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Case Report

Endodontic Treatment of an Autogenous Transplanted Tooth Using an Er,Cr:YSGG Laser and Radial Firing Tips: Case Report

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Abstract

Objective and background: Although several surgical techniques have been reported, no study has yet reported alternative strategies for endodontic treatment of autogenous transplanted teeth. Therefore, the aim of this clinical report is to present the long-term endodontic outcome of a nonvital autogenously transplanted third molar treated with an Er,Cr:YSGG laser and radial firing tips (RFTs). ***Case report:*** Autogenous tooth transplantation can be considered an alternative to restore edentulous areas and, in donor's teeth with complete root formation, root canal treatment should be performed up to 14 days following transplantation. In the present case report, the patient returned only after 6 months, with clinical and radiological signs of apical periodontitis (AP) associated with the transplanted tooth. ***Methods:*** Instead of traditional endodontic chemical irrigants or medications, the protocol for smear-layer removal and root canal disinfection was based on intracanal irradiation with an Er,Cr:YSGG laser and RFTs. ***Results:*** After 3-years' follow-up, the complete reestablishment of the periodontal ligament and the arrest of the resorptive process could be noticed. ***Conclusions:*** This protocol has shown to be effective for the endodontic treatment of a transplanted multi-rooted tooth with AP. Further randomized clinical trials should be conducted to clearly demonstrate the effectiveness of this laser-assisted endodontic protocol.

Introduction

Autogenous tooth transplantation of third molars may be presented as an excellent alternative to restore edentulous areas (Fig. 1).[1,2] Thereafter, it is often preconized that the root canal treatment (RCT) of an autogenous transplanted tooth[3–6] should take place within 14 days before severe inflammatory reactions start to occur.[7,8] In the present case report, the patient returned 6 months after surgery with signs of apical periodontitis (AP) related to the transplanted tooth (Fig. 2).

For RCT, both sodium hypochlorite (NaOCl) and calcium hydroxide (CH) can arguably be considered the mostly used endodontic disinfectant agents. However, the extent of their clinical effectiveness remains unclear.[9–13] Moreover, there is still no technique able to fully render the canal system free of smear layer (SL) and debris as often preconized.[14–17] Therefore, alternative strategies (e.g., ozone, ultrasonic, lasers) have been purposed to overcome such limitation.[18–20]

Each laser wavelength has a specific absorption coefficient for each tissue component.[21] The rationale for adopting the 2780 nm (Er,Cr:YSGG) laser in endodontics may be briefly described as (1) the interaction with aqueous solutions produces cavitation effects that were shown to be capable to remove the smear layer and debris from the root canal walls[22–24] and (2) the ability to propagate into the dentin, achieving high bactericidal effects deeper than any endodontic solution.[25,26] In addition, the development of radial firing tips (RFTs) has overcome the limitations of plain fiber tips, favoring a homogeneous energy distribution along the root canal wall.[25,27–31]

Despite several *in vitro* investigations having been reported, only few clinical evidences have actually shown the potential benefits of using RFTs and Er,Cr:YSGG laser for RCT.[32,33] As few studies have reported alternative strategies for endodontic disinfection of autogenous transplanted teeth,[34] this case report may be considered useful to support a new laser-assisted endodontic concept.[35] The aim is to present the clinical outcome of a laser-assisted endodontic

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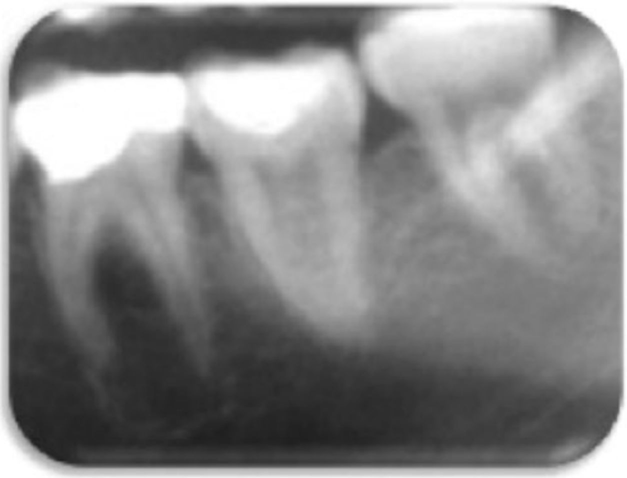

FIG. 1. Initial aspect of the tooth 3.6 with AP and a radiopaque rim lining the lesion (notice the round, unilocular radiolucent area and the resorption of the apical third of mesial roots) compatible with the diagnosis of an apical cyst.

treatment using RFTs in a nonvital autogenously transplanted third molar associated with AP.

Case Report

A 23-year-old male presented an asymptomatic carious lesion in the tooth 3.6, being clinically and radiographically diagnosed as pulp necrosis with extensive AP (Fig. 1). The patient's medical history was not contributory and autogenous transplantation was chosen as preferred treatment plan.

Under local anesthesia, the extraction of tooth 3.6 was performed with cautious preservation of the alveolar surrounding structures. The intra-alveolar septum was trimmed with a bone gauge forceps and the socket rinsed with physiologic solution. The third molar (3.8) was extracted and stored accordingly to Raghoebar et al.[36] After transplantation into the 3.6 socket, the papillae were sutured (4/0 supramid; B. Braun), passing over the crown to immobilize it.

FIG. 2. Clinical aspect of the autogenous transplanted tooth after 6 months (notice the edema at the buccal side).

The patient only returned after 6 months with symptoms of masticatory discomfort, tenderness to percussion, transitory swelling, and negative response to thermal tests. After performing the radiographic examination, the initial diagnosis of AP was confirmed (Fig. 2).

Ethical approval for the endodontic clinical protocol (N_682/068) was obtained and the required consent (Helsinki Declaration, revised in Edinburgh [2000]) was acquired.

Under local anesthesia (2% lidocaíne with 1:100.000 epinephrine, Scandonest, France) and rubber dam isolation (Hygenic Colte'ne/Whaledent), the access cavity was prepared (Zekrya; Dentsply).

The working length (WL) was electronically established (ProPex II; Dentsply) 1 mm short of the biological apex of the root. Patency was confirmed with an ISO#10 K-file and canal preparation was performed with Protaper (Maillefer) sequence up to F3 (#30.09) and F4 (#40.06) files in mesial and distal canals, respectively.

Irrigation was performed between each file with 3 mL of saline solution (Monoject 27G; Kendall-Covidien). No chemical irrigants or interappointment medications were used.

Following preparation, the SL removal and disinfection of the root canal system were performed with the Er,-Cr:YSGG laser using RFTs.[32,33] Laser irradiation was performed with a 270 μm tip (RFT2; Biolase; calibration factor of 0.55) with panel settings of 0.75W (37.5 mJ pulse energy), pulse rate 20 Hz, pulse duration 140 μs, 0% water, and 0% air. The tip was placed 1 mm short of the WL and

FIG. 3. Er,Cr-YSGG laser irradiation using RFT2.

irradiation was performed approximately at the speed of 2 mm·sec^{-1}, withdrawing in coronal direction (Fig. 3). The irradiation procedure was repeated four times: 2× with the canal filled with distilled water, followed by 2× in dry conditions, resting 15 sec between each irradiation. The access cavity was left with a sterile cotton pellet and temporarily sealed (IRM; Dentsply).

At the second appointment (after 1 week), there was a negative history on questioning to pain, tenderness to percussion, or swelling. Under rubber dam isolation, the canals were once again filled with distilled water, and laser irradiation was performed with a 320 μm tip (RFT3, Biolase, USA; calibration factor of 0.85) with panel settings of 1.25 W (62.5 mJ pulse energy), pulse rate 20 Hz, pulse duration 140 μs, and 0% water and air. The irradiation movements and repetitions were identical to the first appointment.

A final rinsing with saline solution (3.0 mL) was performed, and the canal was dried with sterile paper points, checking for the absence of exudate. Filling was performed with tapered gutta-percha (2xF3 and 1xF4) adopting an autofitting technique, vertical compaction, and an epoxy resin-based sealer (TopSeal; Dentsply) (Figs. 4 and 5).

Radiographic controls and clinical records were recorded after 6 months (Fig. 6), 1 year (Fig. 7), 2 years (Fig. 8), and 3 years (Figs. 9 and 10). Over this follow-up period, the tooth remained completely asymptomatic and periapical healing could be noticed.

FIG. 5. Immediate radiographic assessment following laser-assisted endodontic treatment.

Discussion

Data provided by radiographic means can only provide a moderately accurate diagnosis to distinguish between AP and radicular cyst.[37,38] However, the compromised clinical status of the tooth 3.6 justified the extraction along with excision of the lesion content (Fig. 1).

Given that tooth transplantation is considered a predictable treatment option, wisdom teeth often represent the best donor alternative.[2,39] This report may confirm such statements, along with the viability of a single-appointment surgical approach[39,40] and the importance of endodontic treatments, to predict successful outcomes.[6,41]

In teeth with complete root formation, the small size of the apical foramen can play a role by delaying bacterial

FIG. 4. Radiographic assessment of gutta-percha fitting.

FIG. 6. Six months' follow-up.

FIG. 7. 12 months' follow-up.

FIG. 9. Three years' follow-up (notice the complete re-establishment of the periodontal ligament).

contamination during the surgical procedure.[42] Nevertheless, to prevent pulp necrosis and inflammatory reactions, the RCT of transplanted mature teeth is preconized between 7 and 14 days following surgery or performed as soon as the peridontal ligament (PDL) is restored.[3,6]

As our report may confirm, 6 months after transplantation, severe inflammatory reactions could be noticed, surpassing all recommended periods to perform the RCT.[4] This may also highlight the importance of patient compliance with the pre-established protocol.[6]

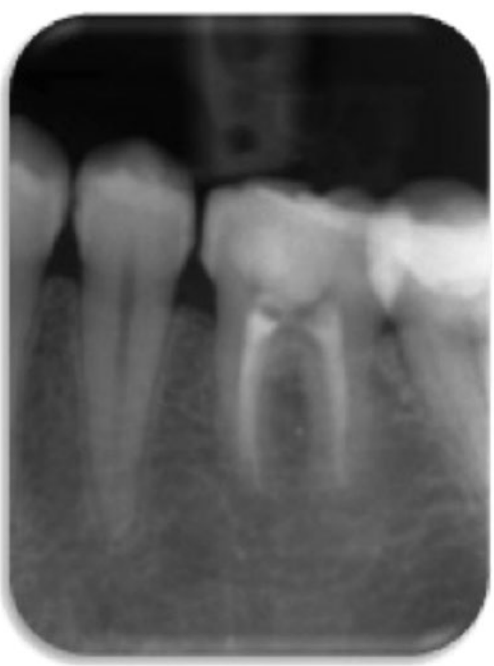

FIG. 8. Two years' follow-up.

Ankylosis and root resorptions are often reported as consequences of tooth transplantation.[43,44] In this clinical case, the apical resorption of the distal root can be related to the breakage of vascular supply and to the AP chronic nature (Fig. 5).[3,8,45]

Despite several reports of distinct surgical techniques, there are still no guidelines for endodontic management (i.e., disinfection) of transplanted mature teeth. Therefore, this report may be of special relevance while adequately reporting a new disinfection technique and its clinical outcome.[35,46] The adoption of laser-assisted disinfection protocol was based on the assumption that (1) third molars often present intricate root canal anatomies where irrigants cannot penetrate effectively and (2) the apical resorption at the distal root could be seen as a predisposal factor for the occurrence of an iatrogenic accident.[47]

The high absorption coefficients of the 2780 nm wavelength in both water and hydroxyapatite justify the selection of this wavelength for both SL removal and disinfection.[48] In fact, it is known that the interaction between this laser wavelength and aqueous solutions induces both primary and secondary cavitation effects that are able to remove debris and SL from the root canal system.[22,49] Previous studies inclusively found that the Er,Cr:YSGG laser could be more efficient than EDTA irrigation or passive ultrasonic irrigation, while minimizing the risk of any irrigant extrusion.[27,49–52] However, to exhibit its maximum bactericidal properties, Er,Cr:YSGG laser irradiation should be performed in dry conditions, allowing the energy to be transmitted through the dentinal tubules[25] and instantaneously interact with the water inside bacterial membranes, as well as the water trapped within endodontic biofilms.[53]

However, *in vitro* studies often provide confounding evidences regarding laser settings and, due to standardization

FIG. 10. Three years' follow-up panoramic radiography.

demands, do not take into account relevant clinical factors. Therefore, the laser settings used in this clinical case were based on a previously reported clinical trial.[31,33] The protocol consists of two irradiations with distilled water in the main canal for debris and SL removal, followed by two other irradiations—in dry conditions—to achieve higher dentin disinfection depth.

The present protocol is in contrast with the one reported by Christo et al. that attempted to use the Er,Cr:YSGG laser for NaOCl activation, but did not show any bactericidal improvements.[54] Moreover, it is known that the activation of chemical irrigants by erbium lasers with relatively high output powers may eventually induce their apical extrusion.[55]

Independently of the wavelength, laser bare fibers have been used since many years for endodontic purposes. These fibers are required to be inserted in the main canal and withdrawn from apical to coronal region in a rotating motion to overcome their relatively small beam divergence.[56] Despite their relative success, such technique is known to be operator sensitive and to produce inconsistent results.[48,57,58] In contrast, RFTs can spread laser energy toward the direction of dentinal tubules and were shown to increase cavitation effects toward the root canal walls without being hazardous to the periapical tissues.[25,27] Moreover, they were shown to produce clinically safer temperature increments with complete absence of molecular dentine changes[28–31] and to be highly efficient in biofilm disaggregation.[53,59] RFTs also demonstrate the potential to overcome the airlock effect, allowing irrigant solutions to safely reach the apical third.[60]

Despite the absence of a cone beam computed tomography (CBCT) assessment to further validate the outcome of this report,[61] it is still debatable whether such tridimensional techniques overestimate periapical images or if they are even able to identify various forms of periapical bone tissue changes.[62]

The present clinical findings are in agreement with the majority of *in vitro* studies that demonstrate the capability of the Er,Cr:YSGG laser to remove SL and to provide a uniform deep disinfection of the entire root canal system.[25,31,50] This report may also attest the effectiveness, safety, and clinical outcomes reported for single-rooted teeth.[33]

Conclusions

After 3-years of follow-up and, despite the intrinsic limitations of a single-case report, our findings may attest that RFTs can be considered for the endodontic treatment of multi-rooted teeth associated with AP, inclusively in autogenous transplanted teeth. Further randomized clinical trials should be conducted to clearly demonstrate its effectiveness.

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Author Disclosure Statement

No competing financial interests exist.

References

1. Jang JH, Lee SJ, Kim E. Autotransplantation of immature third molars using a computer-aided rapid prototyping model: a report of 4 cases. J Endod 2013;39:1461–1466.
2. Tsukiboshi M. Autotransplantation of teeth: requirements for predictable success. Dent Traumatol 2002;18:157–180.
3. Marques-Ferreira M, Rabaca-Botelho MF, Carvalho L, Oliveiros B, Palmeirao-Carrilho EV. Autogenous tooth transplantation: evaluation of pulp tissue regeneration. Med Oral Patol Oral Cir Bucal 2011;16:e984–e989.
4. Azevedo PC, Moura CC, Zanetta-Barbosa D, Bernadineli N. Time of endodontic treatment in autogenic transplants of mature teeth: histological study in dogs. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104:287–293.
5. Kim E, Jung JY, Cha IH, Kum KY, Lee SJ. Evaluation of the prognosis and causes of failure in 182 cases of autogenous tooth transplantation. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2005;100:112–119.
6. Czochrowska EM, Stenvik A, Bjercke B, Zachrisson BU. Outcome of tooth transplantation: survival and success rates 17–41 years posttreatment. Am J Orthod Dentofacial Orthop 2002;121:110–119; quiz 193.
7. Andreasen JO, Paulsen HU, Yu Z, Bayer T. A long-term study of 370 autotransplanted premolars. Part IV. Root

development subsequent to transplantation. Eur J Orthod 1990;12:38–50.
8. Pohl Y, Filippi A, Kirschner H. Results after replantation of avulsed permanent teeth. I. Endodontic considerations. Dent Traumatol 2005;21:80–92.
9. Bystrom A, Sundqvist G. The antibacterial action of sodium hypochlorite and EDTA in 60 cases of endodontic therapy. Int Endod J 1985;18:35–40.
10. Orstavik D, Haapasalo M. Disinfection by endodontic irrigants and dressings of experimentally infected dentinal tubules. Endod Dent Traumatol 1990;6:142–149.
11. Stojicic S, Zivkovic S, Qian W, Zhang H, Haapasalo M. Tissue dissolution by sodium hypochlorite: effect of concentration, temperature, agitation, and surfactant. J Endod 2010;36:1558–1562.
12. Dahlen G, Samuelsson W, Molander A, Reit C. Identification and antimicrobial susceptibility of enterococci isolated from the root canal. Oral Microbiol Immunol 2000; 15:309–312.
13. Paredes-Vieyra J, Enriquez FJ. Success rate of single- versus two-visit root canal treatment of teeth with apical periodontitis: a randomized controlled trial. J Endod 2012; 38:1164–1169.
14. The second brighton life table. Br Med J 1903;2:1223–1224.
15. Violich DR, Chandler NP. The smear layer in endodontics—a review. Int Endod J 2010;43:2–15.
16. Fogel HM, Pashley DH. Dentin permeability: effects of endodontic procedures on root slabs. J Endod 1990;16:442–445.
17. Shahravan A, Haghdoost AA, Adl A, Rahimi H, Shadifar F. Effect of smear layer on sealing ability of canal obturation: a systematic review and meta-analysis. J Endod 2007;33: 96–105.
18. Estrela C, Estrela CR, Decurcio DA, Hollanda AC, Silva JA. Antimicrobial efficacy of ozonated water, gaseous ozone, sodium hypochlorite and chlorhexidine in infected human root canals. Int Endod J 2007;40:85–93.
19. Ahmad M, Pitt Ford TR, Crum LA, Walton AJ. Ultrasonic debridement of root canals: acoustic cavitation and its relevance. J Endod 1988;14:486–493.
20. Gutknecht N, van Gogswaardt D, Conrads G, Apel C, Schubert C, Lampert F. Diode laser radiation and its bactericidal effect in root canal wall dentin. J Clin Laser Med Surg 2000;18:57–60.
21. Cercadillo-Ibarguren I, Espana-Tost A, Arnabat-Dominguez J, Valmaseda-Castellon E, Berini-Aytes L, Gay-Escoda C. Histologic evaluation of thermal damage produced on soft tissues by CO2, Er,Cr:YSGG and diode lasers. Med Oral Patol Oral Cir Bucal 2010;15:e912–e918.
22. De Moor RJ, Blanken J, Meire M, Verdaasdonk R. Laser induced explosive vapor and cavitation resulting in effective irrigation of the root canal. Part 2: evaluation of the efficacy. Lasers Surg Med 2009;41:520–523.
23. Matsumoto H, Yoshimine Y, Akamine A. Visualization of irrigant flow and cavitation induced by Er:YAG laser within a root canal model. J Endod 2011;37:839–843.
24. Keles A, Arslan H, Kamalak A, Akcay M, Sousa-Neto MD, Versiani MA. Removal of filling materials from oval-shaped canals using laser irradiation: a micro-computed tomographic study. J Endod 2015;41:219–224.
25. Franzen R, Esteves-Oliveira M, Meister J, et al. Decontamination of deep dentin by means of erbium, chromium:yttrium-scandium-gallium-garnet laser irradiation. Lasers Med Sci 2009;24:75–80.
26. Lopez-Jimenez L, Arnabat-Dominguez J, Vinas M, Vinuesa T. Atomic force microscopy visualization of injuries in *Enterococcus faecalis* surface caused by Er,Cr:YSGG and diode lasers. Med Oral Patol Oral Cir Bucal 2015; 20:e45–e51.
27. Peeters HH, Mooduto L. Radiographic examination of apical extrusion of root canal irrigants during cavitation induced by Er,Cr:YSGG laser irradiation: an in vivo study. Clin Oral Investig 2013;17:2105–2112.
28. Ishizaki NT, Matsumoto K, Kimura Y, et al. Thermographical and morphological studies of Er,Cr:YSGG laser irradiation on root canal walls. Photomed Laser Surg 2004; 22:291–297.
29. Altundasar E, Ozcelik B, Cehreli ZC, Matsumoto K. Ultramorphological and histochemical changes after ER,-CR:YSGG laser irradiation and two different irrigation regimes. J Endod 2006;32:465–468.
30. Schoop U, Goharkhay K, Klimscha J, et al. The use of the erbium, chromium:yttrium-scandium-gallium-garnet laser in endodontic treatment: the results of an in vitro study. J Am Dent Assoc 2007;138:949–955.
31. Gordon W, Atabakhsh VA, Meza F, et al. The antimicrobial efficacy of the erbium, chromium:yttrium-scandium-gallium-garnet laser with radial emitting tips on root canal dentin walls infected with *Enterococcus faecalis*. J Am Dent Assoc 2007;138:992–1002.
32. Martins MR, Carvalho MF, Vaz IP, Capelas JA, Martins MA, Gutknecht N. Efficacy of Er,Cr:YSGG laser with endodontical radial firing tips on the outcome of endodontic treatment: blind randomized controlled clinical trial with six-month evaluation. Lasers Med Sci 2013;28:1049–1055.
33. Martins MR, Carvalho MF, Pina-Vaz I, Capelas JA, Martins MA, Gutknecht N. Outcome of Er,Cr:YSGG laser-assisted treatment of teeth with apical periodontitis: a blind randomized clinical trial. Photomed Laser Surg 2014;32: 3–9.
34. Candeiro GT, Alencar-Junior EA, Scarparo HC, Furtado-Junior JH, Gavini G, Caldeira CL. Eight-year follow-up of autogenous tooth transplantation involving multidisciplinary treatment. J Oral Sci 2015;57:273–276.
35. Gagnier JJ, Kienle G, Altman DG, et al. The CARE guidelines: consensus-based clinical case reporting guideline development. BMJ Case Rep 2013;2013:bcr2013201554.
36. Raghoebar GM, Vissink A. Results of intentional replantation of molars. J Oral Maxillofac Surg 1999;57:240–244.
37. White SC, Sapp JP, Seto BG, Mankovich NJ. Absence of radiometric differentiation between periapical cysts and granulomas. Oral Surg Oral Med Oral Pathol 1994;78: 650–654.
38. Guo J, Simon JH, Sedghizadeh P, Soliman ON, Chapman T, Enciso R. Evaluation of the reliability and accuracy of using cone-beam computed tomography for diagnosing periapical cysts from granulomas. J Endod 2013;39:1485–1490.
39. Nimcenko T, Omerca G, Varinauskas V, Bramanti E, Signorino F, Cicciu M. Tooth auto-transplantation as an alternative treatment option: a literature review. Dent Res J 2013;10:1–6.
40. Sartaj R, Sharpe P. Biological tooth replacement. J Anat 2006;209:503–509.
41. Lundberg T, Isaksson S. A clinical follow-up study of 278 autotransplanted teeth. Br J Oral Maxillofac Surg 1996;34: 181–185.
42. Andreasen JO, Paulsen HU, Yu Z, Bayer T, Schwartz O. A long-term study of 370 autotransplanted premolars. Part II.

Tooth survival and pulp healing subsequent to transplantation. Eur J Orthod 1990;12:14–24.
43. Scheller EL, Krebsbach PH, Kohn DH. Tissue engineering: state of the art in oral rehabilitation. J Oral Rehabil 2009; 36:368–389.
44. Gault PC, Warocquier-Clerout R. Tooth auto-transplantation with double periodontal ligament stimulation to replace periodontally compromised teeth. J Periodontol 2002;73: 575–583.
45. Bauss O, Schilke R, Fenske C, Engelke W, Kiliaridis S. Autotransplantation of immature third molars: influence of different splinting methods and fixation periods. Dent Traumatol 2002;18:322–328.
46. Fedorowicz Z, Nasser M, Sequeira-Byron P, de Souza RF, Carter B, Heft M. Irrigants for non-surgical root canal treatment in mature permanent teeth. Cochrane Database Syst Rev 2012;9:CD008948.
47. Kleier DJ, Averbach RE, Mehdipour O. The sodium hypochlorite accident: experience of diplomates of the American Board of Endodontics. J Endod 2008;34:1346–1350.
48. Minas NH, Gutknecht N, Lampert F. In vitro investigation of intra-canal dentine-laser beam interaction aspects: II. Evaluation of ablation zone extent and morphology. Lasers Med Sci 2010;25:867–872.
49. Blanken J, De Moor RJ, Meire M, Verdaasdonk R. Laser induced explosive vapor and cavitation resulting in effective irrigation of the root canal. Part 1: a visualization study. Lasers Surg Med 2009;41:514–519.
50. De Moor RJ, 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;36:1580–1583.
51. George R, Meyers IA, Walsh LJ. Laser activation of endodontic irrigants with improved conical laser fiber tips for removing smear layer in the apical third of the root canal. J Endod 2008;34:1524–1527.
52. George R, Walsh LJ. Thermal effects from modified endodontic laser tips used in the apical third of root canals with erbium-doped yttrium aluminium garnet and erbium, chromium-doped yttrium scandium gallium garnet lasers. Photomed Laser Surg 2010;28:161–165.
53. BagoJuric I, Plecko V, Anic I. Antimicrobial efficacy of Er,Cr:YSGG laser-activated irrigation compared with passive ultrasonic irrigation and RinsEndo((R)) against intracanal *Enterococcus faecalis*. Photomed Laser Surg 2014; 32:600–605.
54. Christo JE, Zilm PS, Sullivan T, Cathro PR. Efficacy of low concentrations of sodium hypochlorite and low-powered Er,Cr:YSGG laser activated irrigation against an *Enterococcus faecalis* biofilm. Int Endod J 2016;49:279–286.
55. Peeters HH, De Moor RJ. Measurement of pressure changes during laser-activated irrigant by an erbium, chromium: yttrium, scandium, gallium, garnet laser. Lasers Med Sci 2015;30:1449–1455.
56. Mohammadi Z. Laser applications in endodontics: an update review. Int Dent J 2009;59:35–46.
57. Strakas D, Franzen R, Kallis A, Vanweersch L, Gutknecht N. A comparative study of temperature elevation on human teeth root surfaces during Nd:YAG laser irradiation in root canals. Lasers Med Sci 2013;28:1441–1444.
58. Zhu L, Tolba M, Arola D, Salloum M, Meza F. Evaluation of effectiveness of Er,Cr:YSGG laser for root canal disinfection: theoretical simulation of temperature elevations in root dentin. J Biomech Eng 2009;131:071004.
59. Licata ME, Albanese A, Campisi G, Geraci DM, Russo R, Gallina G. Effectiveness of a new method of disinfecting the root canal, using Er, Cr:YSGG laser to kill *Enterococcus faecalis* in an infected tooth model. Lasers Med Sci 2015;30:707–712.
60. Peeters HH, De Moor RJ, 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 Med Sci 2015;30:1683–1688.
61. Patel S, Wilson R, Dawood A, Foschi F, Mannocci F. The detection of periapical pathosis using digital periapical radiography and cone beam computed tomography—part 2: a 1-year post-treatment follow-up. Int Endod J 2012;45: 711–723.
62. Petersson A, Axelsson S, Davidson T, et al. Radiological diagnosis of periapical bone tissue lesions in endodontics: a systematic review. Int Endod J 2012;45:783–801.

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