-141.
 5. Ram Z, 1977. Effectiveness of root canal irrigation. *Oral Surg. Oral Med. Oral Pathol.*, 44, 2, 306-312.
 6. Psimma Z, Boutsoukias C, Vasiliadis L, Kastrinakis E, 2013. A new method for real-time quantification of irrigant extrusion during root canal irrigation ex vivo. *Int. Endod. J.*, 46, 7, 619-631.
 7. Boutsoukias C, Verhaagen B, Versluis M, Kastrinakis E, Wesselink PR, van der Sluis LW, 2010. Evaluation of irrigant flow in the root canal using different needle types by an unsteady computational fluid dynamics model. *J. Endod.*, 36, 5, 875-879.
 8. Oswal P, Martand SS, Shenvi S, 2020. To Evaluate the Efficacy of New Brush Covered Irrigation Needle in Removing Root Canal Debris In Vitro: A Scanning Electron Microscopy Study. *International Journal of Dentistry and Oral Science*, 7, 12, 1211-1215.
 9. Al-Hadlaq SM, Al-Turaiki SA, Al-Sulami U, Saad AY, 2006. Efficacy of a new brushcovered irrigation needle in removing root canal debris: a scanning electron microscopic study. *J. Endod.*, 32, 12, 1181-1184.
 10. Gu L-s, Kim JR, Ling J, Choi KK, Pashley DH, Tay FR, 2009. Review of contemporary irrigant agitation techniques and devices. *J. Endod.*, 35, 6, 791-804.
 11. Keir DM, Senia ES, Montgomery S, 1990. Effectiveness of a brush in removing postinstrumentation canal debris. *J. Endod.*, 16, 7, 323-327.
 12. Jiang L-M, Lak B, Eijssvogels LM, Wesselink P, van der Sluis LW, 2012. Comparison of the cleaning efficacy of different final irrigation techniques. *J. Endod.*, 38, 6, 838-841.
 13. Andrabi SMUN, Kumar A, Mishra SK, Tewari RK, Alam S, Siddiqui S, 2013. Effect of manual dynamic activation on smear layer removal efficacy of ethylenediaminetetraacetic acid and SmearClear: an in vitro scanning electron microscopic study. *Aust. Endod. J.*, 39, 3, 131-136.
 14. Tay FR, Gu L-s, Schoeffel GJ, Wimmer C, Susin L, Zhang K ve ark. 2010. Effect of vapor lock on root canal debridement by using a side-vented needle for positive-pressure irrigant delivery. *J. Endod.*, 36, 4, 745-750.
 15. Setlock J, Fayad MI, BeGole E, Bruzick M, 2003. Evaluation of canal cleanliness and smear layer removal after the use of the Quantec-E irrigation system and syringe: a comparative scanning electron microscope study. *Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod.*, 96, 5, 614-617.
 16. Hof R, Perevalov V, Eltanani M, Zary R, Metzger Z, 2010. The self-adjusting file (SAF). Part 2: mechanical analysis. *J. Endod.*, 36, 4, 691-696.
 17. Metzger Z, Teperovich E, Zary R, Cohen R, Hof R, 2010. The self-adjusting file (SAF). Part 1: respecting the root canal anatomy—a new concept of endodontic files and its implementation. *J. Endod.*, 36, 4, 679-690.
 18. Metzger Z, Solomonov M, Kfir A, 2013. The role of mechanical instrumentation in the cleaning of root canals. *Endodontic Topics*, 29, 1, 87-109.
 19. Vaz-Garcia ES, Vieira VTL, Petitet NPdSF, Moreira EJJ, Lopes HP, Elias CN ve ark. 2018. Mechanical properties of anatomic finishing files: XP-Endo Finisher and XP-Clean. *Braz. Dent. J.*, 29, 2, 208-213.
 20. Sağlam BC, Hazar E, Koçak MM, Koçak S, Türker SA, 2021. The Cleaning Efficacy of Passive Ultrasonic Irrigation and XP-Endo Finisher After Post Space Preparation.
 21. FKG Dentaire SA, 2016. XP-endo Finisher file brochure.
 22. Ragul P, Dhanraj M, Jain AR, 2018. Irrigation technique used in cleaning and shaping during endodontic treatment-A review. *Drug Invent. Today*, 10, 5, 739-743.
 23. Hülsmann M, Peters OA, Dummer PM, 2005. Mechanical preparation of root canals: shaping goals, techniques and means. *Endodontic Topics*, 10, 1, 30-76.
 24. Weller RN, Brady JM, Bernier WE, 1980. Efficacy of ultrasonic cleaning. *J. Endod.*, 6, 9, 740-743.

25. Souza CC, Bueno CE, Kato AS, Limoeiro AG, Fontana CE, Pelegrine RA, 2019. Efficacy of passive ultrasonic irrigation, continuous ultrasonic irrigation versus irrigation with reciprocating activation device in penetration into main and simulated lateral canals. *J. Conserv. Dent. Endod.*, 22, 2, 155-159.
26. Lee B-S, Lin C-P, Hung Y-L, Lan W-H, 2004. Structural changes of Er: YAG laser- irradiated human dentin. *Photomed. Laser Ther.*, 22, 4, 330-334.
27. Van der Sluis L, Versluis M, Wu M, Wesselink P, 2007. Passive ultrasonic irrigation of the root canal: a review of the literature. *International Endodontic Journal*, 40, 6, 415-426.
2. Tronstad L, Barnett F, Schwartzben L, Frasca P, 1985. Effectiveness and safety of a sonic vibratory endodontic instrument. *Dent. Traumatol.*, 1, 2, 69-76.
29. Ahmad M, Ford TRP, Crum LA, 1987. Ultrasonic debridement of root canals: an insight into the mechanisms involved. *J. Endod.*, 13, 3, 93-101.
30. Kanter V, Weldon E, Nair U, Varella C, Kanter K, Anusavice K ve ark. 2011. A quantitative and qualitative analysis of ultrasonic versus sonic endodontic systems on canal cleanliness and obturation. *Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod.*, 112, 6, 809-813.
31. Rödiger T, Bozkurt M, Konietzschke F, Hülsmann M, 2010. Comparison of the Vibringe system with syringe and passive ultrasonic irrigation in removing debris from simulated root canal irregularities. *J. Endod.*, 36, 8, 1410-1413.
32. Plotino G, Grande NM, Mercade M, Cortese T, Staffoli S, Gambarini G ve ark. 2019. Efficacy of sonic and ultrasonic irrigation devices in the removal of debris from canal irregularities in artificial root canals. *J. Appl. Oral Sci.*, 27.
33. Conde A, Estevez R, Loroño G, Valencia de Pablo Ó, Rossi-Fedele G, Cisneros R, 2017. Effect of sonic and ultrasonic activation on organic tissue dissolution from simulated grooves in root canals using sodium hypochlorite and EDTA. *Int. Endod. J.*, 50, 10, 976-982.
34. Neuhaus KW, Liebi M, Stauffacher S, Eick S, Lussi A, 2016. Antibacterial efficacy of a new sonic irrigation device for root canal disinfection. *J. Endod.*, 42, 12, 1799-1803.
35. Urban K, Donnermeyer D, Schäfer E, Bürklein S, 2017. Canal cleanliness using different irrigation activation systems: a SEM evaluation. *Clin. Oral Investig.*, 21, 2681-2687.
36. Toljan I, Bago I, Anić I, 2016. Eradication of intracanal *Enterococcus faecalis* biofilm by passive ultrasonic irrigation and RinsEndo system. *Acta Stomatologica Croatica*, 50, 1, 14.
37. Vivan RR, Bortolo MV, Duarte MAH, Moraes IGd, Tanomaru-Filho M, Bramante CM, 2010. Scanning electron microscopy analysis of RinsEndo system and conventional irrigation for debris removal. *Brazilian Dental Journal*, 21, 305-309.
38. Adorno C, Fretes V, Ortiz C, Mereles R, Sosa V, Yubero M ve ark. 2016. Comparison of two negative pressure systems and syringe irrigation for root canal irrigation: an ex vivo study. *Int. Endod. J.*, 49, 2, 174-183.
39. Boutsoukis C, Psimma Z, Van der Sluis L, 2013. Factors affecting irrigant extrusion during root canal irrigation: a systematic review. *Int. Endod. J.*, 46, 7, 599-618.
- Haapasalo M, Shen Y, Qian W, Gao Y, 2010. Irrigation in endodontics. *Br. Dent. J.*, 216, 6, 299-303.
40. Kimura Y, Wilder-Smith P, Matsumoto K, 2000. Lasers in endodontics: a review. *Int. Endod. J.*, 33, 3, 173-185.
41. Matsumoto H, Yoshimine Y, Akamine A, 2011. Visualization of irrigant flow and cavitation induced by Er: YAG laser within a root canal model. *J. Endod.*, 37, 6, 839-843.
42. Schoop U, Moritz A, Kluger W, Patruta S, Goharkhay K, Sperr W ve ark. 2002. The Er: YAG laser in endodontics: results of an in vitro study. *Lasers Surg. Med.*, 30, 5, 360-364.
43. Blanken J, De Moor RJG, Meire M, Verdaasdonk R, 2009. Laser induced explosive vapor and cavitation resulting in effective irrigation of the root canal. Part 1: a visualization study. *Lasers Surg. Med.*, 41, 7, 514-519.
44. Su Z, Li Z, Shen Y, Bai Y, Zheng Y, Pan C ve ark. 2021. Characteristics of the Irrigant flow in a simulated Lateral Canal under two typical laser-activated irrigation regimens. *Lasers Surg.*

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- Med., 53, 4, 587-594.
45. Yavari HR, Rahimi S, Shahi S, Lotfi M, Barhaghi MH, Fatemi A ve ark. 2010. Effect of Er, Cr: YSGG laser irradiation on *Enterococcus faecalis* in infected root canals. *Photomed. Laser Surg.*, 28, S1, S-91-S-96.
 46. Haapasalo M, Wang Z, Shen Y, Curtis A, Patel P, Khakpour M, 2014. Tissue dissolution by a novel multisonic ultracleaning system and sodium hypochlorite. *J. Endod.*, 40, 8, 1178-1181.
 47. Akcay M, Arslan H, Durmus N, Mese M, Capar ID, 2016. Dentinal tubule penetration of AH Plus, iRoot SP, MTA fillapex, and guttaflow bioseal root canal sealers after different final irrigation procedures: A confocal microscopic study. *Lasers Surg. Med.*, 48, 1, 70-76.
 48. Coaguila-Llerena H, Gaeta E, Faria G, 2022. Outcomes of the GentleWave system on root canal treatment: a narrative review. *Restor. Dent. Endod.*, 47, 1.

BÖLÜM 25

ENDODONTİK CERRAHİDE GÜNCEL DURUM DEĞERLENDİRMESİ VE GELECEĞE BAKIŞ

Emine ŞİMŞEK ¹

GİRİŞ

Endodontik cerrahi, diş hekimliğinde köklü bir geçmişe sahip bir uygulama alanıdır. Apikal cerrahiye ilişkin ilk kavramlar 19. yüzyılın sonları ile 20. yüzyılın başlarında çeşitli klinisyenler tarafından ortaya koyulmaktadır. Bu dönemde apikal cerrahide temel amaç, apeksin nekrotik kısmının uzaklaştırılması ve hastalıklı periapikal dokuların eksizyonudur (1). Ancak bu yaklaşımlar, kök kanalı içerisindeki (intraradiküler) enfeksiyonun varlığını yeterince dikkate alınmamaktadır (2). Kök ucu rezeksiyonu, Partsch (3, 4) ile Faulhaber ve Neumann'ın (5) yayımları sonrasında daha fazla ilgi görmektedir. Bu erken dönem uygulamalarının ardından, endodontik cerrahi tekniklerinde farklı düzeylerde kabul gören ve değişken başarı oranlarına sahip çok sayıda modifikasyon ve gelişim süreci yaşandı. Uzun yıllar boyunca osteotomi ve kök ucu rezeksiyonu için cerrahi frezler kullanılmaktadır. Kök ucu dolgu materyali olarak ise amalgam tercih edilmektedir (6). Bununla birlikte, kök kanal tedavisi ve cerrahi olmayan yeniden tedavi (retreatment) yöntemlerindeki ilerlemeler sonrasında, düşük başarı oranları bildiren bazı klinik çalışmalar nedeniyle endodontik cerrahinin gerekliliği tartışılmaktadır (7). Bu düşük başarı oranlarının, cerrahi girişim sonrasında intra- ve/veya ekstraradiküler enfeksiyonun devam etmesiyle ilişkili olduğu düşünülmektedir.

Endodontik cerrahinin modern uygulamaları, yüksek büyütme ve güçlü aydınlatma sağlayan cerrahi operasyon mikroskopları veya büyütme gözlüklerinin (loupe) kullanımıyla daha hassas hâle gelmektedir. Ayrıca ultrasonik kök ucu preparasyonu ve kalsiyum silikat esaslı simanlarla yapılan kök ucu dolguları sayesinde önceki dönemlerde karşılaşılan birçok sorunun büyük ölçüde üstesinden gelinmektedir. (8).

Başarılı bir cerrahi yaklaşım için öncelikle doğru tanı ve uygun vaka seçimi esastır. Gerekli durumlarda retreatment tedavisi ile kombine edilmesi tedavinin

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matik segmentasyonu (52) ve mandibular sinir kanalının belirlenmesi (53) yer almaktadır. Ayrıca derin öğrenme teknikleri kullanılarak kistik periapikal lezyonlar ile granülomların ayırıcı tanısına yönelik çalışmalar da yapılmaktadır (54).

Yakın gelecekte rehberli cerrahi tekniklerin yapay zekâ tabanlı uygulamalarla entegre edilmesi muhtemeldir. Yapay zekâ, cerrahi gerekliliğin değerlendirilmesinde (kist-granülom ayrımı), cerrahinin uygulanabilirliğinin belirlenmesinde (örneğin kırık tespiti) ve cerrahi rehberlerin üretimine yönelik otomatik planlama desteğinde (lezyon konumu, mandibular kanal, diğer anatomik yapılar ve diş segmentasyonu) yardımcı olabilir. Bu gelişmeler nihayetinde, implantolojide ilk örnekleri görülen robotik cerrahi uygulamalarının endodontik mikrocerrahide de geliştirilmesi ve uygulanması ile sonuçlanabilir (55, 56).

SONUÇ

Endodontik cerrahi, köklü bir geçmişe sahip olup araştırma alanındaki gelişmeler ve klinik uygulamalardaki ilerlemeler doğrultusunda sürekli bir evrim süreci içerisinde. Günümüzde ulaşılan aşama olan endodontik mikrocerrahi, hem kısa hem de uzun dönem sonuçlar açısından yüksek başarı oranları ile etkinliğini kanıtlamaktadır.

Gelişmiş teknik donanım, yüksek büyütme sağlayan optik sistemler, ultrasonik preparasyon yöntemleri ve biyouyumlu modern dolgu materyalleri; endodontik cerrahiyi, özellikle endodonti alanında uzmanlaşmış klinisyenler için standart bir tedavi yaklaşımı hâline getirmektedir.

Endodontik cerrahinin geleceği ise yeni biyomateryaller, rejeneratif yaklaşımlar, dijital planlama ve rehberli cerrahi teknikler gibi yeniliklerle şekillenmektedir. Bu gelişmeler, minimal invaziv prensipler doğrultusunda daha öngörülebilir, biyolojik olarak daha uyumlu ve hasta konforunu artıran uygulamaların önünü açmaktadır. Tüm bu ilerlemeler, endodontik cerrahinin gelecekte de dinamik ve gelişmeye açık bir alan olmaya devam edeceğini göstermektedir.

KAYNAKLAR

1. Setzer FC, Karabucak B. Surgical endodontics. Essential Endodontology: Prevention and Treatment of Apical Periodontitis. 2019:345-85.
2. Regan J, Gutmann J, Witherspoon D. Comparison of Diaket and MTA when used as root-end filling materials to support regeneration of the periradicular tissues. *International endodontic journal*. 2002;35(10): 840-847.
3. Partsch C. Drifter Bericht der Poliklinik für Zahn-und Mundkrankheiten des zahnärztlichen Instituts der Königl. *Universität Breslau Dtsch Monatschr Zahnheilkd*. 1896;14:486-499.
4. Partsch C, Kunert A. Über Wurzelspitzenresection. *Deutsche Monatszeitschrift für Zahnheilkunde*. 1898;16:80-86.

5. Faulhaber B, Neumann R. *Die chirurgische Behandlung der Wurzelkrankungen*. Berlin: Hermann Meusser; 1912; p. 19.
6. Oginni AO, Olusile AO. Follow-up study of apicectomised anterior teeth. *South African Dental Journal*. 2002;57(4):136-140.
7. Frank AL, Glick DH, Patterson SS, Weine FS. Long-term evaluation of surgically placed amalgam fillings. *Journal of Endodontics*. 1992;18(8):391-398.
8. Kim S, Kratchman S. Modern endodontic surgery concepts and practice: a review. *Journal of endodontics*. 2006;32(7):601-623.
9. Setzer FC, Hinckley N, Kohli MR, Karabucak B. A survey of cone-beam computed tomographic use among endodontic practitioners in the United States. *Journal of endodontics*. 2017;43(5):699-704.
10. Menezes RFd, Araújo NCd, Santa Rosa JMC, Carneiro VSM, Santos Neto APd, Costa V, et al. Detection of vertical root fractures in endodontically treated teeth in the absence and in the presence of metal post by cone-beam computed tomography. *BMC Oral Health*. 2016;16(1):48.
11. Bornstein MM, Lauber R, Sendi P, Von Arx T. Comparison of periapical radiography and limited cone-beam computed tomography in mandibular molars for analysis of anatomical landmarks before apical surgery. *Journal of endodontics*. 2011;37(2):151-157.
12. Mitsis F. Flap operation techniques for the treatment of certain endodontic and periodontic problems. *International Endodontic Journal*. 1970;4(1):6-9.
13. von Arx T, Salvi GE. Incision techniques and flap designs for apical surgery in the anterior maxilla. *European Journal of Esthetic Dentistry*. 2008;3(2):110-122
14. Jang J, Kwak S, Ha J, Kim H. Anatomical relationship of maxillary posterior teeth with the sinus floor and buccal cortex. *Journal of oral rehabilitation*. 2017;44(8):617-625.
15. Rubinstein RA, Kim S. Short-term observation of the results of endodontic surgery with the use of a surgical operation microscope and Super-EBA as root-end filling material. *Journal of Endodontics*. 1999;25(1):43-48.
16. Lin L, Chen MY-H, Ricucci D, Rosenberg PA. Guided tissue regeneration in periapical surgery. *Journal of Endodontics*. 2010;36(4):618-625.
17. Nesari R, Kratchman S, Saad M, Kohli MR. Selective curettage: a conservative microsurgical approach to treating large and complicated lesions. *Journal of endodontics*. 2020;46(11):1782-1790.
18. Kim S, Pecora G, Rubinstein R. Comparison of traditional and microsurgery in endodontics. In: Kim S, Pecora G, Rubinstein R, editors. *Color Atlas of Microsurgery in Endodontics*. Philadelphia: W.B. Saunders; 2001. p. 5-11.
19. Gutmann JL, Harrison JW. Posterior endodontic surgery: anatomical considerations and clinical techniques. *International Endodontic Journal*. 1985;18(1):8-34.
20. Gilheany PA, Figdor D, Tyas MJ. Apical dentin permeability and microleakage associated with root end resection and retrograde filling. *Journal of Endodontics*. 1994;20(1):22-26.
21. Mannocci F, Peru M, Sherriff M, Cook R, Pitt Ford T. The isthmuses of the mesial root of mandibular molars: a micro-computed tomographic study. *International Endodontic Journal*. 2005;38(8):558-563.
22. Shovelton D. The presence and distribution of micro-organisms within non-vital teeth. *British Dental Journal*. 1964;117:101-107.
23. Carr GB, Bentkover S. Surgical endodontics. *Pathways of the pulp*. 1994;6:531-567.
24. Sultan M, Ford TP. Ultrasonic preparation and obturation of root-end cavities. *International Endodontic Journal*. 1995;28(5):231-238.
25. Layton CA, Marshall JG, Morgan LA, Baumgartner JC. Evaluation of cracks associated with ultrasonic root-end preparation. *Journal of endodontics*. 1996;22(4):157-160.
26. Beling KL, Marshall JG, Morgan LA, Baumgartner JC. Evaluation of cracks associated with ultrasonic root-end preparation of gutta-percha filled canals. *Journal of endodontics*. 1997;23(5):323-326.

27. Stropko JJ, Doyon GE, Gutmann JL. Root-end management: resection, cavity preparation, and material placement. *Endodontic Topics*. 2005;11(1):131-151.
28. Chong BS, Pitt Ford TR. Root-end filling materials: rationale and tissue response. *Endodontic topics*. 2005;11(1):114-130.
29. Shinbori N, Grama AM, Patel Y, Woodmansey K, He J. Clinical outcome of endodontic microsurgery that uses EndoSequence BC root repair material as the root-end filling material. *Journal of endodontics*. 2015;41(5):607-612.
30. Bortoluzzi EA, Niu L-n, Palani CD, El-Awady AR, Hammond BD, Pei D-d, et al. Cytotoxicity and osteogenic potential of silicate calcium cements as potential protective materials for pulpal revascularization. *Dental Materials*. 2015;31(12):1510-1522.
31. Collado-González M, García-Bernal D, Oñate-Sánchez RE, Ortolani-Seltenerich PS, Álvarez-Muro T, Lozano A, et al. Cytotoxicity and bioactivity of various pulpotomy materials on stem cells from human exfoliated primary teeth. *International endodontic journal*. 2017;50:e19-e30.
32. Degerliyurt K, Akar V, Denizci S, Yucel E. Bone lid technique with piezosurgery to preserve inferior alveolar nerve. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*. 2009;108(6):e1-e5.
33. Lee S-M, Yu Y-H, Wang Y, Kim E, Kim S. The application of “bone window” technique in endodontic microsurgery. *Journal of endodontics*. 2020;46(6):872-880.
34. Hirsch V, Kohli MR, Kim S. Apicoectomy of maxillary anterior teeth through a piezoelectric bony-window osteotomy: two case reports introducing a new technique to preserve cortical bone. *Restorative Dentistry & Endodontics*. 2016;41(4):310-315.
35. Pappalardo S, Guarnieri R. Randomized clinical study comparing piezosurgery and conventional rotatory surgery in mandibular cyst enucleation. *Journal of Cranio-Maxillofacial Surgery*. 2014;42(5):e80-e85.
36. Horton J. The healing of surgical defects in alveolar bone produced with ultrasonic instrumentation, chisel, and rotary bur. *Plastic and Reconstructive Surgery*. 1976;57(2):257.
37. Maurer P, Kriwalsky MS, Block Veras R, Brandt J, Heiss C. Auflichtmikroskopische Untersuchungen an der Kaninchenkalotte nach ultraschallgestützter und konventioneller Osteotomie [Light microscopic examination of rabbit skulls following conventional and piezosurgery osteotomy]. *Biomedizinische Technik*. 2007;52:351-355.
38. Bharathi J, Mittal S, Tewari S, Tewari S, Duhan J, Sangwan P, et al. Effect of the piezoelectric device on intraoperative hemorrhage control and quality of life after endodontic microsurgery: a randomized clinical study. *Journal of Endodontics*. 2021;47(7):1052-1060.
39. Schloss T, Sonntag D, Kohli MR, Setzer FC. A comparison of 2- and 3-dimensional healing assessment after endodontic surgery using cone-beam computed tomographic volumes or periapical radiographs. *Journal of Endodontics*. 2017;43(7):1072-1079.
40. Safi C, Kohli MR, Kratchman SI, Setzer FC, Karabucak B. Outcome of endodontic microsurgery using mineral trioxide aggregate or root repair material as root-end filling material: a randomized controlled trial with cone-beam computed tomographic evaluation. *Journal of Endodontics*. 2019;45(7):831-839.
41. von Arx T, Steiner RG, Tay F. Apical surgery: endoscopic findings at the resection level of 168 consecutively treated roots. *International endodontic journal*. 2011;44(4):290-302.
42. Curtis DM, VanderWeele RA, Ray JJ, Wealleans JA. Clinician-centered outcomes assessment of retreatment and endodontic microsurgery using cone-beam computed tomographic volumetric analysis. *Journal of Endodontics*. 2018;44(8):1251-1256.
43. Scarfe WC, Levin MD, Gane D, Farman AG. Use of cone beam computed tomography in endodontics. *International Journal of Dentistry*. 2009;1:1-20.
44. Strbac GD, Schnappauf A, Giannis K, Moritz A, Ulm C. Guided modern endodontic surgery: a novel approach for guided osteotomy and root resection. *Journal of Endodontics*. 2017;43(3):496-501.
45. Ahn S-Y, Kim N-H, Kim S, Karabucak B, Kim E. Computer-aided design/computer-aided ma-

- nufacturing-guided endodontic surgery: guided osteotomy and apex localization in a mandibular molar with a thick buccal bone plate. *Journal of Endodontics*. 2018;44(4):665-670.
46. Giacomino CM, Ray JJ, Wealleans JA. Targeted endodontic microsurgery: a novel approach to anatomically challenging scenarios using 3-dimensional-printed guides and trephine burs—a report of 3 cases. *Journal of Endodontics*. 2018;44(4):671-677.
 47. Ray JJ, Giacomino CM, Wealleans JA, Sheridan RR. Targeted endodontic microsurgery: digital workflow options. *Journal of endodontics*. 2020;46(6):863-871.
 48. Smith BG, Pratt AM, Anderson JA, Ray JJ. Targeted endodontic microsurgery: implications of the greater palatine artery. *Journal of Endodontics*. 2021;47(1):19-27.
 49. Dianat O, Nosrat A, Mostoufi B, Price J, Gupta S, Martinho F. Accuracy and efficiency of guided root-end resection using a dynamic navigation system: a human cadaver study. *International endodontic journal*. 2021;54(5):793-801.
 50. Orhan K, Bayrakdar I, Ezhov M, Kravtsov A, Özyürek T. Evaluation of artificial intelligence for detecting periapical pathosis on cone-beam computed tomography scans. *International endodontic journal*. 2020;53(5):680-689.
 51. Shah H, Hernandez P, Budin F, Chittajallu D, Vimort JB, Walters R, et al. Automatic quantification framework to detect cracks in teeth. *Proceedings of the Society of Photo-Optical Instrumentation Engineers*. 2018;10578:105781K.
 52. Lahoud P, EzEldeen M, Beznik T, Willems H, Leite A, Van Gerven A, et al. Artificial intelligence for fast and accurate 3-dimensional tooth segmentation on cone-beam computed tomography. *Journal of Endodontics*. 2021;47(5):827-835.
 53. Kwak GH, Kwak E-J, Song JM, Park HR, Jung Y-H, Cho B-H, et al. Automatic mandibular canal detection using a deep convolutional neural network. *Scientific Reports*. 2020;10(1):5711.
 54. Okada K, Rysavy S, Flores A, Linguraru MG. Noninvasive differential diagnosis of dental periapical lesions in cone-beam CT scans. *Medical physics*. 2015;42(4):1653-1665.
 55. Haidar ZS. Autonomous robotics: A fresh era of implant dentistry... is a reality! *Oral Research*. 2017;6:230-231.
 56. Wu Y, Wang F, Fan S, Chow J. Robotics in Dental Implantology. *Oral and Maxillofacial Surgery Clinics of North America*. 2019;31(3):513-518.

BÖLÜM 26

ENDODONTİDE LAZER KULLANIMI: TEMEL PRENSİPLER, KLİNİK UYGULAMALAR VE GÜNCEL YAKLAŞIMLAR

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GİRİŞ

Modern diş hekimliği, geleneksel tedavi yöntemlerinin sınırlamalarını aşmak ve tedavi başarısını artırmak amacıyla sürekli olarak yeni teknolojileri tedavilere entegre etme arayışındadır. Bu teknolojilerin başında, yaklaşık 1990'lı yıllardan itibaren popülerlik kazanan ve günümüzde sert dokuya yönelik uygulamalar, yumuşak dokuya yönelik uygulamalar, kök kanal tedavisi ve ağrı yönetimi gibi çok çeşitli alanlarda kullanılan lazerler gelmektedir (1). Light Amplification by the Stimulated Emission of Radiation (Uyarılmış Radyasyon Emisyonu ile Işığın Güçlendirilmesi) kelimelerinin baş harflerinden oluşan LASER, modern endodontide sadece bir yardımcı araç olmaktan çıkıp, dezenfeksiyon, smear tabakasının uzaklaştırılması, rejeneratif prosedürler ve post-operatif ağrı kontrolü gibi kritik aşamalarda merkezi bir rol oynamaya başlamıştır (2). Lazerler, hem yumuşak dokuda hem de diş ve kemik gibi sert dokularda etkili olması, dokuya doğrudan temas etmemesi, titreşime neden olmaması, kanama ya da ağrı olmadan hızlı ve etkili tedavi olanağı sunması nedeniyle diş hekimliğinin birçok alanında da kullanılmaktadır (3).

Endodontik tedavinin temel amacı, kök kanal sistemindeki patojen mikroorganizmaları ortadan kaldırmak ve periapikal iyileşmeyi sağlamaktır (4). Ancak kök kanal sisteminin anatomik karmaşıklığı —istmuslar, yan kanallar ve apikal deltalar— geleneksel kemo-mekanik preparasyon yöntemlerinin etkinliğini sınırlamaktadır (5). Geleneksel iğne irrigasyonu ve mekanik egeleme karmaşık anatomik bölgelerde biyofilmleri tamamen ortadan kaldırmakta sıklıkla yetersiz

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KAYNAKLAR

1. Sachelarie L, Cristea R, Burlui E, et al. Laser technology in dentistry: from clinical applications to future innovations. *Dentistry journal*. 2024;12(12):420. <https://doi.org/10.3390/dj12120420>
2. Alharbi KH, AlMarwani WT, Alsulami RA, et al. New Insight Into Laser Applications in Endodontic Dentistry: A Comprehensive Review. *Australian Endodontic Journal*. 2025;51(2):527-535. <https://doi.org/10.1111/aej.12959>
3. Coluzzi, D.J. and R.A. Convissar, 2 - *Laser Fundamentals*, in *Principles and Practice of Laser Dentistry*. 2011, Mosby: Saint Louis. p. 12-26.
4. Nammour S, El Mobadder M, Namour M, et al. Success Rate of Direct Pulp Capping with Conventional Procedures Using Ca (OH)₂ and Bioactive Tricalcium Silicate Paste vs. Laser-Assisted Procedures (Diode 980 nm, CO₂, and Er: YAG). *Photonics*. 2023;10(7):834. <https://doi.org/10.3390/photonics10070834>
5. Huang D, Wang X, Liang J, et al. Expert consensus on difficulty assessment of endodontic therapy. *International Journal of Oral Science*. 2024;16(1):22. <https://doi.org/10.1038/s41368-024-00285-0>
6. Meire M, De Moor RJ. Principle and antimicrobial efficacy of laser-activated irrigation: A narrative review. *International Endodontic Journal*. 2024;57(7):841-860. <https://doi.org/10.1111/iej.14042>
7. Stenhoff S, Mills J. Basic principles of lasers. *Anaesthesia & Intensive Care Medicine*. 2024;25(2), 133-137.
8. Diaci J, Gaspiric B. Comparison of Er: YAG and Er, Cr: YSGG lasers used in dentistry. *J laser health Acad*. 2012;1(1):1-13.
9. Ribeiro L, Fischer B, Vitali F, et al. Advances in laser-assisted regenerative endodontic procedures: a scoping review. *Journal of Dentistry*. 2025;158:105783. <https://doi.org/10.1016/j.jdent.2025.105783>
10. Vogel, A. and V. Venugopalan, *Mechanisms of pulsed laser ablation of biological tissues*. Chem Rev, 2003. **103**(2): p. 577-644. <https://doi.org/10.1021/cr010379n>
11. Bordea I, Hanna R, Chiniforush N, et al. Evaluation of the outcome of various laser therapy applications in root canal disinfection: A systematic review. *Photodiagnosis and photodynamic therapy*, 2020;29:101611. <https://doi.org/10.1016/j.pdpdt.2019.101611>
12. De Moor RJG, Meire M, Goharkhay K, Moritz A, Vanobbergen J. Efficacy of ultrasonic versus laser-activated irrigation to remove artificially placed dentin debris plugs. *Journal of endodontics*. 2010;36(9):1580-3. <https://doi.org/10.1016/j.joen.2010.06.007>
13. Cheng X, Wang X, Liu N, et al. Effect of various laser-activated irrigation protocols on endodontic sealer penetration into the dentinal tubules: A confocal laser scanning microscopy study. *Photobiomodulation, Photomedicine, and Laser Surgery*. 2021;39(8):544-9. <https://doi.org/10.1089/photob.2020.4924>
14. Trindade AC, De Figueiredo JAP, Steier L, Weber JBB. Photodynamic Therapy in Endodontics: A Literature Review. *Photomedicine and laser surgery*. 2015;33(3):175-82. <https://doi.org/10.1089/pho.2014.3776>
15. Matsumoto H, Yoshimine Y, Akamine, A. Visualization of irrigant flow and cavitation induced by Er: YAG laser within a root canal model. *Journal of endodontics*. 2011; 37(6):839-843. <https://doi.org/10.1016/j.joen.2011.02.035>
16. Swimberghe RCD, Tzourmanas R, De Moor RJ, et al. Explaining the working mechanism of laser-activated irrigation and its action on microbial biofilms: a high-speed imaging study. *International Endodontic Journal*. 2022;55(12):1372-1384. <https://doi.org/10.1111/iej.13824>
17. Koch JD, Jaramillo DE, DiVito E, et al. Irrigant flow during photon-induced photoacoustic streaming (PIPS) using Particle Image Velocimetry (PIV). *Clinical oral investigations*. 2016;20(2):381-386. <https://doi.org/10.1007/s00784-015-1562-9>
18. Gregorčič B, Jezeršek M, Možina J. Optodynamic energy-conversion efficiency during an Er:

- YAG-laser-pulse delivery into a liquid through different fiber-tip geometries. *Journal of biomedical optics*. 2012;17(7):075006-075006. <https://doi.org/10.1117/1.JBO.17.7.075006>
19. Lukač N, Jezeršek M. Amplification of pressure waves in laser-assisted endodontics with synchronized delivery of Er: YAG laser pulses. *Lasers in medical science*. 2018;33(4):823-833. <https://doi.org/10.1007/s10103-017-2435-z>
 20. Jezeršek M, Lukač N, Lukač M. Measurement of simulated debris removal rates in an artificial root canal to optimize laser-activated irrigation parameters. *Lasers in Surgery and Medicine*. 2021;53(3):411-417. <https://doi.org/10.1002/lsm.23297>
 21. Peters O, Bardsley S, Fong J, et al. Disinfection of root canals with photon-initiated photoacoustic streaming. *Journal of endodontics*. 2011;37(7):1008-1012. <https://doi.org/10.1016/j.joen.2011.03.016>
 22. Badami V, Akarapu S, Kethineni H, et al. Efficacy of laser-activated irrigation versus ultrasonic-activated irrigation: a systematic review. *Cureus*. 2023;15(3):e36352. <https://doi.org/10.7759/cureus.36352>
 23. Peeters HH, De Moor RJG, Suharto D. Visualization of removal of trapped air from the apical region in simulated root canals by laser-activated irrigation using an Er,Cr:YSGG laser. *Lasers in Medical Science*. 2015;30(6):1683-1688. <https://doi.org/10.1007/s10103-014-1643-z>
 24. Violich DR, Purton DG, Chandler NP, Monteith BD. Effect of the smear layer on a pulp proximity-indicating instrument. *Odontology*. 2012;100(1):47-53. <https://doi.org/10.1007/s10266-011-0014-5>
 25. George S, Kishen A, Song P. The role of environmental changes on monospecies biofilm formation on root canal wall by *Enterococcus faecalis*. *Journal of endodontics*. 2005;31(12):867-872. <https://doi.org/10.1097/01.don.0000164855.98346.fc>
 26. Botero T, Chrepa V, Shrestha A, et al. Web-Based Survey on Regenerative Endodontic Practices among Members of the American Association of Endodontists. *Journal of endodontics*. 2024;50(9):1281-1288. <https://doi.org/10.1016/j.joen.2024.05.016>
 27. Kolberg-Babrzyńska I, Grzech-Leśniak K, Kiryk J. Effects of endodontic retreatment by conventional therapy compared to combined therapy with an Er: YAG laser and photobiomodulation: A randomized clinical trial. *Dental and Medical Problems*. 2025; 26. <https://doi.org/10.17219/dmp/188864>
 28. Pandey P, Jasarasia N, Bharti R, et al. Clinical, radiographic, and biomarker perspectives of low-level laser therapy during regenerative endodontic procedures in necrotic immature young teeth: a randomized clinical study. *Lasers in Medical Science*. 2025;40(1):504. <https://doi.org/10.1007/s10103-025-04764-6>
 29. Ismail H, Obeid M, Hassanien E. Efficiency of diode laser in control of post-endodontic pain: a randomized controlled trial. *Clinical Oral Investigations*. 2023;27(6):2797-2804. <https://doi.org/10.1007/s00784-023-04864-z>

BÖLÜM 27

ENDODONTİDE KANAL TEDAVİSİNİN TEKNİK KALİTESİNİN DEĞERLENDİRİLME KRİTERLERİ VE PROGNOZ ÜZERİNE ETKİSİ

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GİRİŞ

Endodontik tedavinin başarısı; etkin bir kemomekanik preparasyon ile kök kanal sistemindeki biyofilmin uzaklaştırılması, temizlenen kanalın biyoyoumlu bir materyalle 3 boyutlu olarak doldurulması ve sızdırmaz bir koronal restorasyon ile ilişkilidir.

Avrupa Endodonti Derneği (ESE) kalite kılavuzlarında; uygun endikasyonun belirlenmesi, aseptik koşulların sağlanması (rubber dam kullanımı dahil), çalışma boyunun doğru saptanması, sızdırmaz bir obturasyon yapılması ve nitelikli bir koronal restorasyonun gerçekleştirilmesi, “kaliteli endodontik tedavi”nin vazgeçilmez unsurları olarak tanımlanmaktadır.[1]

Kök kanal tedavisinin teknik kalitesinin tedavi sonrası hastalık gelişimi üzerinde büyük ölçüde etkili olduğu bilinmektedir. Teknik kalite; apikal sonlanım, dolgu yoğunluğu ve homojenitesi, kanal konikliği, işlem sırasında oluşabilecek hatalar ve koronal sızdırmazlık gibi unsurları kapsamaktadır. Literatürde, özellikle preoperatif periapikal lezyon varlığında, apikalde 0–2 mm içinde boşluksuz bir kanal dolgusu yapılması, tüm kanalların tedavi edilmesi (gözden kaçan kanal olmaması) ve nitelikli bir koronal restorasyonun uygulanmasının prognozu anlamlı ölçüde artırdığı vurgulanmaktadır[2]. Başarısının değerlendirilmesinde standartlaştırılmış Periapikal İndeks (PAI) kullanımı ve gerektiğinde CBCT'nin eklenmesi, tanısal duyarlılığı yükseltmektedir[3].

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KAYNAKLAR

1. Endodontology, E.S.o., *Quality guidelines for endodontic treatment: consensus report of the European Society of Endodontology*. International endodontic journal, 2006. **39**(12): p. 921-930.
2. Ng, Y.L., et al., *Outcome of primary root canal treatment: systematic review of the literature -- Part 2. Influence of clinical factors*. Int Endod J, 2008. **41**(1): p. 6-31.
3. Patel, S., et al., *European Society of Endodontology position statement: Use of cone beam computed tomography in Endodontics: European Society of Endodontology (ESE) developed by*. Int Endod J, 2019. **52**(12): p. 1675-1678.
4. Moussa-Badran, S., et al., *Technical quality of root fillings performed by dental students at the dental teaching centre in Reims, France*. International Endodontic Journal, 2008. **41**(8): p. 679-684.
5. Renner, D., et al., *Influence of pulp condition on the accuracy of an electronic foramen locator in posterior teeth: an in vivo study*. Brazilian oral research, 2012. **26**: p. 106-111.
6. Ricucci, D. and K. Langeland, *Apical limit of root canal instrumentation and obturation, part 2. A histological study*. Int Endod J, 1998. **31**(6): p. 394-409.
7. Polyzos, N.K., et al., *Factors Affecting the Outcome of Non-Surgical Endodontic Treatments Performed by Undergraduate Students in a Greek Dental School*. Eur Endod J, 2018. **3**(2): p. 93-100.
8. Sjogren, U., et al., *Factors affecting the long-term results of endodontic treatment*. J Endod, 1990. **16**(10): p. 498-504.
9. Jurič, R., et al., *Factors associated with the outcome of root canal treatment-A cohort study conducted in a private practice*. Int Endod J, 2024. **57**(4): p. 377-393.
10. Park, D.M., W.H. Seok, and J.Y. Yoon, *Factors Influencing Non-Surgical Root Canal Treatment Outcomes in Mandibular Second Molars: A Retrospective Cone-Beam Computed Tomography Analysis*. J Clin Med, 2024. **13**(10).
11. Schilder, H., *Cleaning and shaping the root canal*. Dental clinics of north America, 1974. **18**(2): p. 269-296.
12. Ng, Y.L., V. Mann, and K. Gulabivala, *A prospective study of the factors affecting outcomes of nonsurgical root canal treatment: part 1: periapical health*. International endodontic journal, 2011. **44**(7): p. 583-609.
13. Hülsmann, M., *Endodontide problemler: etiyoloji, tanı ve tedavi*. 2014: Quintessence Yayıncılık.
14. Alhadainy, H.A., *Root perforations: a review of literature*. Oral surgery, oral medicine, oral pathology, 1994. **78**(3): p. 368-374.
15. da Silva, P.Z., et al., *Radiographic evaluation of root canal treatment performed by undergraduate students, part I; iatrogenic errors*. Iranian endodontic journal, 2018. **13**(1): p. 30.
16. Lambrianidis, T., *Ledging and blockage of root canals during canal preparation: causes, recognition, prevention, management, and outcomes*. Endodontic Topics, 2006. **15**(1): p. 56-74.
17. Gulabivala, K. and Y.L. Ng, *Factors that affect the outcomes of root canal treatment and retreatment—A reframing of the principles*. International Endodontic Journal, 2023. **56**: p. 82-115.
18. Gillen, B.M., et al., *Impact of the quality of coronal restoration versus the quality of root canal fillings on success of root canal treatment: a systematic review and meta-analysis*. J Endod, 2011. **37**(7): p. 895-902.
19. Torabinejad, M., B. Ung, and J.D. Kettering, *In vitro bacterial penetration of coronally unsealed endodontically treated teeth*. Journal of endodontics, 1990. **16**(12): p. 566-569.
20. Alaçam, T., *Endodonti*. 1990: Gazi Üniversitesi Basın Yayın Yüksek Okulu Basımevi.
21. Wong, R., *Conventional endodontic failure and retreatment*. Dental Clinics, 2004. **48**(1): p. 265-289.
22. Kabak, Y. and P. Abbott, *Prevalence of apical periodontitis and the quality of endodontic treatment in an adult Belarusian population*. International endodontic journal, 2005. **38**(4): p. 238-245.
23. Sunay, H., et al., *Cross-sectional evaluation of the periapical status and quality of root canal treat-*

- ment in a selected population of urban Turkish adults. *International Endodontic Journal*, 2007. **40**(2): p. 139-145.
24. Burry, J.C., et al., *Outcomes of primary endodontic therapy provided by endodontic specialists compared with other providers*. *Journal of endodontics*, 2016. **42**(5): p. 702-705.
 25. Rhodes, J.S., *Advanced endodontics: clinical retreatment and surgery*. 2005: CRC Press.
 26. Burke, F., et al., *Technical quality of root canal fillings performed in a dental school and the associated retention of root-filled teeth: a clinical follow-up study over a 5-year period*. *Journal of oral rehabilitation*, 2009. **36**(7): p. 508-515.
 27. Burns, L.E., et al., *Outcomes of primary root canal therapy: An updated systematic review of longitudinal clinical studies published between 2003 and 2020*. *Int Endod J*, 2022. **55**(7): p. 714-731.
 28. Lin, L.M., J.E. Skribner, and P. Gaengler, *Factors associated with endodontic treatment failures*. *Journal of endodontics*, 1992. **18**(12): p. 625-627.
 29. WU, M.K. and P.R. Wesselink, *Timeliness and effectiveness in the surgical management of persistent post-treatment periapical pathosis*. *Endodontic Topics*, 2005. **11**(1): p. 25-31.
 30. Tabassum, S. and F.R. Khan, *Failure of endodontic treatment: The usual suspects*. *European journal of dentistry*, 2016. **10**(01): p. 144-147.
 31. Ricucci, D., L.M. Lin, and L.S. Spångberg, *Wound healing of apical tissues after root canal therapy: a long-term clinical, radiographic, and histopathologic observation study*. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*, 2009. **108**(4): p. 609-621.
 32. Orstavik, D., *Essential endodontology: prevention and treatment of apical periodontitis*. 2020: John Wiley & Sons.
 33. Huuonen, S. and D. Ørstavik, *Radiological aspects of apical periodontitis*. *Endodontic topics*, 2002. **1**(1): p. 3-25.
 34. Ng, Y.L., et al., *Outcome of primary root canal treatment: systematic review of the literature—part 1. Effects of study characteristics on probability of success*. *International endodontic journal*, 2007. **40**(12): p. 921-939.
 35. Orstavik, D., K. Kerekes, and H.M. Eriksen, *The periapical index: a scoring system for radiographic assessment of apical periodontitis*. *Endod Dent Traumatol*, 1986. **2**(1): p. 20-34.
 36. Ørstavik, D., K. Kerekes, and H.M. Eriksen, *The periapical index: a scoring system for radiographic assessment of apical periodontitis*. *Dental Traumatology*, 1986. **2**(1): p. 20-34.
 37. Wu, M.K., H. Shemesh, and P. Wesselink, *Limitations of previously published systematic reviews evaluating the outcome of endodontic treatment*. *International endodontic journal*, 2009. **42**(8): p. 656-666.
 38. Lofthag-Hansen, S., et al., *Limited cone-beam CT and intraoral radiography for the diagnosis of periapical pathology*. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*, 2007. **103**(1): p. 114-119.
 39. Çıkman, A.Ş., et al., *Evaluation of endodontically treated teeth and related apical periodontitis using periapical and endodontic status scale: Retrospective cone-beam computed tomography study*. 2022.
 40. Bender, I., S. Seltzer, and W. Soltanoff, *Endodontic success—A reappraisal of criteria: Part I*. *Oral surgery, oral medicine, oral pathology*, 1966. **22**(6): p. 780-789.
 41. Prada, I., et al., *Influence of microbiology on endodontic failure. Literature review*. *Medicina oral, patologia oral y cirugía bucal*, 2019. **24**(3): p. e364.
 42. De Moor, R., et al., *Undergraduate curriculum guidelines for endodontology*. *International endodontic journal*, 2013. **46**(12): p. 1105-1114.
 43. Nair, P., et al., *Microbial status of apical root canal system of human mandibular first molars with primary apical periodontitis after “one-visit” endodontic treatment*. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*, 2005. **99**(2): p. 231-252.
 44. Chandra, A., *Discuss the factors that affect the outcome of endodontic treatment*. *Australian Endodontic Journal*, 2009. **35**(2): p. 98-107.
 45. Kojima, K., et al., *Success rate of endodontic treatment of teeth with vital and nonvital pulps*. *A*

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- meta-analysis*. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology, 2004. **97**(1): p. 95-99.
46. Schaeffer, M.A., R.R. White, and R.E. Walton, *Determining the optimal obturation length: a meta-analysis of literature*. Journal of endodontics, 2005. **31**(4): p. 271-274.
 47. Unal, G.C., et al., *Quality of root canal fillings performed by undergraduate dental students*. European Journal of Dentistry, 2011. **5**(03): p. 324-330.
 48. Ribeiro, D., et al., *Technical quality of root canal treatment performed by undergraduate students using hand instrumentation: a meta-analysis*. International Endodontic Journal, 2018. **51**(3): p. 269-283.
 49. Chakravarthy, P.V.K. and J.R.K. Moorthy, *Radiographic assessment of quality of root fillings performed by undergraduate students in a Malaysian Dental School*. Saudi Endodontic Journal, 2013. **3**(2): p. 77-81.
 50. Karabucak, B., et al., *Prevalence of Apical Periodontitis in Endodontically Treated Premolars and Molars with Untreated Canal: A Cone-beam Computed Tomography Study*. J Endod, 2016. **42**(4): p. 538-41.
 51. Costa, F., et al., *Association between missed canals and apical periodontitis*. Int Endod J, 2019. **52**(4): p. 400-406.
 52. Lin, L.M., P.A. Rosenberg, and J. Lin, *Do procedural errors cause endodontic treatment failure?* The Journal of the American Dental Association, 2005. **136**(2): p. 187-193.
 53. Spili, P., P. Parashos, and H.H. Messer, *The impact of instrument fracture on outcome of endodontic treatment*. J Endod, 2005. **31**(12): p. 845-50.
 54. McGuigan, M.B., C. Louca, and H.F. Duncan, *The impact of fractured endodontic instruments on treatment outcome*. Br Dent J, 2013. **214**(6): p. 285-9.
 55. Ricucci, D. and J.F. Siqueira Jr, *Biofilms and apical periodontitis: study of prevalence and association with clinical and histopathologic findings*. Journal of endodontics, 2010. **36**(8): p. 1277-1288.
 56. Sen, B., B. Piskin, and T. Demirci, *Observation of bacteria and fungi in infected root canals and dentinal tubules by SEM*. Dental Traumatology, 1995. **11**(1): p. 6-9.
 57. Oguntebi, B., *Dentine tubule infection and endodontic therapy implications*. International Endodontic Journal, 1994. **27**(4): p. 218-222.
 58. Baugh, D. and J. Wallace, *The role of apical instrumentation in root canal treatment: a review of the literature*. Journal of endodontics, 2005. **31**(5): p. 333-340.
 59. Yared, G.M. and F.E.B. Dagher, *Influence of apical enlargement on bacterial infection during treatment of apical periodontitis*. Journal of endodontics, 1994. **20**(11): p. 535-537.
 60. Card, S.J., et al., *The effectiveness of increased apical enlargement in reducing intracanal bacteria*. Journal of Endodontics, 2002. **28**(11): p. 779-783.
 61. Aminoshariae, A. and J. Kulild, *Master apical file size—smaller or larger: a systematic review of healing outcomes*. International Endodontic Journal, 2015. **48**(7): p. 639-647.

BÖLÜM 28

ENDODONTİDE ALET KIRIĞI KOMPLİKASYONU: SEBEPLER, KLİNİK YÖNETİMİ VE PROGNOZ

Nilgün BULUT¹

GİRİŞ

Endodontide Mekanik Preparasyonun Önemi

Endodontik başarı; kanalın doldurulmasının yanı sıra etkili bir temizlik, şekillendirme ve dezenfeksiyona bağlıdır. İşte bu noktada, kök kanalını üç boyutlu olarak hazırlayan ve irriganların etkinliğini artıran mekanik preparasyon devreye girer (1, 2). Kanal morfolojisinin karmaşıklığı, özellikle lateral kanallar, isthmus alanları ve apikal dallanmalar gibi anatomik varyasyonlar, preparasyonun etkinliğini doğrudan etkilemektedir. Anatomik faktörler, preparasyonun başarısını belirleyen başlıca unsurlar arasında yer alır; bu sebeple modern preparasyon teknikleri hem konik form yaratmayı hem de orijinal kanal anatomisini korumayı hedefler (1).

Modern endodontik yaklaşımlar, mekanik preparasyonun sadece kanal içeriğini uzaklaştırmakla kalmayıp aynı zamanda kanalın gövde ve apikal bölümünde uygun bir koniklik ve hacim oluşturarak irrigasyon ve obturasyonu optimize ettiğini vurgulamaktadır (3-5). Mekanik aletlerin evölüsyonu, özellikle NiTi döner ege sistemlerinin geliştirilmesi sayesinde, preparasyon daha hızlı, daha kontrollü ve klinik hatalara daha az eğilimli hale gelmiştir (3).

Mekanik preparasyonun başarıları aynı zamanda dezenfeksiyon etkinliğini artırarak periapikal iyileşme oranlarını yükseltir. Uygun mekanik preparasyon sayesinde irrigasyon solüsyonları kanal terminusuna daha etkili ulaşabilir ve böylece bakteriyel yükü azaltarak apikal periodontitisin iyileşmesine katkı sağlar (1). 2025 tarihli bir derleme, güncel biyomekanik preparasyon tekniklerinin endodontik hastalıkla baş etmede daha iyi güvenilirlik ve öngörülebilirlik sunduğunu bildirmiştir. Bu teknikler, kanal boşluğunun genişliğini ve formunu kontrol ederek hem irrigasyon etkinliğini hem de obturasyonun kalitesini artırır (5).

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karma işlemleri sırasında uygulanan protokolün dentin kaybı, perforasyon ve stres dağılımı gibi yönlerden prognostik riskler taşıdığını göstermektedir (51).

Bu nedenle klinik karar verme sürecinde: kanal anatomisi, kırık aletin lokalizasyonu, çıkarma tekniklerinin risk-fayda analizi, dezenfeksiyon ve sızdırmazlık hedefleri birlikte değerlendirilmelidir. Modern protokoller ve teknolojiye rağmen alet kırığı tamamen önlenemese de etkili önleme ve doğru komplikasyon yönetimi tedavi başarısını artırır.

KAYNAKLAR

1. Sousa-Neto MD, Silva-Sousa YC, Mazzi-Chaves JF, et al. Root canal preparation using micro-computed tomography analysis: a literature review. *Brazilian Oral Research*. 2018;32:e66. doi:10.1590/1807-3107bor-2018.vol32.0066
2. Versiani MA, Martins J, Ordinola-Zapata R. Anatomical complexities affecting root canal preparation: a narrative review. *Australian Dental Journal*. 2023;68(suppl 1):S5-S23. doi:10.1111/adj.12998
3. Tomson PL, Adams N, Kavanagh D, Virdee SS. Non-surgical endodontics: contemporary biomechanical preparation of the root canal system. *British Dental Journal*. 2025;238(7):478-486.
4. Ginjeira A, Baruwa AO, Baumotte K. Evaluation and comparison of manual and mechanical endodontic instrumentation completed by undergraduate dental students on endodontic blocks. *Dentistry Journal*. 2024;12(11):363. doi:10.3390/dj12110363
5. dos Santos LLR, Busarello JA, de Lima Rodrigues E. Instrumentação mecanizada dos canais radiculares: uma revisão de literatura. *Research, Society and Development*. 2023;12(4):e18012440916.
6. Pedullà E, Benites A, La Rosa GM, et al. Cyclic fatigue resistance of heat-treated nickel-titanium instruments after immersion in sodium hypochlorite and/or sterilization. *Journal of Endodontics*. 2018;44(4):648-653.
7. Generali L, Puddu P, Borghi A, et al. Mechanical properties and metallurgical features of new and ex vivo used Reciproc Blue and Reciproc. *International Endodontic Journal*. 2020;53(2):250-264. doi:10.1111/iej.13214
8. Schäfer E, Bürklein S, Donnermeyer D. A critical analysis of research methods and experimental models to study the physical properties of NiTi instruments and their fracture characteristics. *International Endodontic Journal*. 2022;55(suppl 1):72-94.
9. Sjögren U, Hägglund B, Sundqvist G, Wing K. Factors affecting the long-term results of endodontic treatment. *Journal of Endodontics*. 1990;16(10):498-504. doi:10.1016/S0099-2399(07)80180-4
10. Panitvisai P, Parunnit P, Sathorn C, Messer HH. Impact of a retained instrument on treatment outcome: a systematic review and meta-analysis. *Journal of Endodontics*. 2010;36(5):775-780. doi:10.1016/j.joen.2009.12.029
11. Hülsmann M, Schinkel I. Influence of several factors on the success or failure of removal of fractured instruments from the root canal. *Endodontics & Dental Traumatology*. 1999;15(6):252-258.
12. McGuigan MB, Louca C, Duncan HF. The impact of fractured endodontic instruments on treatment outcome. *British Dental Journal*. 2013;214(6):285-289.
13. Dioguardi M, Dello Russo C, Scarano F, et al. Analysis of endodontic successes and failures in the removal of fractured endodontic instruments during retreatment: a systematic review, meta-analysis, and trial sequential analysis. *Healthcare*. 2024;12(21):2180.
14. Eskibağlar M, Özata MY, Ocak MS, Öztekin F. Investigation of fracture prevalence of instruments used in root canal treatments at a faculty of dentistry: a prospective study. *Restorative*

- Dentistry & Endodontics*. 2023;48(4):e35.
15. Khosravi MR, Banafshi Z, Ebrahimi R, Jalali R. Exploring dentists' experiences of endodontic file fracture during root canal treatment: a phenomenological study. *BMC Oral Health*. 2025;25:963.
 16. Schäfer E, Dammaschke T. Development and sequelae of canal transportation. *Endodontic Topics*. 2006;15(1):75-90.
 17. Walia HM, Brantley WA, Gerstein H. An initial investigation of the bending and torsional properties of Nitinol root canal files. *Journal of Endodontics*. 1988;14(7):346-351.
 18. Zupanc J, Vahdat-Pajouh N, Schäfer E. New thermomechanically treated NiTi alloys – a review. *International Endodontic Journal*. 2018;51(10):1088-1103. doi:10.1111/iej.12924
 19. Plotino G, Grande NM, Bellido MM, Testarelli L, Gambarini G. Influence of temperature on cyclic fatigue resistance of ProTaper Gold and ProTaper Universal rotary files. *Journal of Endodontics*. 2017;43(2):200-202.
 20. Staffoli S, Grande NM, Plotino G, et al. Influence of environmental temperature, heat-treatment and design on the cyclic fatigue resistance of three generations of a single-file nickel-titanium rotary instrument. *Odontology*. 2019;107(3):301-307.
 21. Kasuga Y, Kimura S, Maki K, et al. Phase transformation and mechanical properties of heat-treated nickel-titanium rotary endodontic instruments at room and body temperatures. *BMC Oral Health*. 2023;23(1):825.
 22. Kimura S, Ebihara A, Maki K, et al. Phase transformation behavior and mechanical properties of HyFlex EDM nickel-titanium endodontic rotary instrument: evaluation at body temperature. *Journal of Dental Sciences*. 2024;19(2):929-936.
 23. Yi Gi TE, Cetinkaya I. Effect of temperature on the cyclic fatigue resistance and phase transformation behavior of three different NiTi endodontic instruments. *Cureus*. 2024;16(1):e52916. doi:10.7759/cureus.52916
 24. Yum HW, Oh S, Perinpanayagam H, et al. Phase transformation and mechanical behaviour of different heat-treated nickel-titanium rotary instruments. *International Dental Journal*. 2025;75(2):1183-1193.
 25. Ahmed HMA. A critical analysis of laboratory and clinical research methods to study root and canal anatomy. *International Endodontic Journal*. 2022;55:229-280.
 26. Silva E, Pinto K, Ferreira C, et al. Methodologic concerns regarding the evidence of a higher prevalence of apical periodontitis and endodontic treatment need in tobacco smokers. *International Endodontic Journal*. 2020;53(12):1744-1747.
 27. Azim AA, Tarrosh M, Azim KA, Piasecki L. Comparison between single-file rotary systems: part 2—the effect of length of the instrument subjected to cyclic loading on cyclic fatigue resistance. *Journal of Endodontics*. 2018;44(12):1837-1842.
 28. Pedullà E, Canova FS, La Rosa GRM, et al. Influence of NiTi wire diameter on cyclic and torsional fatigue resistance of different heat-treated endodontic instruments. *Materials*. 2022;15(19):6649.
 29. Abdellatif D, Iandolo A, Scorziello M, Sangiovanni G, Pisano M. Cyclic fatigue of different Ni-Ti endodontic rotary file alloys: a comprehensive review. *Bioengineering*. 2024;11(5):499. doi:10.3390/bioengineering11050499
 30. Moreira EJJ, Antunes HDS, Vieira VTL, et al. Effects of clinical use of NiTi reciprocating instruments on cyclic and torsional resistance, and on roughness. *Brazilian Oral Research*. 2021;35:e021. doi:10.1590/1807-3107bor-2021.vol35.0021
 31. Karas B, Kotela A, Laszczynska M, et al. Effect of endodontic irrigants on the cyclic fatigue resistance of nickel-titanium rotary instruments: a systematic review. *Materials*. 2025;18(17):3924.
 32. De-Deus G, Silva EJ, Vieira VT, et al. Blue thermomechanical treatment optimizes fatigue resistance and flexibility of the Reciproc files. *Journal of Endodontics*. 2017;43(3):462-466.
 33. Yildiz T, Zan R. Comparative evaluation of the cyclic fatigue resistance of four Ni-Ti instruments in simulated root canal curvatures using CAD/CAM technology. *BMC Oral Health*.

- 2025;25(1):1366.
34. Alsunboli MH, Ihsan SSA, Sabah DQ. The effect of canal curvature on cyclic fatigue resistance of rotary instruments using different irrigation materials (in vitro study). *F1000Research*. 2023;12:449.
 35. Pessoa OF, da Silva JM, Gavini G. Cyclic fatigue resistance of rotary NiTi instruments after simulated clinical use in curved root canals. *Brazilian Dental Journal*. 2013;24(2):117-120.
 36. Ertugrul IF, Arslan HK. Investigation of four nickel titanium endodontic instruments, with cyclic fatigue resistance, scanning electron microscopy, and energy dispersive x-ray spectroscopy. *Microscopy Research and Technique*. 2024;87(11):2801-2807.
 37. Patel S, Brown J, Semper M, Abella F, Mannocci F. European Society of Endodontology position statement: use of cone beam computed tomography in Endodontics. *International Endodontic Journal*. 2019;52(12):1675-1678.
 38. AAE and AAOMR Joint Position Statement. Use of cone beam computed tomography in endodontics 2015 update. *Journal of Endodontics*. 2015;41(9):1393-1396. doi:10.1016/j.joen.2015.07.013
 39. Aminsobhani M, Hashemi N, Hamidzadeh F, Sarraf P. Broken instrument removal methods with a minireview of the literature. *Case Reports in Dentistry*. 2024;2024:9665987. doi:10.1155/2024/9665987
 40. Portela NN, Rech JP, Marchionatti AME, Barasuol JC. Techniques to address fractured instruments in the middle or apical third of the root canal in human permanent teeth: a systematic review of the in vitro studies. *Clinical Oral Investigations*. 2022;26(1):131-139.
 41. Lakshmaiah D, Raj Kumar J, Sakthi N, Karunakaran J, Vishwanath S. The management of fractured dental instruments: a case series. *Cureus*. 2023;15(11):e49132. doi:10.7759/cureus.49132
 42. Sunde PT, Giving E, Dilshad T, Handal T, Ørstavik D. Radiographic outcome of endodontic treatment of teeth with primary apical periodontitis: results from a postgraduate clinic. *Dentistry Journal*. 2025;13(12):366.
 43. Morfini M. Articular status of haemophilia patients with inhibitors. *Haemophilia*. 2008;14(suppl 6):20-22.
 44. Mathew S, Yaw-Chyn L, Kishen A. Immunogenic potential of *Enterococcus faecalis* biofilm under simulated growth conditions. *Journal of Endodontics*. 2010;36(5):832-836.
 45. Kaufman B, Spångberg L, Barry J, Fouad AF. *Enterococcus* spp. in endodontically treated teeth with and without periradicular lesions. *Journal of Endodontics*. 2005;31(12):851-856.
 46. Miller S, Deller S, Stallmann J. Rural exposure to pension reductions. *Choices*. 2018;33(1).
 47. Susila A, Minu J. Activated irrigation vs. conventional non-activated irrigation in endodontics - a systematic review. *European Endodontic Journal*. 2019;4(3):96-110.
 48. Spili P, Parashos P, Messer HH. The impact of instrument fracture on outcome of endodontic treatment. *Journal of Endodontics*. 2005;31(12):845-850.
 49. Argilés A, Mourad G, Lorho R, et al. Medical treatment of severe hyperparathyroidism and its influence on anaemia in end-stage renal failure. *Nephrology Dialysis Transplantation*. 1994;9(12):1809-1812.
 50. Wang Y, Tu KC, Ong NP, Bassler BL, Wingreen NS. Protein-level fluctuation correlation at the microcolony level and its application to the *Vibrio harveyi* quorum-sensing circuit. *Biophysical Journal*. 2011;100(12):3045-3053.
 51. Amza O, Dimitriu B, Suci I, Bartok R, Chirila M. Etiology and prevention of an endodontic iatrogenic event: instrument fracture. *Journal of Medicine and Life*. 2020;13(3):378-381.
 52. Lup VM, Malvicini G, Gaeta C, Grandini S, Ciavoi G. Glide path in endodontics: a literature review of current knowledge. *Dentistry Journal*. 2024;12(8):234.