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ORIGINAL ARTICLE

# Evaluation of root canal smear layer removal by two types of lasers: A scanning electron microscopy study

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## ABSTRACT

**Objective:** This study was to compare the effects of Erbium: Yttrium-Aluminium-Garnet (Er: YAG), and Neodimium: Yttrium-Aluminium-Garnet (Nd: YAG) lasers on removing the smear layer using scanning electron microscopy. **Background:** Removing Smear layer and exposure of dentinal tubules facilitate a tight-fitting root canal filling, which is necessary for a successful endodontic treatment and one of the proposed methods for removing the smear layer is the use of lasers. **Materials and Methods:** In this experimental study, 55 human single-rooted teeth were examined. Instrumentation was done using the step-back technique with hand files up to file #40 at the apical area and file #80 at the coronal area. The samples were divided into three groups: Samples irradiated by the Er: YAG laser (1 W, 10 Hz, 130.7 J/cm$^2$) in Group 1 ($n$=25), the Nd: YAG laser (2 W, 15 Hz, 188.25 J/cm$^2$) in Group 2 ($n$=25) and samples irrigated by 5.25% NaOCl as the control in Group 3 ($n$=5). Next, roots were bisected longitudinally and prepared for scanning electron microscopy. Data were analyzed using the Kruskal-Wallis, Mann-Whitney, Friedman and Wilcoxon tests ($P$<0.05). **Results:** The Er: YAG laser can remove more of the smear layer from the root canal wall than the Nd: YAG laser ($P$=0.000). Comparisons between three regions showed that both of the lasers proved less efficient in apical parts of the root canal. **Conclusion:** Based on the findings of the present study, irradiation by the Er: YAG laser was more effective in smear layer removal than the Nd: YAG laser.

**Key words**
Erbium: Yttrium-Aluminium-Garnet laser, neodymium: Yttrium-aluminum-garnet laser, smear layer

## INTRODUCTION

The mechanical instrumentation of root canals and the removal of dentin give rise to the formation of a thin smear layer covering the whole root canal wall.[1] McComb and Smith first described this layer in instrumented root canals.[2] The smear layer is a structure composed of organic and inorganic parts, including fragments of odontoblastic processes, microorganisms and necrotic tissue. It has an amorphous, irregular and granular structure under the scanning electron microscope.[3] The presence of this smear layer prevents the penetration of intracanal medication into the irregularities of the root canal system and the dentinal tubule and prevents well adaptation of obturating materials to the prepared root canal surface.[4,5] Although the effect of smear layer removal on a successful root canal treatment remains controversial, it seems that its removal is beneficial.[6,7]

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Different irrigants and chelating agents, such as Ethylene Diamine Tetra acetic Acid (EDTA), citric acid, and phosphoric acid, have been recommended to remove the inorganic component of the smear layer, and sodium hypochlorite has been recommended for the removal of the organic component.[8] However, many studies have pointed the limited capacity of irrigants to reach all internal surfaces of the root canal structure. Therefore, more effective methods to clean and penetrate dentinal walls are necessary.[9]

Since the early 1970s, lasers have been used for non-surgical root canal treatments. In general, dental lasers provide access to otherwise unreachable parts of the tubular network, according to this fact that they penetrate dental tissues better than rinsing solutions.[10]

The laser diode has a wavelength of 810 nm and favorable bactericidal capabilities as shown by Moritz *et al.*[11] Onal *et al.* demonstrated the capacity of a $CO_2$ laser to remove organic tissue from root canals, fuse hydroxyapatite, and open dentinal tubules.[12] Takeda *et al.* found that the $CO_2$ laser can remove and melt the smear layer on instrumented root canal walls.[13] Harashima *et al.* observed that argon laser irradiation of instrumented root canals produced melted dentin surfaces and vaporized debris and pulpal tissue.[14] For the removal of dental hard tissue, Erbium: Yttrium-Aluminium-Garnet (Er: YAG) laser provides the most suitable wavelength (2,940 nm) and approved by the Food and Drug Administration (FDA) for the cleaning and shaping of the root canal.[15] This laser acts through photoablation because its wavelength correlates closely with the maximum absorbance of hydroxyapatite. When irradiated, the water in the dental hard tissue evaporates instantaneously and thereby ablates the surrounding tissue with minimal thermal side effects. This has been demonstrated in various studies by Hibst and Keller.[16-20] Previously, the application of the Er: YAG laser was limited to the rigid delivery of fibers in non-contact mode. The development of narrow and flexible fibers distinctly broadened the spectrum of this laser's possibilities. Teeth with narrow or bent root canals can also be easily treated.[21] The most widely used laser in endodontic is the Neodimium: Yttrium-Aluminium-Garnet (Nd: YAG) laser, which has a wavelength of 1,064 nm. Because the wavelength is in the near-infrared range, flexible conductors can be used in narrow and curved root canals.[10] This laser provides a bactericidal effect on root canal surfaces and in the deeper dentin layers.[22] There have been many studies yielding different results regarding the application of lasers in endodontics. With the above facts in mind, the aim of this study was to compare the effects of Er: YAG and Nd: YAG laser systems on the removal of the smear layer of the root canal wall; this evaluation was made using scanning electron microscopy.

## MATERIALS AND METHODS

### Specimen preparation

For this experimental study, 55 human mature teeth that had been extracted because of periodontal or prosthetic reasons were used. The intact, randomly selected permanent teeth had not previously received any root canal medicaments, and the root lengths were approximately 13 mm. Each tooth was radiographed to verify the presence of a single canal, a mature apex and the absence of any resorption or endodontic obturation. Superficial soft tissues were removed with a brush, and then the teeth were stored in normal saline until use.

### Root canal instrumentation

After access cavity preparation using diamond fissure burs (Tizcavan, Tehran, Iran), the canal length was determined by reducing 1 mm from the length recorded when a #15 k-file was placed through the apical foramen. All tooth apexes were sealed with utility wax to prevent flow through them. Instrumentation was done using the step-back technique with hand files up to file #40 at the apical area and file #80 at the coronal area. During instrumentation, irrigation was done between each file by 1 ml of 5.25% NaOCl using a 30-gauge needle. The teeth were decoronated and randomly separated into three groups.

### Groups

#### *Group 1 (n=25)*

The Er: YAG laser of a 2940-nm wavelength (Fotona, Fidelis plus, Ljubljana, Slovenia) was applied with a fiber optic tip 300 μm in diameter and 20 mm in length [Figure 1], with spiral movement from the apex to the coronal region with the following parameters: Repetition rate=10 Hz, output energy=1 W, and energy density=130.7 J/cm$^2$. The laser was applied 5 times, and each application lasted 3 s along the root canal (a total of 15 s). Air and water were sprayed through the handpiece to prevent the overheating of dentin.

#### *Group 2 (n=25)*

The Nd: YAG laser of a 1064-nm wavelength (Fotona, Fidelis plus, Ljubljana, Slovenia) was applied with a fiberoptic tip 300 μm in diameter [Figure 2], with spiral

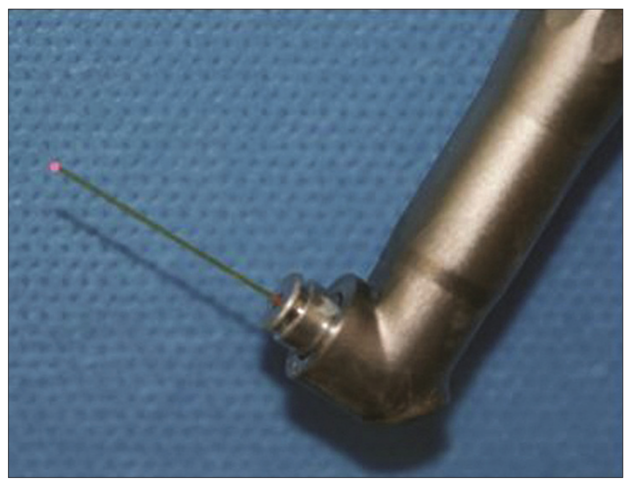

**Figure 1:** Optical fiber of Erbium: Yttrium-Aluminium-Garnet laser

**Figure 2:** Optical fiber of Neodimium: Yttrium-Aluminium-Garnet laser

movement from the apex to the coronal region with the following parameters: Repetition rate=15 Hz, output energy=2 W, and energy density=188.25 J/cm$^2$. The laser was applied 4 times, and each application lasted 10 s (a total of 40 s) with 15-s intervals.

### *Group 3 (n=5)*

Irrigation was done with 5 ml of NaOCl and then with 2.5 ml of distilled water.

Preparation and analysis of specimens for SEM.

All roots were longitudinally bisected to their buccal and lingual segments by the wedging process, and one of the sections was randomly selected for processing.

The specimens from all groups were fixed in 5% glutaraldehyde for 2-3 h and then washed 3 times in phosphate buffer. The specimens were then dehydrated in a graded series of aqueous ethanol solutions (30%, 50%, 70%, 90%, and 100% ethanol). The samples were dried using liquid $CO_2$ for 30 min. They were mounted on SEM stubs and sputter-coated with a gold–palladium alloy under a vacuum (Bio-Rade E 5200 Sputter coater). Each specimen was examined in three regions (apical, middle, and coronal), and photographed at ×2500 magnification with a scanning electron microscope (cam scan mv 2300, Oxford instrument-UK).

### Statistical analysis

A single-blind evaluation of the SEM micrographs was carried out by two examiners according to the rating system shown in Table 1.[23] Data was analyzed using SPSS software, version 16. Kruskal-Wallis and Mann-Whitney tests were used to compare the groups. Friedman and Wilcoxon tests were applied for the comparison of smear layer removal between the three regions.

## RESULTS

The results obtained from this study are summarized in Table 2 and [Figures 3-10] show the SEM photomicrographs of the control and irradiated samples by Er: YAG and Nd: YAG lasers. According to this study, there were statistically significant differences in smear layer removal between the three groups ($P$=0.00). Each laser was more effective at smear layer removal than the control (Nd: YAG ($P$=0.04), Er: YAG ($P$=0.00)). Additionally, the Er: YAG laser was able to remove more smear layer than the Nd: YAG laser ($P$=0.00).

The Nd: YAG laser proved significantly different ($P$=0.009) in smear layer removal among the three regions (coronal > middle > apical). In Er: YAG group, smear layer removal was greater in the coronal and middle regions than the apical region of the root canal ($P$=0.003 and $P$=0.02, respectively) with no differences between the coronal and middle regions ($P$=0.09). In the control group, smear layer removal was similar among the three regions of the root canal ($P$=0.05) [Figure 11].

**Table 1: The rating system**

| Score | Contents |
|---|---|
| 1 | The surface is devoid of debris and smear layer |
| 2 | The surface is devoid of smear layer, but minor debris is observed |
| 3 | The surface has been cleaned, but both smear layer and debris are dispersedly observed |
| 4 | The surface has been cleaned, but the level of smear layer and debris is also noticeable |
| 5 | The clean surface area is a bit greater than the unclean surface area |
| 6 | Almost half of the smear layer and debris have been removed |
| 7 | The greater part of the smear layer and debris are left |
| 8 | The surface is completely covered with smear layer and debris |

**Table 2: Mean amounts of smear layer in groups and regions**

| Groups | Regions | Mean±SD |
|---|---|---|
| Er: YAG laser | Apical | 6.44±1.38 |
| | Middle | 5.36±1.69 |
| | Coronal | 4.62±1.93 |
| Nd: YAG laser | Apical | 7.76±0.45 |
| | Middle | 7.30±1.06 |
| | Coronal | 6.10±2.37 |
| Control | Apical | 7.60±0.41 |
| | Middle | 8.00±0.00 |
| | Coronal | 8.00±0.00 |

Er: YAG – Erbium: Yttrium-Aluminium-Garnet; Nd: YAG – Neodimium: Yttrium-Aluminium-Garnet

## DISCUSSION

Success in root canal treatment depends to a great extent on completely cleaning the root canal.[10] Rinsing solutions used during conventional root canal therapy can partly affect the bacterial content of the canal.[20] It was demonstrated that bacteria penetrate the periluminal dentin up to a depth of 1100 µm,[24] while chemical disinfectants penetrate it to a depth of only 100 µm.[25] Curved root canals or side branches create restrictions in conventional root canal treatment. The use of lasers helps to overcome these problems. The high-penetration depth of laser beams in dentinal tubules seems to be the best explanation of the satisfying of different laser wavelengths, like Nd: YAG, Er: YAG, $CO_2$ and diode lasers.[10]

Up to now, these lasers have been used in endodontic treatments, and many studies have been published on their effects. Among them, the Er: YAG laser provides the most suitable wavelength. Because this laser acts

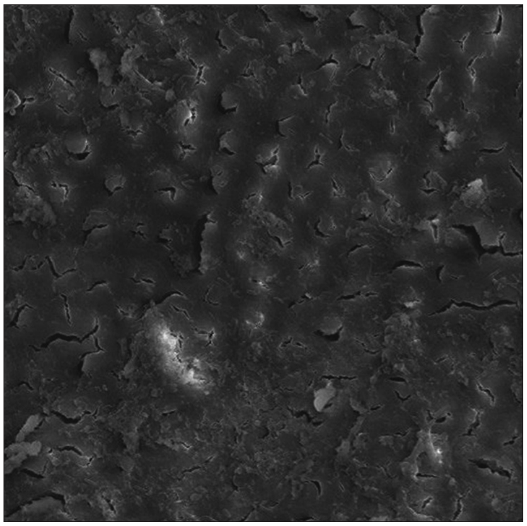

**Figure 3:** Scanning electron micrograph of the coronal part of the root canal in the control group (×2500)

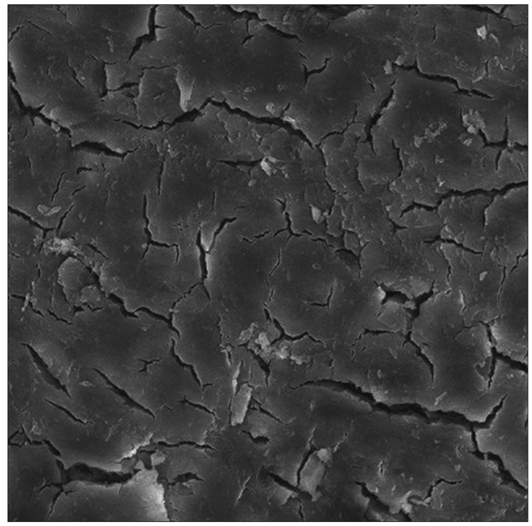

**Figure 4:** Scanning electron micrograph of the apical part of the root canal in the control group (×2500)

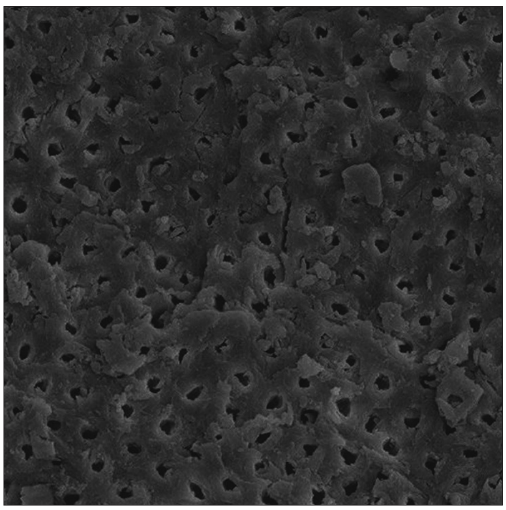

**Figure 5:** Scanning electron micrograph of the coronal part of the root canal in the Erbium: Yttrium-Aluminium-Garnet group (×2500)

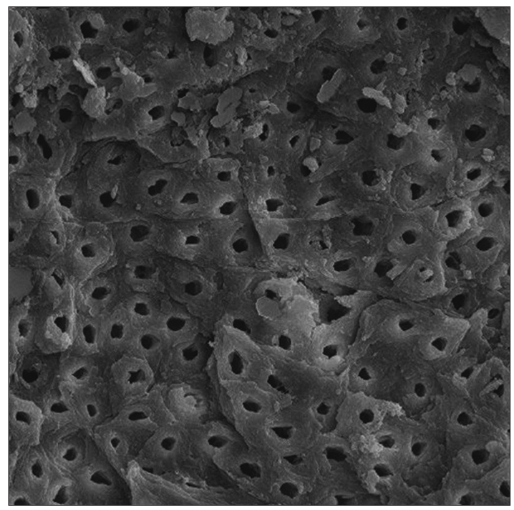

**Figure 6:** Scanning electron micrograph of the middle part of the root canal in the Erbium: Yttrium-Aluminium-Garnet group (×2500)

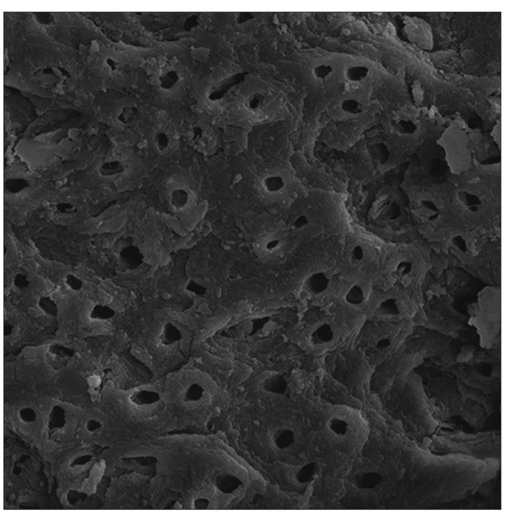

**Figure 7:** Scanning electron micrograph of the apical part of the root canal in the Erbium: Yttrium-Aluminium-Garnet group (×2500)

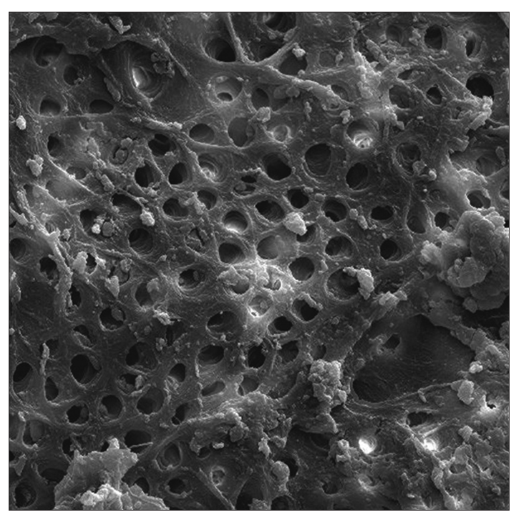

**Figure 8:** Scanning electron micrograph of the coronal part of the root canal in the Neodimium: Yttrium-Aluminium-Garnet group (×2500)

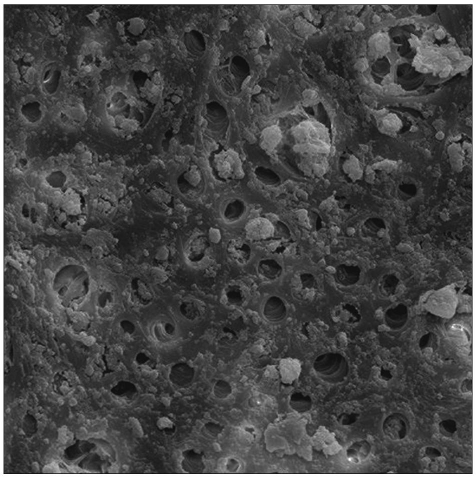

**Figure 9:** Scanning electron micrograph of the middle part of the root canal in the Neodimium: Yttrium-Aluminium-Garnet group (×2500)

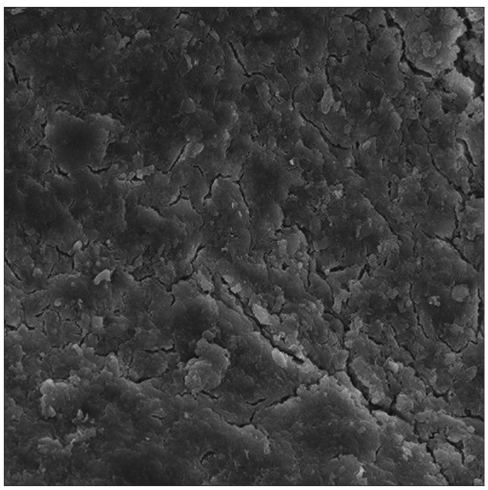

**Figure 10:** Scanning electron micrograph of the apical part of the root canal in the Neodimium: Yttrium-Aluminium-Garnet group (×2500)

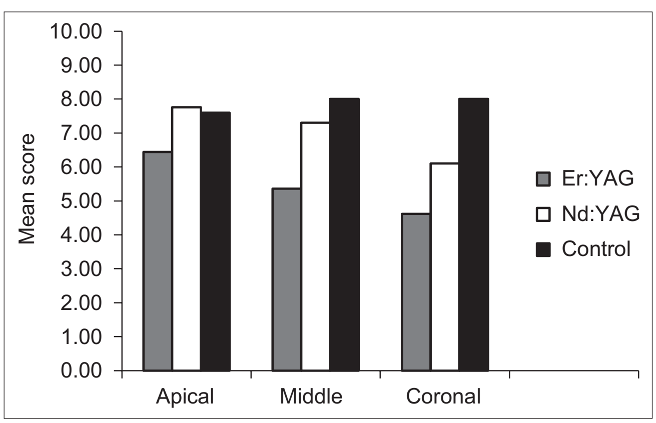


**Figure 11:** Mean amounts of smear layer in groups and regions

through photoablation, so results in minimal thermal side effects on the dental hard tissue and pulp.[16-19]

The mechanism of the Er: YAG laser suggests that the energy of this laser is absorbed by water, and then the water evaporates and ablates the molecules of the specimen (dentine).[26,27] In contrast, the Nd: YAG laser is poorly absorbed by water; it is more efficiently absorbed by protein, pigmented tissue, and dark surfaces.[28] In endodontic applications, the Nd: YAG laser can control bleeding during pulpectomy or apicectomy, improve disinfection, and sterilization, prevent pain after treatment, seal dentinal tubules, and remove debris and smear layer from instrumented root canals.[29]

According to the results of this study, both Er: YAG and Nd: YAG lasers could reduce the amount of smear layers. However, the Er: YAG laser proved more effective than the Nd: YAG laser. This finding is inconsistent with the results published by Kivanç *et al.*, which stated that neither the Nd: YAG or Er: YAG lasers reduced the amount of smear layer and debris produced during root canal preparation.[29] This could be due to a difference in laser parameters and the scoring system.

However, it has been reported by Goya *et al.* that the removal of smear layer with the Er: YAG laser is greater than removal with the Nd: YAG laser,[30] which is in agreement with the results of our study.

Esteves *et al.* showed that among the three types of lasers (Nd: YAG, Er: YAG, and diode), the Er: YAG laser caused the highest increase in dentin permeability, while the lowest was related to the Nd: YAG laser. Especially in the cervical and middle thirds, the Nd: YAG laser means of percentage of dye penetration were even statistically significantly lower than the control, which is in contrast with the results of this study.[31]

When we compared the three regions of the root canal, smear layer removal was distinctly higher in the coronal, and middle regions than the apical area in the laser groups. This may be attributed to the conical shape of the canals and the efficient access of the laser to the coronal region.

Comparisons among the three regions in the Nd: YAG group in this study agree with the study published by Zhang and Barbacow, but disagree with the study published by Kivanc *et al.*, which can be attributed to subjective technical differences and differing laser parameters.[28,29,32]

The Er: YAG laser differs distinctly from other laser systems regarding, its effect on the root canal wall, as can be seen in the present SEM investigation. The Er: YAG laser is capable of removing infected dentinal surfaces, and the smear layer creates after all forms of mechanical root canal preparation. The orifices of the dentinal tubules are exposed, facilitating a tight-fitting root canal filling, which is inevitable for a successful endodontic treatment. The temperature changes on the root surface recorded by the infrared camera are within acceptable limits when laser settings do not exceed 1 W and when the laser fiber is kept in constant motion to avoid unjustifiably high temperatures. Schoop *et al*. stated that irradiation settings of more than 1 W are not necessary to remove most of the endodontic bacterial species with an Er: YAG laser,[21] as we used in this study.

The use of water cooling combined with laser irradiation prevents the temperature rise and damages in the root canal dentin layer.[33,34] Furthermore, data is available about the bactericidal effects of the Er: YAG laser in the deep layers of dentin.[35] Despite the presence of data in favor of using an Er: YAG laser in removing smear layer during root canal preparation *in vitro*, further studies are necessary to assess the effects of laser treatment in endodontics *in vivo*.

## CONCLUSION

Based on the findings of the present study and considering the limitations, irradiation by the Er: YAG laser was more effective in smear layer removal than irradiation by the Nd: YAG laser.

## REFERENCES


1. Shokouhinejad N, Sharifian MR, Aligholi M, Assadian H, Tabor RK, Nekoofar MH. The sealing ability of resilon and gutta-parcha following different smear layer removal methods: An *ex vivo* study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;110:e45-9.
2. McComb D, Smith DC. A preliminary scanning electron microscopic study of root canals after endodontic procedures. J Endod 1975;1:238-42.
3. Mello I, Coil J, Antoniazzi JH. Does a final rinse to remove smear layer interfere on dentin permeability of root canals? Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;107:e47-51.
4. Torabinejad M, Handysides R, Khademi AA, Bakland LK. Clinical implications of the smear layer in endodontics: A review. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2002;94:658-66.
5. Violich DR, Chandler NP. The smear layer in endodontics: A review. Int Endod J 2010;43:2-15.
6. 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.
7. Mancini M, Armellin E, Casaglia A, Cerroni L, Cianconi L. A comparative study of smear layer removal and erosion in apical intraradicular dentine with three irrigating solutions: A scanning electron microscopy evaluation. J Endod 2009;35:900-3.
8. Pérez-Heredia M, Ferrer-Luque CM, González-Rodríguez MP, Martín-Peinado FJ, González-Lópezz S. Decalcifying effect of 15% EDTA, 15% citric acid, 5% phosphoric acid and 2.5% sodium hypochlorite on root canal dentine. Int Endod J 2008;41:418-23.
9. DiVito E, Peters OA, Olivi G. Effectiveness of the erbium: YAG laser and new design radial and stripped tips in removing the smear layer after root canal instrumentation. Lasers Med Sci 2012;27:273-80.
10. Schoop U, Goharkhay K, Klimscha J, Zagler M, Wernisch J, Georgopoulos A, *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;138:949-55.
11. Moritz A, Gutknecht N, Goharkhay K, Schoop U, Wernisch J, Sperr W. *In vitro* irradiation of infected root canals with a diode laser: Results of microbiologic, infrared spectrometric, and stain penetration examinations. Quintessence Int 1997;28:205-9.
12. Onal B, Ertl T, Siebert G, Müller G. Preliminary report on the application of pulsed $CO_2$ laser radiation on root canals with AgCl fibers: A scanning and transmission electron microscopic study. J Endod 1993;19:272-6.
13. Takeda FH, Harashima T, Kimura Y, Matsumoto K. A comparative study of the removal of smear layer by three endodontic irrigants and two types of laser. Int Endod J 1999;32:32-9.
14. Harashima T, Takeda FH, Zhang C, Kimura Y, Matsumoto K. Effect of argon laser irradiation on instrumented root canal walls. Endod Dent Traumatol 1998;14:26-30.
15. Schoop U, Barylyak A, Goharkhay K, Beer F, Wernisch J, Georgopoulos A, *et al*. The impact of an erbium, chromium: Yttrium-scandium-gallium-garnet laser with radial-firing tips on endodontic treatment. Lasers Med Sci 2009;24:59-65.
16. Hibst R, Keller U. Experimental studies of the application of the Er: YAG laser on dental hard substances: I. Measurement of the ablation rate. Lasers Surg Med 1989;9:338-44.
17. Keller U, Hibst R. Ablative effect of an Er: YAG laser on enamel and dentin. Dtsch Zahnarztl Z 1989;44:600-2.
18. Hibst R. Lasereinsatz in der zahnmedizin. Med Tech 1999;4:18-23.
19. Keller U, Raab WH, Hibst R. Pulp reactions during Erbium YAG laser irradiation of hard tooth structure. Dtsch Zahnarztl Z 1991;46:158-60.
20. Keller U, Hibst R. Ablative effect of an Er: YAG laser on enamel and dentin. Dtsch Zahnarztl Z. 1989;44:600-2.
21. Schoop U, Moritz A, Kluger W, Patruta S, Goharkhay K, Sperr W, *et al*. The Er: YAG laser in endodontics: Results of an *in vitro* study. Lasers Surg Med 2002;30:360-4.
22. White JM, Goodis HE, Cohen JN. Bacterial reduction of contaminated dentine by Nd: YAG laser. J Dent Res 1991;70:412.
23. Khademi A, Yazdizadeh M, Feizianfard M. Determination of the minimum instrumentation size for penetration of irrigants to the apical third of root canal systems. J Endod 2006;32:417-20.
24. Kouchi Y, Ninomiya J, Yasuda H, Fukui K, Moriyama T, Okamoto H. Location of *Streptococcus mutans* in the dentinal tubules of open infected root canals. J Dent Res 1980;59:2038-46.
25. Berutti E, Marini R, Angeretti A. Penetration ability of different irrigants into dentinal tubules. J Endod 1997;23:725-7.
26. Sasaki KM, Aoki A, Ichinose S, Ishikawa I. Ultrastructural analysis of bone tissue irradiated by Er: YAG Laser. Lasers Surg Med 2002;31:322-32.
27. Lee BS, Lin CP, Hung YL, Lan WH. Structural changes of Er: YAG laser-irradiated human dentin. Photomed Laser Surg 2004;22:330-4.
28. Barbakow F, Peters O, Havranek L. Effects of Nd: YAG lasers on root canal walls: A light and scanning electron microscopic study. Quintessence Int 1999;30:837-45.
29. Kivanç BH, Ulusoy OI, Görgül G. Effects of Er: YAG laser and Nd: YAG laser treatment on the root canal dentin of human teeth: A SEM study. Lasers Med Sci 2008;23:247-52.
30. Goya C, Yamazaki R, Tomita Y, Kimura Y, Matsumoto K. Effects of pulsed Nd:YAG laser irradiation on smear layer at the apical stop and apical leakage after obturation. Int Endod J 2000;33:266-71.
31. Esteves-Oliveira M, de Guglielmi CA, Ramalho KM, Arana-Chavez VE, de Eduardo CP. Comparison of dentin root canal permeability and morphology after irradiation with Nd: YAG, Er: YAG, and diode lasers. Lasers Med Sci 2010;25:755-60.
32. Zhang C, Kimura Y, Matsumoto K, Harashima T, Zhou H. Effects of pulsed Nd: YAG laser irradiation on root canal wall dentin with different laser initiators. J Endod 1998;24:352-5.
33. White JM, Fagan MC, Goodis HE. Intrapulpal temperatures during

pulsed Nd: YAG laser treatment of dentin, *in vitro*. J Periodontol 1994;65:255-9.
34. Armengol V, Jean A, Rohanizadeh R, Hamel H. Scanning electron microscopic analysis of diseased and healthy dental hard tissues after Er: YAG laser irradiation: *In vitro* study. J Endod 1999; 25:543-6.
35. Yasuda Y, Kawamorita T, Yamaguchi H, Saito T. Bactericidal effect of Nd: YAG and Er: YAG lasers in experimentally infected curved root canals. Photomed Laser Surg 2010;28:S75-8.

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