Effects of Er:YAG and Nd:YAG Laser Irradiation on Radicular Dentine Permeability Using Different Irrigating Solutions

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Background and Objectives: To evaluate the effect of Er:YAG and Nd:YAG laser on radicular dentine permeability when using distilled and deionized water and 1% NaClO as irrigating solutions.
Study Design/Materials and Methods: Thirty human maxillary canines were divided randomly into six groups. The root canals were instrumented with K files and the step-back technique. Group I, irrigation with distilled and deionized water; Group II, irrigation with 1% NaClO; Group III, irrigation with distilled and deionized water and Er:YAG laser application (140 mJ input, 61 mJ output 15 Hz, 300 pulses, and 42 J); Group IV, irrigation with 1% NaClO and Er:YAG laser application (same parameters as Group III); Group V, irrigation with distilled and deionized water and Nd:YAG laser application (150 mJ, 15 Hz, 2,25 W); Group VI, irrigation with 1% NaClO and Nd:YAG laser application (same parameters as Group V). During laser application the teeth were always filled with the irrigating solution. The tip was withdrawn gently in helicoidal movement from the apex to the cervical portion. The teeth were processed for histochemical evaluation.
Results: The Tukey test showed that the cervical and middle thirds were statistically similar ($P > 0.05$) and significantly greater than the apical third ($P < 0.05$). The Scheffé test showed significantly greater dentine permeability in root canals in which water and Er:YAG laser were used and were significantly different from the other treatments ($P < 0.05$).
Conclusions: The use of distilled and deionized water and Er:YAG laser showed the greater increase of dentine permeability. The use of 1% NaClO with Nd:YAG laser, distilled, and deionized water with Nd:YAG laser and the use of water increased dentine permeability less than the other groups. The use of 1% NaClO with and without Er:YAG laser application were positioned intermediately among the treatments. Lasers Surg. Med. 33:256–259, 2003. © 2003 Wiley-Liss, Inc.

Key words: irrigation; root canal; dentin permeability; Er:YAG laser; Nd:YAG laser

INTRODUCTION

Permeability is an inherent characteristic of dentine because this tissue is composed of a great number of dentine canaliculli. The study of this permeability is very important because root canal therapy is performed with the association of instrumentation and irrigating solutions, which penetrate into these canaliculli, remove debris, and smear layer, easing and improving the final sealing [1–9].

Er:YAG and Nd:YAG lasers have been reported to be effective for root canal smear layer removal [10–12]. Considering this effect and its action on dentine permeability, Tani and Kawada [13], Stabholz et al. [14], and Miserandino et al. [15] reported that Nd:YAG laser irradiation reduces tissue permeability by closing the canals by tissue fusion. However, Pécora et al. [8] showed that water and Er:YAG laser increases dentine permeability.

These apparently contradictory results are due to the different wavelengths, Er:YAG $\lambda = 2.94$ μm and Nd:YAG $\lambda = 1.06$ μm, which lead to different interactions with dental tissue.

Therefore, the aim of this study was to evaluate the action Er:YAG and Nd:YAG lasers on radicular dentine permeability, after instrumentation of the canals with water and 1% sodium hypochlorite.

MATERIALS AND METHODS

The lasers used in this study was Er:YAG (Kavo Key Laser II, Biberach, Germany) and Nd:YAG (Deka, Firenze, Itália). Sodium hypochlorite (1%) and distilled and deionized water were obtained from the Endodontic Research Laboratory (FORP-USP, Ribeirão Preto, SP, Brazil). The NaOCl was also titrated.

Thirty human maxillary canines kept in 0.1% thymol solution were randomly divided into six groups of five teeth each. The root canals were instrumented with K files (Maillefer, Ballaigues, Switzerland) using the step-back technique until a #50 file at 1 mm from the apex. Two milliliters of the chosen irrigating solution was used at each file change. Root canals were also filled with the selected irrigating solution before laser irradiation. Group I, canal

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instrumentation with distilled and deionized water as the irrigating solution; Group II, canal instrumentation with 1% NaOCl as the irrigating solution; Group III: canal instrumentation with distilled and deionized water as the irrigating solution followed by Er:YAG laser irradiation with a 2055 Gr 50×28 fiber optic tip (external diameter 0.470 mm, 28 mm length, 0.46 transmission factor that means that the fiber allows 46% of the input energy to the tip of the fiber, output energy) in a helicoidal movement (140 mJ input, before the fiber, and 61 mJ output, after the fiber, 15 Hz, 300 pulses, and 42 J); Group IV, canal instrumentation with 1% NaOCl as the irrigating solution followed by Er:YAG laser irradiation as Group III; Group V, canal instrumentation with distilled and deionized water as the irrigating solution followed by Nd:YAG (150 mJ, 15 Hz, and 2.25 W) irradiation; Group VI, canal instrumentation with 1% sodium hypochlorite as the irrigating solution followed by Nd:YAG laser irradiation with the same parameters as Group V. The optic fiber tip was introduced until the apical region; the laser was activated and gently withdrawn from the root canal to the coronary region with a helicoidal movement. The teeth were immersed in 10% copper sulfate for 30 minutes, in a vacuum for the first 5 minutes. The teeth were then dried with paper points and placed in a 1% rubeanic acid, for the same periods in solution and vacuum as above. Rubeanic acid reveals copper ions, forming a stained compound ranging in color from deep blue to black, depending on the quantity of copper ions present. Copper ion penetration thus indicates the depth of permeability of the used irrigating solution (Figs. 1 and 2).

Upon completion of this reaction, the tooth was placed in an acrylic resin block and 150-µm thick transverse sections were obtained with a diamond disk from the cervical, middle, and apical thirds. During the sectioning process, constant irrigation with water was used to prevent dentin burn. According to established criteria, each root third was cut perpendicularly to the long axis into four slices and the second and fourth slices of each root third were used. The slices were then sanded under tap water to a thickness of approximately 100 µm and washed for 4 hours, and were dehydrated in a series of increasing alcohol solutions, cleared three times in xylol and mounted on glass slides for microscopic examination.

The quantification of the penetration of copper ions was done by morphometric analysis with a 400-point grid. The number of points in the stained and non-stained areas of the dentin were counted. The percent of copper ion penetration in the dentin (p(d)%) was calculated by the following equation: $p(d)\% = PM/(PT - PC) \times 100$, where: PM = points in the stained area, PT = total number of points counted, and PC = points in the canal area.

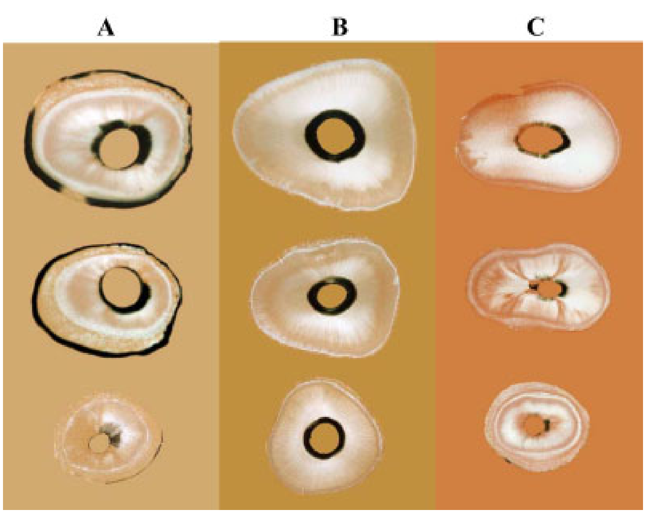

Fig. 1. Cu^{2+} ion penetration in the root canal dentine wall in cervical (**top**), middle (**middle**), and apical (**bottom**) thirds instrumented and irrigated with distilled deionized water (**A**), or irrigated with distilled deionized water and irradiated with Er:YAG laser (**B**) or Nd:YAG laser (**C**). [Figure can be viewed in color online via www.interscience.wiley.com.]

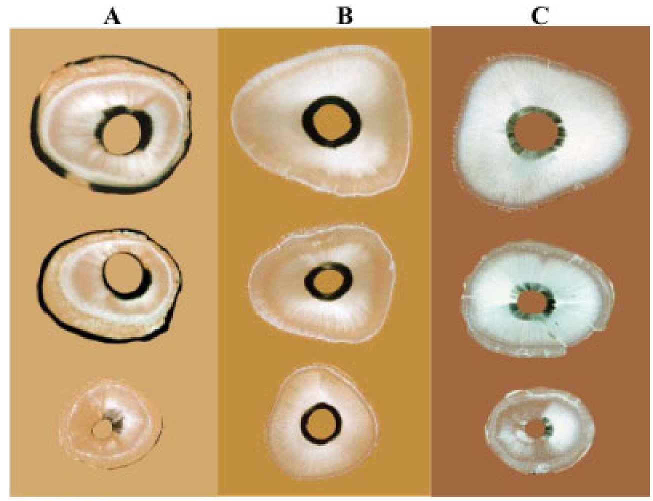

Fig. 2. Cu^{2+} ion penetration in the root canal dentine wall in cervical (**top**), middle (**middle**), and apical (**bottom**) thirds instrumented and irrigated with 1.0% sodium hypochlorite (**A**), or irrigated with 1.0% sodium hypochlorite and irradiated with Er:YAG (**B**) laser or Nd:YAG laser (**C**). [Figure can be viewed in color online via www.interscience.wiley.com.]

RESULTS

The 90 data obtained in this study were the values corresponding to the penetration of cooper ions in the dentin of the canal walls (five teeth × six treatments × three values per root = 90; Table 1).

The test for normality showed that the distribution of the sample was normal, permitting the application of the parametric ANOVA. The Tukey test indicated that the cervical and middle thirds showed statistically similar results ($P > 0.05$) that were significantly greater than the apical third ($P < 0.05$). The Scheffé post-hoc test showed significantly greater dentine permeability of canals in which distilled and deionized water and Er:YAG laser

TABLE 1. Percentage of Penetration (Mean ± SD) of Cooper Ions in the Dentin of the Canal Walls

	Er:YAG + 1% NaOCl	Er:YAG + water	Nd:YAG + water	Nd:YAG + 1% NaOCl	Water	1% NaOCl
Cervical	11.6 ± 2.0	14.7 ± 2.1	7.5 ± 1.5	9.0 ± 1.1	6.1 ± 1.2	12.6 ± 1.6
Middle	12.0 ± 3.9	15.8 ± 2.4	5.3 ± 1.0	9.4 ± 1.3	4.4 ± 0.3	11.4 ± 2.5
Apical*	6.2 ± 3.0	10.1 ± 1.4	3.1 ± 1.2	4.0 ± 2.2	1.5 ± 1.1	6.4 ± 1.0

*$P < 0.05$ compared to cervical and middle thirds which were statistically similar.

(Group III) were used than the other treatments ($P < 0.05$). The use of 1% sodium hypochlorite irrigation with Nd:YAG laser (Group VI), distilled and deionized water with Nd:YAG application (Group V) and the isolated use of water (Group I), had the lowest levels of dentine permeability and were statistically similar ($P > 0.05$). The use of 1% sodium hypochlorite with or without subsequent application of Er:YAG laser showed statistically similar levels of dentine permeability ($P > 0.05$) and were grouped in an intermediate position among the treatments studied. Therefore, the groups can be placed in the following decreasing order of permeability: III > II = IV > I = V = VI.

DISCUSSION

Increasing root dentine permeability leads to higher cleanliness and more open tubules. This is an important factor for the disinfection of root canals and a higher mechanical bonding between the root canal sealer and dentine. Different irrigating solutions have different effects on the increase of dentine permeability and the application of lasers in the root canal can also alter the original properties of these solutions [8].

The root canals instrumented with water and irradiated with Er:YAG laser showed a greater increase in the radicular dentin permeability when compared with the other methods. The Er:YAG laser has affinity and interacts well with water, promoting greater dentin canaliculi opening. When only water was used as the irrigating solution a small increase in dentin permeability was observed; however, its association with Er:YAG irradiation increased dentin permeability in a statistically significant manner. While Er:YAG laser irradiation is absorbed by water, causing evaporation and micro-explosions (thermo-mechanical ablation), Nd:YAG laser irradiation is absorbed by mineral structures such as hydroxyapatite, phosphate, and carbon, leading to crystal disorder (thermo-chemical ablation). The temperature for water evaporation is lower than the temperature for the disarrangement of the crystals. The high temperature necessary for thermo-chemical reaction causes the bonding and melting of the dentine tissue. Studies on the effects of laser on root canal walls are important to lead to safe applications of this irradiation in dentistry.

Irrigation with water followed by laser irradiation increased dentin permeability significantly when compared with sodium hypochlorite irrigation either alone or with laser irradiation. Sodium hypochlorite did not interact as well as water with laser irradiation.

In order to explain the lower interaction of Er:YAG laser with 1.0% sodium hypochlorite, Pécora et al. [8] verified the ionic conductance of this substance and found values of 46.5 mS whereas water was 1.0 mS. This difference means that the 1.0% sodium hypochlorite solution presents a larger quantity of free ions, which can be a decisive factor in the interaction with the Er:YAG laser. In the present study, we also evaluated the optic density of the substances and verified that this factor can also interfere in the conduction of the laser light in the root canal changing the laser-dentine interaction. The media change alters the propagation angles of the laser light with consequent change in absorbance and interaction of the light with the tissue, changing the results of laser action. The peak of absorbance of water coincides with the Er:YAG laser wavelength, leading to more effective results when compared with the other treatments ($P < 0.005$).

This study is in agreement with the results of Takeda et al. [11,16] who reported that Er:YAG laser was more effective in cleaning the root canal because it increases the permeability of dentine.

When considering the interaction of Nd:YAG laser and irrigation solutions, Miserandino et al. [15] reported that the Nd:YAG laser interacts with the dentine in a different manner than Er:YAG. Thus, we propose that the irrigating solution does not interfere with the Nd:YAG laser dentine canaliculi closure. Our results show that the use of 1% sodium hypochlorite with Nd:YAG laser, distilled, and deionized water with Nd:YAG laser and the use of water were statistically similar ($P < 0.05$) and increased dentine permeability less than the other groups.

The Tukey test showed that the cervical and middle thirds presented statistically similar results for the permeability of the root thirds that was greater than the apical third. These findings are in accordance with Zuolo et al. [17] and Pécora et al. [7,9].

This study leads to new perspectives for research on the interactions of irrigating solutions with Er:YAG and Nd:YAG laser irradiation of root canals.

CONCLUSIONS

In the present study, greater dentine permeability was found with the use of Er:YAG laser and distilled and deionized water than with the use of 1% sodium hypochlorite and Er:YAG laser. Thus, we conclude that researchers and clinicians may have to review some concepts when performing root canal therapy associating irrigating solutions and laser due to the interactions between them.

REFERENCES

1. Marshall FJ, Massler M, Dute HL. Effects of endodontic treatment of root dentine. Oral Surg 1960;13:208–223.
2. Anderson DJ, Ronning GA. Dye diffusion in human dentine. Arch Oral Biol 1962;7:501–512.
3. Stewart GG, Kapsimals P, Rappaport H. EDTA and urea peroxide for root canal preparation. J Am Dent Assoc 1969; 78:335–338.
4. Cohen S, Stewart GG, Laster LL. Acids, alkalies, and chelating agents on dentine permeability. Oral Surg 1970;9:631–634.
5. Frois IM, Renberg AM, Robazza CRC, Costa WF, Antoniazzi JH. Permeabilidade da dentina radicular: Um novo método de avaliação. Rev Paul Endod 1981;2:77–83.
6. Pashley DH, Michelin V, Kerl MS. Dentin permeability: Effects of smear layer removal. J Prosthet Dent 1981;46:531–537.
7. Pécora JD, Costa WF, Campos GM, Roselino RB. Presentation of a histochemical methods for the study of root dentine permeability. Rev Odont USP 1987;1:3–9.
8. Pécora JD, Brugnera A, Jr., Cussioli AL, Zanin F, Silva R. Evaluation of dentin root canal permeability after instrumentation and Er:YAG application. Lasers Surg Med 2000; 26(3):277–281.
9. Pécora JD, Marchesan MA, Sousa Neto MD, Guerisoli DMZ, Silva RS. Effect of *Ricinus communis* detergent and papaine gel on radicular dentine permeability. J Isr Dent Assoc 2000; 17:8–11.
10. Harashima T, Takeda FH, Kimura Y, Matsumoto K. Effect of Nd:YAG laser irradiation for removal of intracanal debris and smear layer in extracted human teeth. J Clin Laser Med Surg 1997;5:131–135.
11. Takeda FH, Harashima T, Kimuta Y, Matsumoto K. Efficacy of Er:YAG laser irradiation in removing debris and smear layer on root canal walls. J Endod 1998;24:548–551.
12. Matsuoka E, Kimura Y, Matsumoto K. Studies on the removal of debris near the apical seats by Er:YAG laser and assessment with fiberscope. J Clin Laser Med Surg 1998;16: 255–261.
13. Tani Y, Kawada H. Effects of laser irradiation on dentin. Effect on smear layer. J Dent Mat 1987;6:127–134.
14. Stabholz A, Khayat A, Ravanshad SH, McCarthy DW, Neev J, Torabinejad M. Effects of Nd:YAG laser on apical seal of teeth after apicoectomy and retrofill. J Endod 1992; 18:371–375.
15. Miserendino LJ, Levy GC, Rizoiv IM. Effect of Nd:YAG laser on the permeability of root canal wall dentin. J Endod 1995; 21:83–87.
16. Takeda FH, Harashima T, Eto JN, Kimura Y, Matsumoto K. Effect of Er:YAG laser treatment on the root canal walls of human teeth: An SEM study. Endod Dent Traumat 1998;14: 270–273.
17. Zuolo M, Murgel CAF, Pecora JD, Antoniazzi JH, Costa WF. Ação do EDTA e suas associações com tensoativos na permeabilidade dentinária radicular. Rev Odontol USP 1987;1: 18–23.