BÖLÜM 4

TEKRARLAYAN KÖK KANAL TEDAVİLERİNDE ANTİMİKROBİYAL YAKLAŞIM

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GİRİŞ

Endodonti literatüründe endodontik tedavi "başarısızlığının" birçok nedeni vardır. Bunlar arasında; hatalı giriş kavite tasarımı, ulaşılamamış kanallar (hem ana hem de aksesuar), yetersiz temizleme ve iyi doldurulmamış kanallar, enstrümantasyon komplikasyonları (basamak oluşumu, perforasyonlar veya kırık aletler) ve kök kanal dolgusunun taşkın olması gibi iyatrojenik prosedür hataları bulunur (1).

Amerikan Endodontistler Birliği (AAE), ilk işlem sırasında tedavi edilememiş dar veya eğimli kanallar, fark edilemeyen kompleks kanal anatomisi, endodontik tedaviyi takiben restorasyonunun geciktirilmesi ve iyi yapılmamış izolasyon gibi durumların kök kanal tedavisi yapılmasına rağmen beklendiği gibi iyileşmeyen dişler için gözden kaçan noktalar olduğunu belirtmişlerdir. AAE'nin klinik endodontiye yönelik olan rehberine göre, aşağıdaki klinik durumlardan herhangi biri mevcutsa tekrarlayan kök kanal tedavisinin endike olduğu bildirilmiştir (2):

- Semptomlarla birlikte devam eden periradiküler patoloji
- Kök kanal dolgu kalitesinde radyografik olarak gözlenen yetersizlik (eşlik eden periradiküler patoloji veya semptomlar varlığında)
- Kalıcı semptomların varlığı
- Mevcut kök kanal dolgusunu riske atabilecek restoratif veya protetik işlemlerin planlanması
- Önceki tedavi kalitesinin şüpheli olduğu bir dişte restoratif veya protetik işlemlerin planlanması
- Tükürük kontaminasyonu gibi kök kanal sistemine bakteri sızıntısı şüphesi olması

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DOI: 10.37609/akya.3813.c703

oluşan mikroswarmlar, 3 boyutlu helikoid robotlar, helikal silika nanorobotlar üzerinde çalışılan farklı mikrorobotlardır. Mikrorobotikteki ilerlemelerin, karmaşık kök kanal sistemi boyunca biyofilm kaynaklı enfeksiyonların teşhis ve tedavi edilmesi için daha önce hayal bile edilemeyen olanaklar sunduğu bildirilmiştir. Tıbbi mikrorobotik alanı hızla gelişmektedir ve gelecekteki gelişmelerin, kök kanal sistemi içerisinde ilaç taşıma, dezenfeksiyon ve doku rejenerasyonu için hassas yönlendirmeli endodontik mikrorobotlara odaklanması beklenmektedir.

SONUÇ

Primer apikal periodontitis gibi, tedavi sonrası apikal periodontitis; intraradiküler ve bazen ekstraradiküler enfeksiyonların neden olduğu bir hastalıktır. Bu vakaların endodontik olarak tekrarlayan kök kanal tedavileri, çeşitli zorluklar barındırır ve birçok yönden primer endodontik tedaviden farklı olan kendi başına bir tedavi şeklidir. Tekrarlayan endodontik tedaviyi başarı ile uygulayabilmek için; özellikle güncel gelişmeleri takip etmek ve gelişen teknoloji ile birlikte tedavi seçeneklerini de güncellemek gerekmektedir.

Bu bölümde özellikle antimikrobiyal etkiler ele alınmış olsa da, tekrarlayan endodontik tedaviler çok geniş bir yelpazede ele alınmalıdır. Dental büyütme ve görüntüleme ile farklı anatomik varyasyonları daha iyi teşhis ederek, farklı solventler veya farklı döner aletler ile daha iyi temizleme yaparak, farklı irrigasyon teknikleri ve farklı irrigasyon solüsyonları ile daha etkili dezenfeksiyon sağlayarak, nano boyutta geliştirilen yeni ürünler ile ileri antimikrobiyal etki elde ederek, bu savaşta gün geçtikçe daha fazla alternatif olması tedavilerdeki başarı oranımızı arttıracağını düşündürtmektedir.

KAYNAKLAR

1. Roda RS, Gettleman BH, Johnson SC. Nonsurgical retreatment. Berman LH, Hargreaves KM, (Eds.). *Cohen's pathways of the pulp* içinde. 12th ed. St. Louis: Elsevier; 2020. p. 343–410.
2. American Association of Endodontists. *Guide to clinical endodontics 2016*. (14/08/2025 tarihinde https://www.aae.org/specialty/clinical-resources/guide-clinical-endodontics/adresinden ulaşılmıştır).
3. Kakehashi S, Stanley HR, Fitzgerald RJ. The effects of surgical exposures of dental pulps in germ-free and conventional laboratory rats. *Oral Surgery, Oral Medicine, Oral Pathology*. 1965;20(3):340–349. doi:10.1016/0030-4220(65)90166-0
4. Möller ÅJR, Fabricius L, Dahlén G, et al. Influence on periapical tissues of indigenous oral bacteria and necrotic pulp tissue in monkeys. *European Journal of Oral Sciences*. 1981;89(6):475–484. doi:10.1111/j.1600-0722.1981.tb01711.x
5. Sundqvist G. Bacteriological studies of necrotic dental pulps. Umeå: Umeå University; 1976.
6. Nair PNR, Sjögren U, Krey G, et al. Intraradicular bacteria and fungi in root-filled, asymptomatic human teeth with therapy-resistant periapical lesions: A long-term light and electron microscopic follow-up study. *Journal of Endodontics*. 1990;16(12):580–588. doi:10.1016/S0099-2399(07)80201-9

7. Del Fabbro M, Corbella S, Sequeira-Byron P, et al. Endodontic procedures for retreatment of periapical lesions. *The Cochrane Database of Systematic Reviews*. 2016;10(10):CD005511. doi:10.1002/14651858.CD005511.pub3
8. Siqueira JF, Jr., Rôças IN, Ricucci D, et al. Causes and management of post-treatment apical periodontitis. *British Dental Journal*. 2014;216(6):305–312. doi:10.1038/sj.bdj.2014.200
9. 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
10. Siqueira JR. JF, Rôças IN. Microbiology of endodontic infections. Berman LH, Hargreaves KM, (Eds.). *Cohen's pathways of the pulp* içinde. 12th ed. St. Louis: Elsevier; 2020. p. 585–618.
11. Signoretti FG, Gomes BP, Montagner F, et al. Investigation of cultivable bacteria isolated from longstanding retreatment-resistant lesions of teeth with apical periodontitis. *Journal of Endodontics*. 2013;39(10):1240–1244. doi:10.1016/j.joen.2013.06.018
12. Karabucak B, Bunes A, Chehoud C, et al. Prevalence of Apical Periodontitis in Endodontically Treated Premolars and Molars with Untreated Canal: A Cone-beam Computed Tomography Study. *Journal of Endodontics*. 2016;42(4):538–541. doi:10.1016/j.joen.2015.12.026
13. Kamble AP, Pawar RR, Mattigatti S, et al. Cone-beam computed tomography as advanced diagnostic aid in endodontic treatment of molars with multiple canals: Two case reports. *Journal of Conservative Dentistry*. 2017;20(4):273–277. doi:10.4103/0972-0707.219194
14. Rossi-Fedele G, Ahmed HM. Assessment of Root Canal Filling Removal Effectiveness Using Micro-computed Tomography: A Systematic Review. *Journal of Endodontics*. 2017;43(4):520–526. doi:10.1016/j.joen.2016.12.008
15. Penukonda R, Pattar H, Nambiar P, et al. Middle mesial canal in mandibular first molar: A narrative review. *The Saudi Dental Journal*. 2023;35(5):468–475. doi:10.1016/j.sdentj.2023.05.008
16. Azim AA, Deutsch AS, Solomon CS. Prevalence of middle mesial canals in mandibular molars after guided troughing under high magnification: an in vivo investigation. *Journal of Endodontics*. 2015;41(2):164–168. doi:10.1016/j.joen.2014.09.013
17. Bansal R, Hegde S, Astekar M. Morphology and prevalence of middle canals in the mandibular molars: A systematic review. *Journal of Oral and Maxillofacial Pathology*. 2018;22(2):216–226. doi:10.4103/jomfp.JOMFP_194_17
18. Bukhary S, Alkahtany SM, Bukhari A, et al. Prevalence of middle mesial canal using cone beam computed tomography: A systematic review and meta-analysis. *The Saudi Dental Journal*. 2023;35(8):904–915. doi:10.1016/j.sdentj.2023.08.009
19. Martins JNR, Alkhawas MAM, Altaki Z, et al. Worldwide Analyses of Maxillary First Molar Second Mesiobuccal Prevalence: A Multicenter Cone-beam Computed Tomographic Study. *Journal of Endodontics*. 2018;44(11):1641–1649. doi:10.1016/j.joen.2018.07.027
20. Ordinola-Zapata R, Martins JNR, Plascencia H, et al. The MB3 canal in maxillary molars: a micro-CT study. *Clinical Oral Investigations*. 2020;24(11):4109–4121. doi:10.1007/s00784-020-03284-7
21. Wolf TG, Wentaschek S, Wierichs RJ, et al. Interradicular Root Canals in Mandibular First Molars: A Literature Review and Ex Vivo Study. *Journal of Endodontics*. 2019;45(2):129–135. doi:10.1016/j.joen.2018.10.019
22. Mohammadi Z, Shalavi S, Jafarzadeh H. Extra roots and root canals in premolar and molar teeth: review of an endodontic challenge. *The Journal of Contemporary Dental Practice*. 2013;14(5):980–986. doi:10.5005/jp-journals-10024-1437
23. Martins JNR, Nole C, Ounsi HF, et al. Worldwide Assessment of the Mandibular First Molar Second Distal Root and Root Canal: A Cross-sectional Study with Meta-analysis. *Journal of Endodontics*. 2022;48(2):223–233. doi:10.1016/j.joen.2021.11.009
24. Martins JNR, Versiani MA. Worldwide Anatomic Characteristics of the Mandibular Canine-A Multicenter Cross-Sectional Study with Meta-Analysis. *Journal of Endodontics*. 2024;50(4):456–471. doi:10.1016/j.joen.2024.01.016
25. Martins JNR, Versiani MA. Worldwide Prevalence of the Lingual Canal in Mandibular Incisors: A Multicenter Cross-sectional Study with Meta-analysis. *Journal of Endodontics*.

2023;49(7):819–835. doi:10.1016/j.joen.2023.05.012
26. Martins JNR, Zhang Y, von Zuben M, et al. Worldwide Prevalence of a Lingual Canal in Mandibular Premolars: A Multicenter Cross-sectional Study with Meta-analysis. *Journal of Endodontics*. 2021;47(8):1253–1264. doi:10.1016/j.joen.2021.04.021
27. von Zuben M, Martins JNR, Berti L, et al. Worldwide Prevalence of Mandibular Second Molar C-Shaped Morphologies Evaluated by Cone-Beam Computed Tomography. *Journal of Endodontics*. 2017;43(9):1442–1447. doi:10.1016/j.joen.2017.04.016
28. Martins JNR, Francisco H, Ordinola-Zapata R. Prevalence of C-shaped Configurations in the Mandibular First and Second Premolars: A Cone-beam Computed Tomographic In Vivo Study. *Journal of Endodontics*. 2017;43(6):890–895. doi:10.1016/j.joen.2017.01.008
29. Martins JN, Mata A, Marques D, et al. Prevalence and Characteristics of the Maxillary C-shaped Molar. *Journal of Endodontics*. 2016;42(3):383–389. doi:10.1016/j.joen.2015.12.013
30. Zmener O, Pameijer CH, Banegas G. Retreatment efficacy of hand versus automated instrumentation in oval-shaped root canals: an ex vivo study. *International Endodontic Journal*. 2006;39(7):521–526. doi:10.1111/j.1365-2591.2006.01100.x
31. Paranjpe A, de Gregorio C, Gonzalez AM, et al. Efficacy of the self-adjusting file system on cleaning and shaping oval canals: a microbiological and microscopic evaluation. *Journal of Endodontics*. 2012;38(2):226–231. doi:10.1016/j.joen.2011.10.014
32. Chuppani Dastgerdi A, Navabi M, Rakhshan V. Isthmuses, accessory canals, and the direction of root curvature in permanent mandibular first molars: an in vivo computed tomography study. *Restorative Dentistry & Endodontics*. 2020;45(1):e7. doi:10.5395/rde.2020.45.e7
33. Lima FJ, Montagner F, Jacinto RC, et al. An in vitro assessment of type, position and incidence of isthmus in human permanent molars. *Journal of Applied Oral Science*. 2014;22(4):274–281. doi:10.1590/1678-775720130585
34. Costa F, Pacheco-Yanes J, Siqueira JF, Jr., et al. Association between missed canals and apical periodontitis. *International Endodontic Journal*. 2019;52(4):400–406. doi:10.1111/iej.13022
35. Fariniuk LF, Westphalen VP, Silva-Neto UX, et al. Efficacy of five rotary systems versus manual instrumentation during endodontic retreatment. *Brazilian Dental Journal*. 2011;22(4):294–298. doi:10.1590/s0103-64402011000400006
36. Gorduysus M, Nagas E, Torun OY, et al. A comparison of three rotary systems and hand instrumentation technique for the elimination of Enterococcus faecalis from the root canal. *Australian Endodontic Journal*. 2011;37(3):128–133. doi:10.1111/j.1747-4477.2010.00239.x
37. Karataş E, Gültekin E, Arslan H, et al. Evaluation of instrumentation systems in reducing E. faecalis from root canals: TF adaptive and ProTaper next versus single file systems. *The International Journal of Artificial Organs*. 2015;38(3):161–164. doi:10.5301/ijao.5000397
38. Rodrigues RC, Antunes HS, Neves MA, et al. Infection Control in Retreatment Cases: In Vivo Antibacterial Effects of 2 Instrumentation Systems. *Journal of Endodontics*. 2015;41(10):1600–1605. doi:10.1016/j.joen.2015.06.005
39. Azim AA, Wang HH, Tarrosh M, et al. Comparison between Single-file Rotary Systems: Part 1-Efficiency, Effectiveness, and Adverse Effects in Endodontic Retreatment. *Journal of Endodontics*. 2018;44(11):1720–1724. doi:10.1016/j.joen.2018.07.022
40. Maliza AGA, Leal RMS, Cavenago BC, et al. Endodontic retreatment of curved canals using Reciproc, Hyflex CM and Prodesign Duo Hybrid Systems. *Brazilian Oral Research*. 2025;39:e061. doi:10.1590/1807-3107bor-2025.vol39.061
41. Kiraz G, Kaya B, Ocak M, et al. Micro-CT evaluation of the removal of root fillings using rotary and reciprocating systems supplemented by XP-Endo Finisher, the Self-Adjusting File, or Er,Cr:YSGG laser. *Restorative Dentistry & Endodontics*. 2023;48(4):e36. doi:10.5395/rde.2023.48.e36
42. Özlek E, Gündüz H. Effectiveness of different rotary file systems in removing the root canal filling material: A micro-computed tomography study. *Journal of Dental Research Dental Clinics Dental Prospects*. 2021;15(4):273–278. doi:10.34172/joddd.2021.045
43. Almnea RA. Dual-Action Experimental Solvent Achieves Effective Removal of Aged Gut-

ta-Percha and Bioceramic Sealer From Root Canals: A Micro-CT Evaluation. *Australian Endodontic Journal*. 2025:1–10. doi:10.1111/aej.12977
44. Martos J, Bassotto AP, González-Rodríguez MP, et al. Dissolving efficacy of eucalyptus and orange oil, xylol and chloroform solvents on different root canal sealers. *International Endodontic Journal*. 2011;44(11):1024–1028. doi:10.1111/j.1365-2591.2011.01912.x
45. Jantarat J, Malhotra W, Sutimuntanakul S. Efficacy of grapefruit, tangerine, lime, and lemon oils as solvents for softening gutta-percha in root canal retreatment procedures. *Journal of Investigative and Clinical Dentistry*. 2013;4(1):60–63. doi:10.1111/j.2041-1626.2012.00143.x
46. Kulkarni G, Podar R, Singh S, et al. Comparative evaluation of dissolution of a new resin-coated gutta-percha, by three naturally available solvents. *Endodontology*. 2016;28(2):143–147. doi:10.4103/0970-7212.195442
47. Karobari MI, Adil AH, Assiry AA, et al. Herbal medications in endodontics and its application-A review of literature. *Materials (Basel)*. 2022;15(9). doi:10.3390/ma15093111
48. Tewari R, Kapoor B, Mishra S, et al. Role of herbs in endodontics. *Journal of Oral Research and Review*. 2016;8(2):95–99. doi:10.4103/2249-4987.192248
49. Murray PE, Farber RM, Namerow KN, et al. Evaluation of Morinda citrifolia as an endodontic irrigant. *Journal of Endodontics*. 2008;34(1):66–70. doi:10.1016/j.joen.2007.09.016
50. Alaçam T. Kök kanallarının irrigasyonu. Alaçam T, (Ed.). *Endodonti* içinde. Ankara: Özyurt Matbaacılık; 2012. p. 529–588.
51. Alaçam T. Kök kanallarında ilaç kullanımı. Alaçam T, (Ed.). *Endodonti* içinde. Ankara: Özyurt Matbaacılık; 2012. p. 673–704.
52. Peters OA, Peters CI, Basrani B. Cleaning and shaping of the root canal system. Berman LH, Hargreaves KM, (Eds.). *Cohen's pathways of the pulp* içinde. 12th ed. St. Louis: Elsevier; 2020. p. 236–303.
53. Siqueira Jr JF, Roças IN. Kanal içi ilaç (medikament) uygulaması. Chong BS, (Ed.). *Harty klinik uygulamada endodonti* içinde. (Özçelik B, Çev. Ed.). 7th ed. Ankara: Güneş Tıp Kitabevleri; 2019. p. 129–150.
54. Zandi H, Rodrigues RC, Kristoffersen AK, et al. Antibacterial Effectiveness of 2 Root Canal Irrigants in Root-filled Teeth with Infection: A Randomized Clinical Trial. *Journal of Endodontics*. 2016;42(9):1307–1313. doi:10.1016/j.joen.2016.06.006
55. Lima RK, Guerreiro-Tanomaru JM, Faria-Júnior NB, et al. Effectiveness of calcium hydroxide-based intracanal medicaments against Enterococcus faecalis. *International Endodontic Journal*. 2012;45(4):311–316. doi:10.1111/j.1365-2591.2011.01976.x
56. Zerella JA, Fouad AF, Spångberg LS. Effectiveness of a calcium hydroxide and chlorhexidine digluconate mixture as disinfectant during retreatment of failed endodontic cases. *Oral Surgery, Oral Medicine, Oral Pathology, Oral radiology, and Endodontics*. 2005;100(6):756–761. doi:10.1016/j.tripleo.2005.05.072
57. Saatchi M, Shokraneh A, Navaei H, et al. Antibacterial effect of calcium hydroxide combined with chlorhexidine on Enterococcus faecalis: a systematic review and meta-analysis. *Journal of Applied Oral Science*. 2014;22(5):356–365. doi:10.1590/1678-775720140032
58. de Lucena JM, Decker EM, Walter C, et al. Antimicrobial effectiveness of intracanal medicaments on Enterococcus faecalis: chlorhexidine versus octenidine. *International Endodontic Journal*. 2013;46(1):53–61. doi:10.1111/j.1365-2591.2012.02093.x
59. Ganesh A, Nagendrababu V, John A, et al. The Effect of Addition of an EPS Degrading Enzyme with and without Detergent to 2% Chlorhexidine on Disruption of Enterococcus faecalis Biofilm: A Confocal Laser Scanning Microscopic Study. *Journal of Clinical and Diagnostic Research*. 2015;9(11):Zc61–65. doi:10.7860/jcdr/2015/14602.6829
60. Arias-Moliz MT, Ferrer-Luque CM, González-Rodríguez MP, et al. Eradication of Enterococcus faecalis biofilms by cetrimide and chlorhexidine. *Journal of Endodontics*. 2010;36(1):87–90. doi:10.1016/j.joen.2009.10.013
61. María Ferrer-Luque C, Teresa Arias-Moliz M, Ruíz-Linares M, et al. Residual activity of cetrimide and chlorhexidine on Enterococcus faecalis-infected root canals. *International Journal of*

Oral Science. 2014;6(1):46–49. doi:10.1038/ijos.2013.95
62. Ferrer-Luque CM, Conde-Ortiz A, Arias-Moliz MT, et al. Residual activity of chelating agents and their combinations with cetrimide on root canals infected with Enterococcus faecalis. *Journal of Endodontics*. 2012;38(6):826–828. doi:10.1016/j.joen.2012.01.013
63. Boutsioukis C, Arias-Moliz MT. Present status and future directions - irrigants and irrigation methods. *International Endodontic Journal*. 2022;55 Suppl 3(Suppl 3):588–612. doi:10.1111/iej.13739
64. Gomes B, Aveiro E, Kishen A. Irrigants and irrigation activation systems in Endodontics. *Brazilian Dental Journal*. 2023;34(4):1–33. doi:10.1590/0103-6440202305577
65. Prada I, Micó-Muñoz P, Giner-Lluesma T, et al. Update of the therapeutic planning of irrigation and intracanal medication in root canal treatment. A literature review. *Journal of Clinical and Experimental Dentistry*. 2019;11(2):e185–e193. doi:10.4317/jced.55560
66. Alves FR, Almeida BM, Neves MA, et al. Disinfecting oval-shaped root canals: effectiveness of different supplementary approaches. *Journal of Endodontics*. 2011;37(4):496–501. doi:10.1016/j.joen.2010.12.008
67. Jain M, Singhal A, Gurtu A, et al. Influence of Ultrasonic Irrigation and Chloroform on Cleanliness of Dentinal Tubules During Endodontic Retreatment-An Invitro SEM Study. *Journal of Clinical and Diagnostic Research*. 2015;9(5):Zc11–15. doi:10.7860/jcdr/2015/12127.5864
68. Trevisan L, Huerta IR, Michelon C, et al. The Efficacy of Passive Ultrasonic Activation of Organic Solvents on Dissolving Two Root Canal Sealers. *Iranian Endodontic Journal*. 2017;12(1):25–28. doi:10.22037/iej.2017.05
69. Grischke J, Müller-Heine A, Hülsmann M. The effect of four different irrigation systems in the removal of a root canal sealer. *Clinical Oral Investigations*. 2014;18(7):1845–1851. doi:10.1007/s00784-013-1161-6
70. 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:10.1016/j.joen.2018.09.010
71. de Gregorio C, Estevez R, Cisneros R, et al. Efficacy of different irrigation and activation systems on the penetration of sodium hypochlorite into simulated lateral canals and up to working length: an in vitro study. *Journal of Endodontics*. 2010;36(7):1216–1221. doi:10.1016/j.joen.2010.02.019
72. Miller TA, Baumgartner JC. Comparison of the antimicrobial efficacy of irrigation using the EndoVac to endodontic needle delivery. *Journal of Endodontics*. 2010;36(3):509–511. doi:10.1016/j.joen.2009.10.008
73. Kumar T, Dhillon JS, Gill GS, et al. An in vitro comparison of the antimicrobial efficacy of positive pressure and negative pressure irrigation techniques in root canals infected with Enterococcus faecalis. *Journal of Conservative Dentistry*. 2018;21(4):438–442. doi:10.4103/jcd.Jcd_328_17
74. Kim KH, Lévesque C, Malkhassian G, et al. Efficacy of the GentleWave System in the removal of biofilm from the mesial roots of mandibular molars before and after minimal instrumentation: An ex vivo study. *International Endodontic Journal*. 2024;57(7):922–932. doi:10.1111/iej.14044
75. Donnermeyer D, Dust PC, Schäfer E, et al. Comparative Analysis of Irrigation Techniques for Cleaning Efficiency in Isthmus Structures. *Journal of Endodontics*. 2024;50(5):644–650.e641. doi:10.1016/j.joen.2024.02.008
76. Galler KM, Grubmüller V, Schlichting R, et al. Penetration depth of irrigants into root dentine after sonic, ultrasonic and photoacoustic activation. *International Endodontic Journal*. 2019;52(8):1210–1217. doi:10.1111/iej.13108
77. Jiang S, Zou T, Li D, et al. Effectiveness of Sonic, Ultrasonic, and Photon-Induced Photoacoustic Streaming Activation of NaOCl on Filling Material Removal Following Retreatment in Oval Canal Anatomy. *Photomedicine and Laser Surgery*. 2016;34(1):3–10. doi:10.1089/pho.2015.3937
78. Bergmans L, Moisiadis P, Huybrechts B, et al. Effect of photo-activated disinfection on endo-

dontic pathogens ex vivo. *International Endodontic Journal*. 2008;41(3):227–239. doi:10.1111/j.1365-2591.2007.01344.x
79. Rios A, He J, Glickman GN, et al. Evaluation of photodynamic therapy using a light-emitting diode lamp against Enterococcus faecalis in extracted human teeth. *Journal of Endodontics*. 2011;37(6):856–859. doi:10.1016/j.joen.2011.03.014
80. Cretella G, Lajolo C, Castagnola R, et al. The Effect of Diode Laser on Planktonic Enterococcus faecalis in Infected Root Canals in an Ex Vivo Model. *Photomedicine and Laser Surgery*. 2017;35(4):190–194. doi:10.1089/pho.2016.4174
81. Asnaashari M, Ashraf H, Rahmati A, et al. A comparison between effect of photodynamic therapy by LED and calcium hydroxide therapy for root canal disinfection against Enterococcus faecalis: A randomized controlled trial. *Photodiagnosis and Photodynamic Therapy*. 2017;17:226–232. doi:10.1016/j.pdpdt.2016.12.009
82. Camacho-Alonso F, Julián-Belmonte E, Chiva-García F, et al. Bactericidal Efficacy of Photodynamic Therapy and Chitosan in Root Canals Experimentally Infected with Enterococcus faecalis: An In Vitro Study. *Photomedicine and Laser Surgery*. 2017;35(4):184–189. doi:10.1089/pho.2016.4148
83. Li Y, Sun K, Ye G, et al. Evaluation of Cold Plasma Treatment and Safety in Disinfecting 3-week Root Canal Enterococcus faecalis Biofilm In Vitro. *Journal of Endodontics*. 2015;41(8):1325–1330. doi:10.1016/j.joen.2014.10.020
84. Case PD, Bird PS, Kahler WA, et al. Treatment of root canal biofilms of Enterococcus faecalis with ozone gas and passive ultrasound activation. *Journal of Endodontics*. 2012;38(4):523–526. doi:10.1016/j.joen.2011.12.020
85. Farac RV, Pizzolitto AC, Tanomaru JM, et al. Ex-vivo effect of intracanal medications based on ozone and calcium hydroxide in root canals contaminated with Enterococcus faecalis. *Brazilian Dental Journal*. 2013;24(2):103–106. doi:10.1590/0103-6440201301992
86. Barros J, Silva MG, Rôças IN, et al. Antibiofilm effects of endodontic sealers containing quaternary ammonium polyethylenimine nanoparticles. *Journal of Endodontics*. 2014;40(8):1167–1171. doi:10.1016/j.joen.2013.12.021
87. Bukhari S, Kim D, Liu Y, et al. Novel endodontic disinfection approach using catalytic nanoparticles. *Journal of Endodontics*. 2018;44(5):806–812. doi:10.1016/j.joen.2017.12.003
88. Moradi F, Haghgoo R. Evaluation of Antimicrobial Efficacy of Nanosilver Solution, Sodium Hypochlorite and Normal Saline in Root Canal Irrigation of Primary Teeth. *Contemporary Clinical Dentistry*. 2018;9(Suppl 2):S227–s232. doi:10.4103/ccd.ccd_95_18
89. Kushwaha V, Yadav RK, Tikku AP, et al. Comparative evaluation of antibacterial effect of nanoparticles and lasers against Endodontic Microbiota: An in vitro study. *Journal of Clinical and Experimental Dentistry*. 2018;10(12):e1155–e1160. doi:10.4317/jced.55076
90. Çorak M, Kaya Mumcu A, Gülbandılar A. Comparative evaluation of the effectiveness of various intracanal medicaments in eliminating Enterococcus faecalis from simulated internal resorption cavities. *Scientific Reports*. 2025;15(1):19862. doi:10.1038/s41598-025-03072-x
91. Şeker İD, Alacam T, Akca G, et al. The antimicrobial effect of R-limonene and its nano emulsion on Enterococcus faecalis - In vitro study. *European Oral Research*. 2025;59(1):33–39. doi:10.26650/eor.20241459780
92. Turner S, Love R, Lyons K. An in-vitro investigation of the antibacterial effect of nisin in root canals and canal wall radicular dentine. *International Endodontic Journal*. 2004;37(10):664–671. doi:10.1111/j.1365-2591.2004.00846.x
93. Somanath G, Samant PS, Gautam V, et al. To comparatively evaluate the antimicrobial efficacy of chlorhexidine, nisin and linezolid as an intracanal medicament on Enterococcus faecalis: An in vitro study. *Indian Journal of Dental Research*. 2015;26(6):613–618. doi:10.4103/0970-9290.176926
94. Babeer A, Bukhari S, Alrehaili R, et al. Microrobotics in endodontics: A perspective. *International Endodontic Journal*. 2024;57(7):861–871. doi:10.1111/iej.14082