Lasers as Aids for Cleaning, Shaping, and Obturation of the Root Canal System

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LEARNING OBJECTIVES:

After reading this article, the individual will learn:

- Study results pertaining to the use of lasers in cleaning, shaping, and obturation of the root canal system.
- Effects of laser irradiation on the dentin walls of root canals.

ABOUT THE AUTHORS

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INTRODUCTION

This article reviews the clinical uses of lasers as aids for cleaning, shaping, and obturating the root canal system during endodontic treatment, and the effects of laser irradiation on the dentin walls of root canals. A brief historical perspective of laser development is provided.

BACKGROUND

LASER is an acronym for light amplification by stimulated emission of radiation. The concepts of stimulated emission of radiant energy that were the foundational basis for modern laser physics were discussed in the literature by Einstein in 1917. In 1960 Maiman constructed the first working laser using a ruby rod, and in 1961 Javan, et al developed a continuously generating helium and neon (HeNe) laser (633 nm [wavelength]) of low power.

Laser light is a man-made single photon wavelength which occurs when an atom is stimulated to emit a photon before this event spontaneously occurs (spontaneous emission of a photon by one atom stimulates the release of a subsequent photon, creating a chain event). Stimulated emission (man-made) generates a very coherent (synchronous waves), monochromatic (single wavelength), and collimated form (parallel rays) of light that is not found in nature. The concentrated light energy of a laser can target tissue at a much lower energy level than natural light. The photon that is emitted has a specific wavelength (expressed in “nm”), depending on the state of the electron’s energy when the photon is released. The characteristics of a laser depend on its wavelength.

Laser light that reaches tissue can be reflected, scattered, absorbed, or transmitted to surrounding tissues. Absorption of laser light by biological tissues is mainly due to the presence of free water molecules, proteins, pigments, and other macromolecules, with the absorption coefficient strongly dependent on the wavelength of the laser irradiation. Absorption by water molecules plays a significant role in thermal interactions. For water, the absorption coefficient ($\alpha$: cm$^{-1}$) for the argon laser (514 nm) is 0.00029; for the diode laser (800 nm) it is 0.20; for the neodymium:yttrium-aluminum-garnet (Nd:YAG) laser (1,064 nm) it is 0.61; for the erbium:YAG laser (2,940 nm) it is 12,000; and for the CO$_2$ laser (10,600 nm) it is 860.

LASERS IN DENTISTRY

The investigation of lasers for use in clinical dentistry began in the early 1960s with efforts to develop the basic laser parameters pertaining to dental hard and soft tissues. Due to the fact that synthetic ruby was the only available material used routinely as the active laser medium, many researchers at that time, including Stern and Sognnaes and Goldman, et al used the ruby laser to study tissue interaction with enamel and dentin. After these initial experiments, clinicians began using other lasers, including...
argen (Ar; 514 nm), carbon dioxide (CO₂; 10,600 nm), Nd:YAG (1,064 nm), and Er:YAG (2,940 nm) lasers.⁹

The first laser use in endodontics was reported by Weichman and Johnson¹⁰; they attempted in vitro sealing of the apical foramen using a high power-infrared (CO₂) laser. This was unsuccessful, but the data they obtained encouraged other studies, including attempts to seal the apical foramen using the Nd:YAG laser.

Currently, wavelengths emitted at the ultraviolet portion of the electromagnetic spectrum appear to be promising in certain endodontic applications. For example, the argon-fluoride (ArF) excimer laser (193 nm) can slowly and selectively remove necrotic debris from the root canal, leaving melted dentin walls that are smooth and free of cracks and fissures. The xenon-chloride (XeCl) excimer laser (308 nm) is capable of melting dentin and closing dentinal tubules.⁵,⁹,¹⁰

**LASERS AS AIDS IN CLEANING, SHAPING, AND OBTURATING THE ROOT CANAL SYSTEM**

**Laser Use in Disinfecting the Root Canal System**

Microorganisms play an essential role in the development and perpetuation of pulpal and periapical diseases.¹¹⁻¹³ Eliminating microorganisms from infected root canals is complex.¹⁴,¹⁵ A variety of instrumentation modalities, irrigation regimens, and intra-canal medicaments have been used in an attempt to reduce the microorganisms in the root canal system. Bactericidal potential is developed through direct cell contact,¹⁶ and chemical disinfection depends on the extent to which substances spread into the system. Sodium hypochlorite (NaOCl)¹⁷ and calcium hydroxide (Ca(OH)₂)¹⁸ have a limited ability to penetrate and disinfect the root canal system (approximately 130 µm penetration). Chlorhexidine and iodine-potassium-iodide are more effective in dentinal tubules than pure Ca(OH)₂ in a water vehicle, but complete disinfection has not been demonstrated.¹⁹,²⁰

In terms of prognosis of endodontic treatment, the relative importance of deep dentinal infection is not yet known. However, it is possible that reservoirs of infection within the root canal system may result in recurrence of infection following treatment.²¹ The monochromatic, coherent, and directional characteristics of laser light, and the fact that direct contact between target and fiber tip is not required, raise the possibility that emission of laser energy could provide a means to disinfect areas deep within the dentin.²²

Moshonov, et al²³ compared the efficacy of Nd:YAG laser irradiation versus NaOCl in disinfecting the root canal system, and found that Nd:YAG laser irradiation significantly reduced the number of bacteria, while NaOCl irrigation effectively disinfected the canals. Gutkencht, et al²⁴ determined that the bactericidal effect of the holmium-doped (Ho):YAG laser (2,100 nm) on root canals in vitro was very efficient. Klinke, et al²⁵ evaluated the bactericidal effects of Nd:YAG laser irradiation in the different thicknesses of the root canal dentin, and found that laser irradiation resulted in a highly significant elimination of bacteria for all thicknesses. Although after penetration of a 1,000-µm dentin slice the intensity of the laser irradiation decreased, the study found that the bactericidal mode of action was still effective. Le Goff, et al²⁶ compared the bactericidal action of the CO₂ laser versus NaOCl on animal teeth that were infected with *Actinomyces odontolyticus*. The study found that in the laser-treated group there was an average decrease of 85% in the colony-forming units compared with the control group. However, the NaOCl treatment was statistically superior to the CO₂ laser treatment.

Moritz, et al²⁷ assessed the disinfecting potential of the Nd:YAG laser through dentin on the cell structure of Gram-negative and Gram-positive bacteria. The study found that the Gram-negative test organism showed immediate structural injury, but the Gram-positive test organism required repeated application of irradiation. The authors concluded that the construction of the cell wall was crucial for their individual sensitivity to laser treatment. Perin, et al²⁸ evaluated the antimicrobial effect of Er:YAG laser irradiation versus 1% NaOCl irrigation for root canal disinfection. The study found that both methods were effective to working length against all microorganisms, but that 70% of the specimens irradiated 3 mm short of the apex remained infected.

Schoop, et al²⁹ found that the disinfecting effect of the chromium: yttrium-scandium-gallium-garnet Er₃(Cr:YSGG)
(2,780 nm) laser in root dentin samples was dependent on the output power but was not specific for the bacterial species investigated. Gordon, et al\textsuperscript{30} investigated the ability of an Er,Cr:YSGG laser with radial emitting tips to disinfect dentin infected with \textit{Enterococcus faecalis}. The study found that bacterial recovery decreased when laser irradiation duration or power increased. A 120-second laser application resulted in a greater degree of disinfection than with NaOCl treatment. A study by Bergmans, et al\textsuperscript{31} concluded that Nd:YAG laser irradiation was not an alternative but a possible supplement to existing protocols for canal disinfection, as the properties of laser light may allow a bactericidal effect beyond 1 mm of dentin.

Berkiten, et al\textsuperscript{32} evaluated the effects of Nd:YAG laser irradiation (both 1.8W and 2.4W) on root canals and dentinal tubules inoculated with \textit{Streptococcus sanguis} and \textit{Prevotella intermedia}. Post-treatment examination using light microscopy found that the 1.8W laser sterilized in 86.3\% of the \textit{S sanguis} sections, and the 2.4W laser sterilized in 98.5\% of these sections. In the \textit{P intermedia} sections, both lasers sterilized all samples.

Hardee, et al\textsuperscript{33} evaluated 50 root canals that were first sterilized, then inoculated with a known quantity of \textit{Bacillus stearothermophilus} spores. Four groups of 10 canals were treated with pulsed Nd:YAG laser irradiation or with 0.5\% NaOCl alone, and in combination. A fifth control group received no treatment. They found a 2-log reduction in colony-forming units among the 4 treatment groups when compared to the control group, but no significant differences were observed among the treatment groups, and none of the treatment groups resulted in sterilized root canals.

Wang, et al\textsuperscript{34} evaluated the bactericidal effect of the Er,Cr:YSGG laser and the Nd:YAG laser in straight root canals that were inoculated with \textit{E faecalis} for 3 weeks. After laser irradiation, the number of bacteria in each root canal was determined. The study found that the Er,Cr:YSGG laser irradiation resulted in a reduction in bacteria of 77\% after irradiation at 1W, and a reduction of 96\% after irradiation at 1.5W, but there was no significant difference. The Nd:YAG laser irradiation resulted in a reduction in bacteria of 97\% at 1W and 98\% at 1.5W, with no significant difference. The authors concluded that the Nd:YAG laser is more effective than the Er,Cr:YSGG laser, but both lasers produced a significant bactericidal effect in the infected root canals.

Schoop, et al\textsuperscript{35} evaluated the use of the Er,Cr:YSGG laser with radial-firing tips in terms of bacteriology, morphology, and temperature measurements in root canals. The canals were inoculated with 2 test strains of bacteria and were irradiated with power settings of 0.6 W and 0.9 W and a repetition rate of 20 Hz. The bacteriological evaluation revealed a decisive disinfectant effect. It was also observed that the smear layer was homogeneously removed from the root canal walls, and temperature elevation at the root surface during irradiation was moderate. The study concluded that in conjunction with radial-firing tips, the Er,Cr:YSGG laser is a suitable device for eliminating bacteria in root canals and for the removal of smear layer.

**Laser Effects on the Dentin Walls of Root Canals**

Endodontic instrumentation produces a smear layer of organic and mineral debris on the wall of the root canal, and although this smear layer may be beneficial by obstructing tubules and decreasing dentin permeability, it also may harbor bacteria and bacterial products.\textsuperscript{36} Therefore, lasers are being studied regarding the removal of the smear layer (and replacing it with a chemical sealant that is not contaminated), or sealing by melting the dentin surface. The laser was first applied for in vitro sealing of the apical foramen.\textsuperscript{10} Pashley, et al\textsuperscript{37} evaluated the in vitro effect of the CO\textsubscript{2} on the structure and permeability of human dentin covered by smear layer, using 3 different energy levels (11, 113, and 566 J/cm\textsuperscript{2}). They found that the lowest exposure to the laser energy increased dentin permeability as a result of partial loss of the superficial smear layer and smear plugs. The intermediate energy level also increased dentin permeability due to the formation of craters, thus resulting in thinner dentin. The surface of the craters that were formed were not uniformly glazed and were porous, communicating with the underlying dentinal tubules; this contributed to the increase in dentin permeability. The highest laser energy resulted in complete glazing of the crater surfaces and sealed the dentinal tubules beneath the crater. However, this level of energy completely removed the smear layer around each crater in a zone about 100-\textmu m wide;
this increased the permeability of the pericrater dentin while decreasing the permeability of the dentin within the crater.

Using a modified Nd:YAG laser, Tewfik, et al\textsuperscript{38} determined that this laser did not change the permeability of the dentin covered by smear layer, however, scanning electron microscope (SEM) examination revealed that the surface of the smear layer was modified. When etched dentin was lased, modest increases in root permeability were produced, which were associated with enlargement and cracking of the orifices of the tubules.

Eto, et al\textsuperscript{39} evaluated in vitro the morphological and atomic analytical changes of the dentin of the root canal wall that had been treated with 38% diamine silver fluoride (Ag[NH₃]₂F) solution and irradiated by CO₂ laser (continuous wave mode). They found that in the control and lased specimens, the smear layer and debris were not completely removed. However, on the specimens treated with Ag[NH₃]₂F and lased at 1W the areas of carbonization of evaporation of smear layer and open dentinal tubules were observed. After laser irradiation, the amount of silver on the root canal surfaces was significantly reduced.

Takeda, et al\textsuperscript{40} created a smear layer in vitro in the middle and apical thirds of root canals using hand instrumentation, then evaluated the effects on this smear layer of 3 endodontic irrigants and 2 types of lasers (Er:YAG and CO₂). The study found that irrigation with 17% EDTA, 6% phosphoric acid, and 6% citric acid did not remove the entire smear layer from the root-canal system. Further, these acidic solutions demineralized the intertubular dentin around tubular openings, enlarging them. The CO₂ laser was useful in removing and melting the smear layer on the instrumented root-canal walls, and the Er:YAG laser was the most effective in removing the smear layer from the root-canal wall.

The in vitro effect of the Er:YAG laser on dentin root canal wall permeability following endodontic instrumentation and irrigation with water or NaOCl was investigated by Pecora, et al\textsuperscript{41} The instrumentation of the root canal irrigated with water followed by Er:YAG laser irradiation resulted in the greatest increase in dentin permeability. A lower level of dentin permeability resulted from the use of the Er:YAG laser alone, 1% NaOCl + the Er:YAG laser, and 1% NaOCl alone. The least dentin permeability was observed following the use of water alone as the irrigating solution.

Kaitsas, et al\textsuperscript{42} investigated the morphological and histological changes on the root canal walls after Nd:YAG laser application. Debris and smear layer on the root canal surface which obscured the dentin tubules was found in the controls. In the root canal walls irradiated with the Nd:YAG laser, a clear glazed surface, some open dentinal tubules, and some surface craters with cracks were observed. These observations indicate that smear layer and debris can be removed with the Nd:YAG laser, but it is difficult to clean all root canal walls. Further, if inadequate energy level and duration of application are employed, thermal damage and morphological changes in dentin structure may be observed.

Moshonov, et al\textsuperscript{43} compared the efficacy of root canal cleanliness with and without the Nd:yttrium-aluminum-peroskite (YAP) laser (1,340 nm) and assessed the effect of the laser on the mineral content of the dentin. The cleanliness of the laser-treated teeth was significantly greater than teeth treated with K files alone. Furthermore, no difference in calcium and phosphorous content was detected when the use of K files was compared to the use of laser.

The effects of copper vapor laser irradiation on the radicular wall of human teeth was analyzed by Niccoli-Filho, et al.\textsuperscript{44} SEM analysis showed a cavity in the region of laser beam impact with melting, recrystallization, and cracking on the edges of the dentin of the cavity caused by heat diffusion. A study by Camargo, et al\textsuperscript{45} evaluated the effects of Nd:YAG laser irradiation that was applied perpendicular or parallel to the root canal dentin wall. SEM analysis indicated that intracanal laser application using circular movements (parallel to the surface) produced limited morphological changes in the dentin walls of the root canal.

**Laser Use in Shaping Root Canals**

Proper shaping of the root canal helps remove organic tissues and facilitate canal irrigation and obturation. Using an optical fiber to improve accessibility, laser beams can be delivered to the root canal after the canal has been widened using conventional methods. The diameter of the fiber that is used inside the canal space ranges from 200 to 400
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micrometers (equivalent to a No. 20-40 file). Laser irradiation from apical to coronal surface in a continuous, circling fashion is considered optimal technique.

Levy found that Nd:YAG irradiation can produce clean and regular root canal walls. Altundasar, et al evaluated the ultramorphological and chemical changes in radicular dentin that had been treated with Er,Cr:YSGG laser irradiation, compared with treatment with NaOCl irrigation and RC-Prep + NaOCl irrigation. SEM analysis found that in the NaOCl-irrigated specimens the smear layer was not removed. In the dentin treated with RC-Prep + NaOCl irrigation, there was moderate-to-total presence of the smear layer with distinct areas of exposed collagen. In the dentin treated with Er,Cr:YSGG laser irradiation, partial or total removal of the smear layer was observed, and was associated with a few small regions of thermal injury, including carbonization and partial melting.

Inamoto, et al evaluated in vitro the cutting efficiency of the Er:YAG laser and morphological changes of root dentin after irradiation. The study found that no smear layer remained after irradiation, and changes in width and depth of the dentin after irradiation led the authors to conclude that under the study conditions the Er:YAG laser was an effective tool for root canal preparation. Minas, et al investigated use of the Er,Cr:YSGG laser in preparing root canals of posterior teeth with step-back technique. The study found that posterior root canal preparation could be achieved by the laser beam transmitted to the canal using endodontic tips. However, the authors cautioned that laser root canal preparation has certain limitations, and improvements are needed in order to achieve better preparation outcomes.

Kesler, et al evaluated the effectiveness of Er:YAG laser microprobes in cleaning and shaping straight root canals without the use of any mechanical instrumentation. The study found that no residual pulp tissue was found in the root canal cavity after laser treatment, and open tubules were observed in all specimens. SEM analysis showed that the root canals were free of debris, the smear layer was removed, and there were different levels of enlargement. The authors concluded that the Er:YAG laser microprobes used in the study were effective in shaping, cleaning, and enlarging straight root canals faster and more efficiently than traditional methods. Shoji, et al developed a cone-shaped laser irradiation tip that delivered 80% of the energy of the laser laterally and 20% forward, equipped it with a water nozzle, and examined the effect of Er:YAG irradiation using this tip on root canal enlargement and debridement. SEM observations indicated that after laser preparation, the dentin surface appeared cleaner than that obtained after preparation by drilling. Further, the laser technique may have the advantage of decreasing preparation time.

Using lasers in root canals has certain limitations. For example, the optic fiber may not touch all canal walls, therefore areas with clean surfaces are interspersed with areas covered by residual debris. Further, when canals are severely curved, access may be difficult or limited.

Laser Use in Obturating the Root Canal System

Root canal obturation involves 3-dimensional sealing of the root canal system with prevention of leakage from the apical foramen up to the coronal aspect of treated teeth. Sealing a root canal completely may increase the clinical success to a rate as high as 96.5%. A study by Maden, et al compared the apical leakage of lateral condensation, gutta-percha softened by the Nd:YAG laser, and System-B techniques. The study found no significant difference in apical microleakage among the 3 groups, however, lateral condensation and System-B resulted in less leakage than laser-softened gutta-percha.

Kimura, et al observed that Er:YAG laser irradiation (170 to 250 mJ, 2 Hz) of the root canal did not affect apical leakage following obturation when compared with conventional methods. They also demonstrated that use of the Nd:YAG laser was useful for the reduction of apical leakage. Sousa-Neto, et al demonstrated that application of Er:YAG laser beam (200 mJ, 4 Hz) for 60 seconds enhanced the adhesion of epoxy resin-based sealers in comparison with zinc oxide-eugenol-based sealers. A study by Sousa-Neto, et al evaluated the adhesion of an epoxy-based sealer to human dentin that had been irradiated with the Er:YAG or Nd:YAG laser using various parameters. The study found that increasing the frequency of the lasers, independent of power settings, resulted in increased adhesion of the sealer. A study by Varella and Pileggi investigated the number of canals and isthmuses obturated.
after Er,Cr:YSGG laser treatment. They found that Er,Cr:YSGG treatment resulted in a statistically significant greater number of canals/isthmuses obturated. de Moura-Netto, et al\textsuperscript{59} investigated the effects of Nd:YAG and diode laser irradiation on apical sealing when applied prior to filling the root canal with 2 different resin-based cements (AH Plus and EndoREZ). The SEM analysis as well as leakage results revealed better filling adaptation for AH-Plus and the Nd:YAG laser group.

**Laser Use in Endodontic Retreatment**

Endodontic failures can be attributed to inadequacies in cleaning, shaping, and/or obturation, iatrogenic events, or reinfection of the root canal system. Regardless of the initial cause, the sum of causes is bacterial contamination. The objective of nonsurgical retreatment is to eliminate sources of irritation to the attachment apparatus from the root canal system. Some of these failures may be managed by endodontic retreatment.\textsuperscript{60}

The rationale for using lasers in nonsurgical retreatment may be attributed to their efficacy in removing gutta-percha and sealer from the root canal space. Yu, et al\textsuperscript{61} found that using the Nd:YAG laser at 3 output powers (1, 2, 3W), enabled the removal of filling material in more than 70% of cases, and broken instruments in 55% of cases. Anjo, et al\textsuperscript{62} examined the usefulness of a pulsed Nd:YAG laser in removing 2 types of endodontic obturation materials from the root canal in vitro. Results showed that although none of the methods used in this study resulted in complete removal of debris from the root canal wall, the time required for the removal of any of the root canal obturation materials using laser ablation was significantly shorter than that required using the conventional method. They concluded that Nd:YAG laser irradiation was an effective tool for the removal of root canal obturation materials, and may offer advantages over the conventional method.

Farge, et al\textsuperscript{63} found that the Nd:YAP laser could not completely remove debris and obturating material from the root canal space.

**CONCLUSIONS**

This article has reviewed the use of lasers in cleaning, shaping, and obturating the root canal system, and the effects of lasers on root canal dentin walls during these laser applications. Certain types of lasers as discussed in this review can remove smear layer and debris from root canal walls; however, cleaning all root canal walls with these devices is difficult because the linear emission of the laser beam makes it almost impossible to irradiate the lateral canal walls, and leaves them rough and uneven. Root canal spaces are rarely straight; more often, they are curved in at least 2 dimensions.

It appears that NaOCl has greater antibacterial efficacy than laser irradiation when cleaning root canal systems. Therefore, laser irradiation should not be considered as an alternative to NaOCl but should be considered as a supplement to existing protocols for canal disinfection; the properties of laser light may allow a bactericidal effect beyond 1 mm of dentin.

Laser irradiated canal walls usually show a clear, glazed surface. Further, smear layer and debris are removable with lasers, however, clearing all root canal walls of smear layer and debris is still difficult and, if the energy level and duration of application are inadequate, a certain degree of thermal damage and morphological changes in dentin structure may be observed.

Lasers increase adhesion of epoxy-based root canal sealers, improve the adaptation of root canal fillings, and dependent on the conditions, may or may not improve the sealing ability of root canal fillings.

As an aid in endodontic retreatment procedures, none of the lasers reviewed result in complete removal of filling materials from the root canal walls. However, the time required for the laser removal of any of the root canal obturation materials appears to be significantly shorter than that required using conventional methods.
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REFERENCES

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### POST EXAMINATION QUESTIONS

1. The first working laser used which of the following:
   a. argon.
   b. helium.
   c. ruby.
   d. carbon dioxide (CO₂).

2. Man-made stimulated emission of a photon generates:
   a. synchronous waves.
   b. parallel rays.
   c. single wavelength.
   d. all of the above.

3. For water, the absorption coefficient for the argon laser is:
   a. 0.00029.
   b. 0.20.
   c. 0.61.
   d. 860.

4. The wavelength of the CO₂ laser is:
   a. 514 nm.
   b. 1,064 nm.
   c. 2,940 nm.
   d. 10,600 nm.

5. The first laser used in endodontics as reported by Weichman and Johnson was which type of laser?
   a. neodymium: yttrium-aluminum-garnet (Nd:YAG)
   b. CO₂
   c. xenon chloride excimer
   d. erbium-doped (Er):YAG

6. The depth of penetration of sodium hypochlorite (NaOCl) and calcium hydroxide (Ca[OH]₂) for disinfection of root canals is approximately:
   a. 130 µm.
   b. 240 µm.
   c. 650 µm.
   d. 1 mm.
7. Klinke, et al determined that Nd:YAG laser irradiation was bactericidal to a dentin depth of penetration of:
   a. 1,000 µm.
   b. 1,500 µm.
   c. 2,000 µm.
   d. 2,500 µm.

8. Le Goff, et al determined that CO₂ laser irradiation of the root canal is bactericidal. CO₂ irradiation was statistically more bactericidal than NaOCl.
   a. The first statement is true; the second statement is false
   b. The first statement is false; the second statement is true
   c. Both statements are true
   d. Both statements are false

9. Schoop, et al found that the disinfecting effect of the Er, chromium: yttrium-scandium-gallium-garnet (Cr:YSGG) laser in root dentin was not dependent on output power. The disinfecting effect was dependent on the specific bacterial species.
   a. The first statement is true; the second statement is false
   b. The first statement is false; the second statement is true
   c. Both statements are true
   d. Both statements are false

10. Wang, et al found that both the Er,Cr:YSGG and the Nd:YAG lasers had a significant bactericidal effect. They found that the Nd:YAG laser was more effective in this regard than the Er,Cr:YSGG laser.
    a. The first statement is true; the second statement is false
    b. The first statement is false; the second statement is true
    c. Both statements are true
    d. Both statements are false

11. Which of the following was found most effective at removing smear layer from root canals?
    a. 17% EDTA
    b. 6% phosphoric acid
    c. CO₂ laser
    d. Er:YAG laser

12. Smear layer and debris can be removed from root canals with the Nd:YAG laser. However, it is difficult to clean all root canal walls with the laser.
    a. The first statement is true; the second statement is false
    b. The first statement is false; the second statement is true
    c. Both statements are true
    d. Both statements are false

13. The diameter of the optical fiber used in laser irradiation of root canals is equivalent to:
    a. No. 15-20 size file.
    b. No. 20-40 size file.
    c. No. 40-50 size file.
    d. No. 50-60 size file.

14. Inamoto, et al found that smear layer remained after irradiation with the Er:YAG laser. They found that the Er:YAG laser was effective for root canal preparation.
    a. The first statement is true; the second statement is false
    b. The first statement is false; the second statement is true
    c. Both statements are true
    d. Both statements are false

15. Sousa-Neto, et al found that application of Er:YAG laser beam for 60 seconds enhanced the adhesion of ___________ to human dentin.
    a. zinc oxide eugenol-based sealer
    b. Ca(OH)₂
    c. epoxy-based sealer
    d. all of the above

16. Moshonov, et al found that the cleanliness of root canals irradiated with the Nd: yttrium-aluminum-peroskite laser was significantly greater than canals reated with K files. There was a significant difference in calcium and phosphorous content of the dentin between the 2 treatments.
    a. The first statement is true; the second statement is false
    b. The first statement is false; the second statement is true
    c. Both statements are true
    d. Both statements are false
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Please check the correct box for each question below.

1. ☐ a ☐ b ☐ c ☐ d
2. ☐ a ☐ b ☐ c ☐ d
3. ☐ a ☐ b ☐ c ☐ d
4. ☐ a ☐ b ☐ c ☐ d
5. ☐ a ☐ b ☐ c ☐ d
6. ☐ a ☐ b ☐ c ☐ d
7. ☐ a ☐ b ☐ c ☐ d
8. ☐ a ☐ b ☐ c ☐ d

9. ☐ a ☐ b ☐ c ☐ d
10. ☐ a ☐ b ☐ c ☐ d
11. ☐ a ☐ b ☐ c ☐ d
12. ☐ a ☐ b ☐ c ☐ d
13. ☐ a ☐ b ☐ c ☐ d
14. ☐ a ☐ b ☐ c ☐ d
15. ☐ a ☐ b ☐ c ☐ d
16. ☐ a ☐ b ☐ c ☐ d

PROGRAM EVALUATION FORM
Please complete the following activity evaluation questions.

Rating Scale: Excellent = 5 and Poor = 0

Course objectives were achieved. ____________________

Content was useful and benefited your clinical practice. ____________________

Review questions were clear and relevant to the editorial. ____________________

Illustrations and photographs were clear and relevant. ____________________

Written presentation was informative and concise. ____________________

How much time did you spend reading the activity & completing the test? ____________________