

Use of Lasers in Dentistry

The use of lasers in dentistry was suggested approximately 35 years ago as a means of using energy generated by light to remove or modify soft and hard tissues in the oral cavity. A **Laser** is an acronym for **Light Amplification by Stimulated Emission of Radiation**. The radiation involved in generating laser light is nonionizing and does not produce the same effects attributed to X-radiation. The Food and Drug Administration has approved the use of various lasers to remove diseased gingival tissues and for other soft tissue applications, in the removal of dental caries, as an aid in placing tooth-colored restorations, and as an adjunct in root canal procedures, such as pulpotomies. This position paper concentrates on laser use in root canal treatment.

Lasers emit light energy that can interact with biologic tissues, such as tooth enamel, dentin, gingiva or dental pulp. Laser classification is based on a variety of factors including wavelength, technique (i.e. direct irradiation, laser activated disinfection), target and laser effects. Parameters of laser light emission include average power (in Watts), energy (in Joules) power density (in W/cm^2) frequency of pulsation (in Hz) and energy fluence ($J/fabricm^2$). The interaction is the effect of the particular properties of laser light including: 1) monochromaticity, where the light is all the same color (same wavelength); 2) coherence, where the waves of light are all in phase; and 3) collimation, where the light rays are parallel to each other and do not diverge. The application of this light energy results in the modification or removal of tissue. In root canal treatment, lasers may be used to remove the dental pulp and organic debris, and to modify the dentinal walls by inducing melting and resolidification cycles resulting in the enlargement of the walls of the root canal system.

Once the preparation is completed, the root canal is obturated, and the laser may be used to soften and mold the obturating material to the prepared root canal system. These procedures are accomplished by the interactions between the laser light, dentin and obturating materials. The net result of laser tissue interaction will depend upon the degree of laser energy that is absorbed or scattered by the tissue or the tissue fluid. Different parameters such as laser wavelength, energy level, mode of application, and tissue characteristics will influence the effect of a particular laser on the tissue. The primary effects of lasers on root dentin are thermodynamic (increased temperature), and photochemical.^{1,2}

Root canal treatment is currently performed using a combination of hand and rotary instruments to remove the soft tissue, clean the root canal space and shape the space to receive the obturating material, usually gutta-percha. This biocompatible material is then placed with a cementing medium using special hand instruments to ensure complete sealing of the root canals. Laser energy, when added to root canal procedures, presents advantages and disadvantages. Currently, root canal procedures clean the canal space by utilizing a combination of mechanical removal of tissue and chemical decontamination. The use of lasers to aid root canal disinfection is more promising than their application in root canal preparation. For disinfection, laser energy can be used directly or in combination with a photosensitive chemical that, when bound to microorganisms, may be activated by low-energy laser light to essentially kill the microorganism (*Photodynamic Therapy (PDT)*). Additional experiments suggest that the propagation of acoustic waves emanating from a pulsed-low energy laser may aid in distributing disinfecting solutions more effectively across the root canal system (*Photon Induced Photoacoustic Streaming (PIPS)*).²

Root canal preparation using laser light has not been proven to be more effective than mechanical shaping¹⁴⁻¹⁶ and comes with several significant disadvantages. Root canal spaces are often curved in at least two dimensions. Conventional root canal instruments follow the curvatures in a root. In contrast, laser light will only travel in a straight path; laser probes must therefore continue to be fabricated in a way that the laser light emerges laterally, uniformly interacting with the root canal wall.³⁻¹³ Further, the interaction between laser energy and tissue can cause a rise in temperature that can affect the canal space as well as the outer surfaces of the tooth. The resulting injury to dentin, soft tissue, and the surrounding bone may result in ankylosis¹⁷ or the eventual loss of the tooth. Moreover, cycles of melting and resolidification of radicular wall dentin apparently have no positive effect on clinical outcomes.

The use of lasers as an aid in disinfection has been researched extensively in the last few years. Currently, there exists a body of evidence from *in vitro/in vivo* studies on the antibacterial efficacy of high-power laser and photodynamic therapy,¹⁸⁻³² and *in vitro* experiments with PIPS³³⁻³⁵ in root canals. However, their effects on the clinical outcomes of root canal therapy are not known at this point. While the FDA has approved one laser (diode) as an adjunct for removal of pulp tissue in a pulpotomy and apicoectomy, more research is required to develop laser energy for use in non-surgical endodontics that is equal to and perhaps one day, superior to present treatment modalities.

References

1. Miserendino L, Robert PM. Lasers in Dentistry, Quintessence Publishing, Hanover Park, IL 1995.
2. Kishen A. Advanced therapeutic options for endodontic biofilms. *Endodontic Topics*, 2010; 22(1); 99-123.
3. Goodis HE, Pashley D, Stabholz A. Pulpal effects of thermal and mechanical irritant, in Seltzer and Benderís Dental Pulp, eds. K.M. Hargreaves and H.E. Goodis, Hanover Park, IL: Quintessence Publishing, 2002: 371-410.
4. Stabholz A, Zeltser R, Sela M, Peretz B, Moshonov J, Ziskind D, Stabholz A. The use of lasers in dentistry: principles of operation and clinical applications. *Compend Contin Educ Dent* 2003; 24: 935-948.
5. George R, Walsh LJ. Performance assessment of novel side firing safe tips for endodontic applications. *J Biomed Opt* 2011; 16: 048004.
6. Noiri Y, Katsumoto T, Azakami H, Ebisu S. Effects of Er:YAG laser irradiation on biofilm-forming bacteria associated with endodontic pathogens *in vitro*. *J Endod* 2008; 34: 826-829.
7. Yavari HR, Rahimi S, Shahi S, Lotfi M, Barhaghi MH, Fatemi A, Abdolrahimi M. Effect of Er, Cr: YSGG laser irradiation on *Enterococcus faecalis* in infected root canals. *Photomed Laser Surg* 2010; 28: S91-S96.
8. Fried D, Glena RE, Featherstone JD, Seka W. Nature of light scattering in dental enamel and dentin at visible and near-infrared wavelengths. *Appl Opt* 1995; 34: 1278-1285.
9. Moriyama EH, Zângaro RA, Villaverde AB, Lobo PD, Munin E, Watanabe IS, Júnior DR, Pacheco MT. Dentin evaluation after Nd:YAG laser irradiation using short and long pulses. *J Clin Laser Med Surg* 2004; 22: 43-50.
10. Armon E, Laufer G. Analysis to determine the beam parameters which yield the most extensive cut with the least secondary damage. *J Biomech Eng* 1995; 107: 286-290.

11. van Leeuwen TG, Jansen ED, Motamedi M, Borst C, Welch AJ. Pulsed laser ablation of soft tissue. In: Welch AJ, van Gemert MJC, eds. "Optical-Thermal Response of Laser-Irradiated Tissue." New York: Plenum Press, 1995.
12. Marchesan MA, Brugnera-Junior A, Souza-Gabriel AE, Correa-Silva SR, Sousa-Neto MD. Ultrastructural analysis of root canal dentine irradiated with 980-nm diode laser energy at different parameters. *Photomed Laser Surg* 2008; 26: 235-240
13. Gurbuz T, Ozdemir Y, Kara N, Zehir C, Kurudirek M. Evaluation of root canal dentin after Nd:YAG laser irradiation and treatment with five different irrigation solutions: a preliminary study. *J Endod* 2008; 34: 318-321.
14. Koba K, Kimura Y, Matsumoto K, Gomyoh H, Komi S, Harada S, Tsuzuki N, Shimada Y. A clinical study on the effects of pulsed Nd:YAG laser irradiation at root canals immediately after pulpectomy and shaping. *J Clin Laser Med Surg* 1999; 17: 53-56.
15. Dostálová T, Jelínková H, Housová D, Sulc J, Nemeč M, Dusková J, Miyagi M, Krátky M. Endodontic treatment with application of Er:YAG laser waveguide radiation disinfection. *J Clin Laser Med Surg*. 2002;20: 135-139.
16. Leonardo MR, Guillén-Carías MG, Pécora JD, Ito IY, Silva LA. Er:YAG laser: antimicrobial effects in the root canals of dogs' teeth with pulp necrosis and chronic periapical lesions. *Photomed Laser Surg* 2005; 23: 295-299.
17. Bahcall J, Howard P, Miserendino L, Walia H. Preliminary investigation of the histological effects of laser endodontic treatment on the periradicular tissues in dogs. *J Endod*. 1992; 18(2): 47-51.
18. Soukos NS, Chen PS, Morris JT, Ruggiero K, Abernethy AD, Som S, Foschi F, Doucette S, Bammann LL, Fontana CR, Doukas AG, Stashenko PP. Photodynamic therapy for endodontic disinfection. *J Endod* 2006; 32: 979-984.
19. Williams JA, Pearson GJ, Colles MJ. Antibacterial action of photoactivated disinfection {PAD} used on endodontic bacteria in planktonic suspension and in artificial and human root canals. *J Dent* 2006; 34: 363-371.
20. Bonsor SJ, Nichol R, Reid TM, Pearson GJ. Microbiological evaluation of photo-activated disinfection in endodontics (an *in vivo* study). *Br Dent J* 2006; 25:337-341.
21. Bonsor SJ, Nichol R, Reid TM, Pearson GJ. An alternative regimen for root canal disinfection. *Br Dent J* 2006; 201:101-105.
22. Foschi F, Fontana CR, Ruggiero K, Riahi R, Vera A, Doukas AG, Pagonis TC, Kent R, Stashenko PP, Soukos NS. Photodynamic inactivation of *Enterococcus faecalis* in dental root canals *in vitro*. *Lasers Surg Med* 2007; 39: 782-787.
23. George S, Kishen A. Photophysical, photochemical, and photobiological characterization of methylene blue formulations for light-activated root canal disinfection. *J Biomed Opt* 2007; 12: 034029.
24. George S, Kishen A. Augmenting the anti-biofilm efficacy of Advanced Noninvasive Light Activated Disinfection with emulsified oxidizer and oxygen carrier. *J Endod* 2008; 34: 1119-1123.
25. Fimple JL, Fontana CR, Foschi F, Ruggiero K, Song X, Pagonis TC, Tanner AC, Kent R, Doukas RG, Stashenko PP, Soukos NS. Photodynamic treatment of endodontic polymicrobial infection *in vitro*. *J Endod* 2008; 34: 728-734.
26. Garcez AS, Nuñez SC, Hamblin MR, Ribeiro MS. Antimicrobial effects of photodynamic therapy on patients with necrotic pulps and periapical lesion. *J Endod* 2008;34:138-142.
27. Meire MA, De Prijck K, Coenye T, Nelis HJ, De Moor RJ. Effectiveness of different laser systems to kill *Enterococcus faecalis* in aqueous suspension and in an infected tooth model. *Int Endod J* 2009; 42: 351-359.

28. Pagonis TC, Chen J, Fontana CR, Devalapally H, Ruggiero K, Song X, Foschi F, Dunham J, Skobe Z, Yamazaki H, Kent R, Tanner AC, Amiji MM, Soukos NS. Nanoparticle-based endodontic antimicrobial photodynamic therapy. *J Endod* 2010; 36: 322-328.
29. Garcez AS, Nuñez SC, Hamblim MR, Suzuki H, Ribeiro MS. Photodynamic therapy associated with conventional endodontic treatment in patients with antibiotic-resistant microflora: a preliminary report. *J Endod*. 2010; 36(9): 1463-6.
30. Kishen A, Upadya M, Tegos GP, Hamblin MR. Efflux Pump Inhibitor Potentiates Antimicrobial Photodynamic Inactivation of *Enterococcus faecalis* Biofilm. *Photochem Photobiol* 2010; 86: 1343-1349.
31. Ng R, Singh F, Papamanou DA, Song X, Patel C, Holewa C, Patel N, Klepac-Ceraj V, Fontana CR, Kent R, Pagonis TC, Stashenko PP, Soukos NS. Endodontic photodynamic therapy *ex vivo*. *J Endod*. 2011; 37(2): 217-22.
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): 1275-8.
33. 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.
34. 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.
35. Peters OA, Bardsley S, Fong J, Pandher G, Divito E. Disinfection of root canals with photon-initiated photoacoustic streaming. *J Endod* 2011; 37: 1008-1012.

The guidance in this statement is not intended to substitute for a clinician's independent judgment in light of the conditions and needs of a specific patient.

Access additional resources at aae.org.

© 2019 American Association of Endodontists (AAE).