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ORIGINAL ARTICLE

Evaluation of temperature rises during the application of different power levels of potassium titanyl phosphate and neodymium-doped:yttrium aluminum garnet lasers to external primary root canals

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Abstract *Background/purpose:* Nowadays, laser systems play crucial roles in endodontic treatments. Therefore, these systems should be investigated in terms of parameters that may prevent periodontal tissues damages during laser irradiation. In this context, the purpose of this study was to evaluate temperature rises during the application of different power levels of potassium titanyl phosphate (KTP) and neodymium-doped:yttrium aluminum garnet (Nd:YAG) lasers to external primary root canals.

Materials and methods: Sixty primary mandibular molars were selected and chemomechanical preparation was performed. KTP laser treatment was applied to 30 of these 60 samples and the remaining 30 received Nd:YAG laser treatment. The teeth samples received laser application (KTP or Nd:YAG) at three different power levels (1 W, 1.5 W, and 2 W, respectively, applied to 10 samples from each group). Nine holes were drilled (1 mm in diameter) through the level of the coronal, middle, and apical third of each tooth canal to provide entry for a Type L thermocouple wire, which was used to measure temperature changes. Data were assessed with two-way analysis of variance and the Tukey test.

Results: All power levels indicated statistically significant differences between Nd:YAG and KTP laser systems ($P < 0.05$). Moreover, the same regional (apical, middle, and coronal) comparisons performed between Nd:YAG and KTP laser systems showed statistically significant differences ($P < 0.05$).

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Conclusion: All parameters of KTP laser indicated lower temperature rises than Nd:YAG laser. Therefore, KTP laser may be preferable to protect the periodontal tissues from harmful thermal effects during the endodontic treatment of primary root canals.

Introduction

In pediatric endodontics, new disinfection approaches have been gaining popularity as most of these procedures are shown to enhance the success of root canal treatments. These alternative disinfection approaches, such as using different laser systems, have been investigated in detail by several researchers.[1–5] For example, potassium titanyl phosphate (KTP) and neodymium-doped:yttrium aluminum garnet (Nd:YAG) lasers are widely used in endodontics, especially for photothermal disinfection in root canal treatments. Both laser systems have similar specific characteristic properties. The KTP (532 nm) laser system is a frequency-doubled Nd:YAG laser (1064 nm) system. However, applications of these laser systems may cause pulpalgia[1] and thermal changes[2] while the energy is transferred into the dentin.[3] Moreover, while a part of the laser energy is absorbed in the tissue, the other part is converted into heat energy acting on the tissue. However, both these events depend on some important factors such as the wavelength of emitted energy, pulse repetition rate, beam diameter, pulse duration, energy density, and optical properties of tissue.[4,5] It is possible to apply the laser beam into narrow root canals using a thin fiber optic delivery system (200 μm).

Compared with permanent teeth, primary teeth have different anatomical and morphological features. For example, the pulp of primary teeth is larger in relation to the crown size than that of permanent teeth. The thicknesses of enamel and dentin are also thinner in primary teeth. Primary molar teeth have longer and more slender roots that flare more as they approach the apex. Moreover, the primary teeth generally exhibit larger apical foramina and accessory canals and are more numerous. Furthermore, multirooted primary teeth show a greater degree of interconnection between pulp canals and the pulp.[6]

A few studies have reported on the effects of temperature rise during the application of laser systems to primary teeth.[4,7,8] Laser systems may cause thermal damage on the periodontal tissues during disinfection of root canals.[1,2] According to Zach and Cohen,[9] a temperature rise of 5.5°C is the threshold value, beyond which thermal damage to pulpal tissue occurs. The temperature rise and morphological effect of a KTP laser were emphasized in a few studies.[4,10] For example, one of these studies reported that although the temperature rise is directly proportional to pulse repetition rates of KTP laser, it shows inversely proportional relations with the dentin thicknesses.[4] Furthermore, Anić et al[11] reported that after the application of intracanal laser irradiation, the highest temperature rise was produced by the argon laser at the external root surface, followed by the Nd:YAG and CO_2 lasers.

However, further investigations evaluating the effect of different laser systems on temperature change during the disinfection of primary root canals are necessary to clarify this clinically relevant issue. Therefore, in this study, we examined and compared the effect of temperature rises during the application of different power levels of KTP and Nd:YAG lasers to external primary root canals.

Materials and methods

Teeth samples

In this study, 60 primary mandibular second molars that were freshly extracted for orthodontic reasons were selected. The periapical radiographs of these primary teeth were obtained to evaluate the number of root canals and morphological properties. We chose the lateral teeth that had two roots and three canals and incomplete apical formation for analysis. Sex distribution was 55% male and 45% female. Informed consent was obtained from the patients and their families before the study, and the study was approved by the Local Ethics Committee on Human Research of Cumhuriyet University, Sivas, Turkey (2012-04/11). After the removal of surface debris and residues, the teeth were kept at +4°C in 0.9% saline solution for up to 1 month.

Root canal preparation

At the beginning of the study, access cavities of primary mandibular second molars were prepared. A Size 15 K file (Mani Inc., Tochigi, Japan) was then introduced into the root canal and the path of the canal was determined. The tip of the file was inserted to measure the length of each canal until it became visible in the apical foramen. It was then withdrawn 1 mm shorter than the measured length (8–10 mm). The root canals were shaped with ProTaper (DENTSPLY Tulsa Dental Specialties, Tulsa, OK, USA) rotary Ni-Ti instruments using the crown-down method with an electric motor (Denta ports DP-ZX; J. MORITA MFG. CORP., Kyoto, Japan). First, the coronal third of the roots were expanded with SX files. The median third of the roots were then reached with S1 and S2 files. F1, F2, and F3 files were successively applied to shape the apical third. Root canals were then irrigated with 1 mL of 5.25% NaOCl after preparation with each file. The roots were irrigated with 5.25% NaOCl and distilled water for 5 minutes to remove the smear layer, which was formed during the root canal preparation, following which root canals were dried with paper points.

Temperature test apparatus

An apparatus composed of cold-cure acrylic resin was developed to standardize temperature measurements and fix the roots. The teeth were then placed into the apparatus and nine holes were drilled (1 mm in diameter) through the level of the coronal, middle, and apical third of each canal to provide entrance for a thermocouple wire (Figures 1A–1C). Through the holes of the acrylic resin (Figure 1D), a thermocouple wire was attached beneath the external surface of the roots.

Laser irradiation

Two types of laser systems were applied to the root canals: KTP laser system (SMARTLITE D; DEKA, Calenzano, Firenze, Italy) and Nd:YAG laser system (SMARTY A10; DEKA). The 10 root canals for each experimental group were irradiated at 1 W, 1.5 W, and 2 W power of KTP and Nd:YAG lasers, respectively.

Throughout the laser treatment in the repetitive pulse mode, the endodontic fiber optic cable (Preciso, diameter 200 μm; DEKA; Figure 1E) was continuously irradiated from the apical foramen to the canal entrance in a circular motion for 5 seconds, interleaved with 15-second recovery intervals for each irradiation. This process was repeated nine times for each canal (total time 3 minutes).

Temperature measurement

The new mold composed of an acrylic-based material was developed to standardize temperature measurements. Nine different holes (1 mm in diameter) were drilled through the center of the mold to provide entry for the thermocouple wire. Teeth were placed and fixed into the prepared acrylic mold. Through the nine different central orifices of the acrylic mold, a thermocouple wire was attached beneath the center of the nine points of the roots. Thus, standardization of the laser beam was ensured at the nine points of root surface. Thermal emission was measured during continuous laser irradiation by a Type L thermocouple (Fe-Const.; Elimko Co., Ankara, Turkey) connected to a data logger (E-680; Elimko Co.). The E-680 series of universal data loggers/scanners have important advantages such as 32-channel digital data recording and enhancement of distortion of the calibration caused by external factors. The new-generation microcontroller-based industrial instruments are compatible with IEC 668 standards. Data were collected and stored in a centrally located personal computer installed with the Data Logger, version 5.1 software (Elimko Co.). During the measurements, the initial temperature was recorded after temperature stabilization (20 ± 0.1°C), and peak temperature was registered. The initial temperature was deducted from the final one to obtain the temperature variation. All measurements were performed by another investigator.

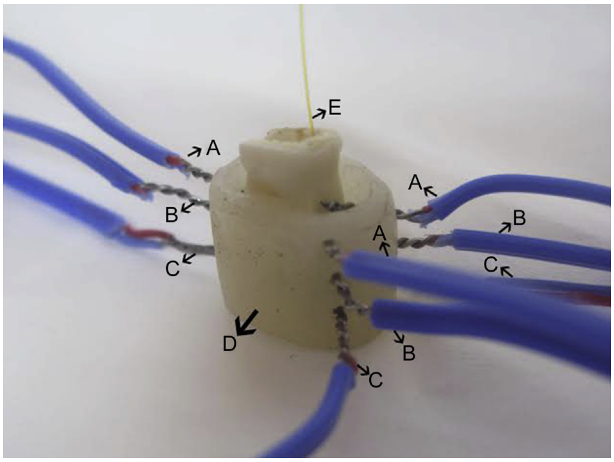

Figure 1 Representative view of the temperature measurements. (A) The thermocouple wire in the coronal third region of the external root surface; (B) the thermocouple wire in the middle third region of the external root surface; (C) the thermocouple wire in the apical third region of the external root surface; (D) acrylic mold; and (E) endodontic fiber optic cable.

Statistical analysis

The temperature variation data were analyzed using an SPSS statistical software program (version 14.0; SPSS Inc., Chicago, IL, USA). A one-way analysis of variance (ANOVA) was applied for comparison of temperature rises among nine points of the external surface. In cases where there were significant differences, the Tukey *post hoc* test was applied to examine pairwise differences at a significance level of 0.05.

Results

The mean values (standard deviation) of all groups together with their statistical comparisons obtained for applications of different power levels of laser systems to the external surface of the root canal are presented in Table 1. The two-way ANOVA revealed significant temperature rise differences among the specimens tested.

Although there was no statistically significant difference between the 1 W and 1.5 W power of the KTP laser system ($P > 0.05$), there were statistically significant differences between the 2 W power and other power levels of the KTP laser system ($P < 0.05$). Moreover, there were no statistically significant differences among the coronal, middle, and apical regions for the different power levels of the KTP laser system ($P > 0.05$).

There were statistically significant differences among all power levels of the Nd:YAG laser system ($P < 0.05$). Moreover, although there was no statistically significant difference between the middle and coronal regions ($P > 0.05$), there were statistically significant differences among the apical region and other regions for the different power levels of the Nd:YAG laser system ($P < 0.05$).

There were statistically significant differences among different power levels of Nd:YAG and KTP lasers ($P < 0.05$). Moreover, the regional (apical, middle, and coronal) comparisons showed statistically significant differences between the two laser systems ($P < 0.05$).

In this study, the power levels of KTP laser showed lower temperature rises than those of Nd:YAG laser. Besides,

Table 1 The mean values (standard deviation) of all groups together with their statistical comparison obtained from different power levels of lasers applied to the external surface of the root canal.[a,b]

Power	KTP laser			Nd:YAG laser		
Energy	Apical 1/3	Middle 1/3	Coronal 1/3	Apical 1/3	Middle 1/3	Coronal 1/3
1 W	2.11 (0.4) ^{A,a}	1.63 (0.3) ^{B,a}	1.51 (0.1) ^{C,a}	4.47 (0.9)	3.33 (0.7) ^{d}	3.05 (0.8) ^{d}
1.5 W	2.54 (0.5) ^{A,b}	2.26 (0.5) ^{B,b}	2.14 (0.5) ^{C,b}	6.96 (0.7)	5.90 (1.2) ^{e}	5.37 (0.8) ^{e}
2 W	4.87 (0.7) ^{c}	4.57 (1.0) ^{c}	4.16 (1.0) ^{c}	11.60 (1.3)	9.09 (1.3) ^{f}	8.52 (0.8) ^{f}

KTP laser = potassium titanyl phosphate laser; Nd:YAG = neodymium-doped:yttrium aluminum garnet.

[a] By two-way analysis of variance: $F = 359.690$, $P < 0.001$, $P < 0.05$ ($n = 30$ specimens/experimental condition).

[b] Values with same small (horizontal rows) and big (vertical columns) superscript letters show no statistical difference at $P > 0.05$ by Tukey test.

none of the KTP laser values reached the critical value (5.5°C). The 1.5- and 2-W Nd:YAG laser irradiations can cause dangerous temperature rises on the external root surface of primary root canals.

Discussion

In pediatric endodontics, complete disinfection of root canals plays a crucial role in the overall success of endodontic treatment. In recent years, laser systems have been widely used to achieve ideal disinfection in infected root canals.[12,13] However, laser systems may cause undesirable temperature rise during laser irradiation. For this purpose, we aimed to evaluate the temperature rise during different power levels of KTP and Nd:YAG laser irradiation on the external primary root surfaces.

In a previous study, the temperature changes of KTP—Nd:YAG laser irradiation on the external root surface were recorded. In that study, the laser parameters considered were different power levels (2.25 W, 3 W, and 4 W) and resting times (0.5—25 seconds). The highest temperature rise was measured with two resting times of 4 W output power. While one of these resting times (15 seconds) caused the temperature rise of 10°C, the other resting time (25 seconds) demonstrated only a lower temperature rise (5.1°C).[14]

In another study, Moritz et al[15] evaluated the effect of Nd:YAG laser in terms of temperature changes on 1-mm thick dentin that was obtained from the upper and middle third of the dentin adjacent to the root canal. Each specimen was exposed to five irradiations of 5 seconds each with 15-second intervals. As a result, while the 1 W power level resulted in an average temperature rise of 3.8°C, irradiation with the 1.5 W power level resulted in a temperature rise of 4.3°C. In another study, Lizarelli et al[7] investigated the effect of temperature variation during Nd:YAG picosecond pulsed laser irradiation with different power levels (4 W, 6 W, and 7 W) on the enamel and dentin of the molar and incisor primary teeth in the pulpal chamber. The temperature rise in that study did not exceed the threshold value (5.5°C) even after subjecting all specimens to noncooling applications. Lan[16] evaluated the effect of temperature rise of Nd:YAG laser irradiation on the apical third of the external root surface. Laser pulse repetition rates ranged from 20 Hz to 30 Hz and energy levels varied from 50 mJ to 200 mJ. The temperature rise remained below 10°C when the pulse repetition rate and energy were under 20 Hz and 100 mJ. In our study, although 1 W Nd:YAG laser and none of KTP laser energies exceeded the threshold value, application of 1.5 W and 2 W power levels of the Nd:YAG laser resulted in higher temperature rises that may cause damage to the periodontal tissues.

Although some results of our study indicate similarities,[14—16] a few results showed differences from the aforementioned studies.[7,15] In our opinion, these differences might be attributed to the types of teeth used, the points of measurements, and the brands of laser devices.

Alfredo et al[17] investigated the temperature effects of different diode laser parameters on the cervical, middle, and apical thirds of the external root surface. When the root canals of canines were irradiated with 5 W power for 20 seconds in helicoidal movement, a temperature rise of 12°C was recorded, whereas a 1.5-W power level irradiation caused a 4.2°C temperature rise. In addition, the cervical third of the root indicated a higher temperature rise than other regions. In another investigation, Scaini et al[18] evaluated the temperature changes on the external surfaces of the apical, middle, and cervical third of the root during erbium:YAG laser irradiation with different tips (sapphire or optical fiber) and pulse repetition rates. The irradiation was performed from the apex to the cervical third with helicoidal movements for 20 seconds. The different types of laser tips did not show statistically significant differences in temperature variation of the root surfaces. In addition, the highest temperature variations were recorded in the apical thirds and the lowest temperature changes were seen in the cervical thirds. Furthermore, an increase in the pulse repetition rate proportionally raised the temperature of the root external surfaces. In another study, temperature changes of the Nd:YAG laser were investigated during tooth preparation for four different thicknesses on the cervical and occlusal locations. In that study, following the decrease in dentin thicknesses, the temperature rise was observed. Furthermore, there was a proportional relationship between power level and temperature rise. In addition, the occlusal location demonstrated a higher temperature rise than the cervical region.[19] In other recent study, thermal and morphological effects of different Nd:YAG laser energies on root canal surfaces were evaluated. Power levels up to 2 W did not exceed the biologically tolerable thermal limit; additionally, the thermal and morphological changes seen at the apical third of the root were greater than those seen at the coronal third.[20] In our study, although the highest temperature rise was recorded from the apical regions, the lowest value was calculated from the coronal regions at all energy levels. While this result indicated similarities to the aforementioned studies,[18–20] Alfredo et al[17] demonstrated a different result. We suggest that this difference emerged from the type of laser and teeth, higher power level, lower application time, and number of measurement points.

Within the limitations of the present study, it can be concluded that although KTP lasers may be used for disinfection techniques, only a maximum power level of 2 W can be applied to primary molar teeth. Moreover, at power levels higher than 1 W, Nd:YAG laser can exceed the critical value (5.5°C) of temperature rise. For this reason, the power level of Nd:YAG laser should be carefully selected for primary root canal treatment. Therefore, different methodologies can be tested to enhance the temperature effect of new-generation laser systems.

KTP lasers indicated lower temperature rises than the Nd:YAG lasers used for the disinfection of primary root canals. In the light of these results, KTP laser may be preferred over the Nd:YAG lasers so as to avoid the power levels exceeding the critical value during the treatment of primary root canals. However, pediatric dentists should be careful during KTP and Nd:YAG laser irradiation because of a high temperature rise on the external apical third of primary teeth, which can cause damages to the permanent teeth germ development and periodontal tissue.

Conflicts of interest

The authors have no conflicts of interest relevant to this article.

References

1. Wigdor HA, Walsh Jr JT, Featherstone JD, Visuri SR, Freid D, Waldvogei JL. Lasers in dentistry. *Lasers Surg Med* 1995;16:103–33.
2. Apel C, Franzen R, Meister J, Sarrafzadegan H, Thelen S, Gutknecht N. Influence of the pulse duration of an Er:YAG laser system on the ablation threshold of dental enamel. *Lasers Med Sci* 2002;17:253–7.
3. Keller U, Hibst R. Experimental studies of the application of the Er:YAG laser on dental hard substances: II light microscopic and SEM investigations. *Lasers Surg Med* 1989;9:345–51.
4. Hubbezoglu I, Unal M, Zan R, Hurmuzlu F. Temperature rise during application of Er:YAG laser under primary dentin thicknesses. *Photomed Laser Surg* 2013;31:201–5.
5. Glockner K, Rumpler J, Ebeleseder K, Stadtler P. Intrapulpal temperature during preparation with the Er:YAG laser compared to the conventional bur: an *in vitro* study. *J Clin Laser Med Surg* 1998;16:153–7.
6. Mathewson RJ, Primosch RE. *Fundamentals of Pediatric Dentistry*, 3rd ed. Chicago, IL: Quintessence Publishing Co, 1995:197–205.
7. Lizarelli RF, Moriyama LT, Bagnato VS. Temperature response in the pulpal chamber of primary human teeth exposed to Nd:YAG laser using a picosecond pulsed regime. *Photomed Laser Surg* 2006;24:610–5.
8. Arrastia AM, Wilder-Smith P, Berns MW. Thermal effects of CO_2 laser on the pulpal chamber and enamel of human primary teeth: an *in vitro* investigation. *Lasers Surg Med* 1995;16:343–50.
9. Zach L, Cohen G. Pulp response to externally applied heat. *Oral Surg Oral Med Oral Pathol* 1965;19:515–30.
10. Machida T, Wilder-Smith P, Arrastia AM, Liaw LH, Berns MW. Root canal preparation using the second harmonic KTP: YAG laser: a thermographic and scanning electron microscopic study. *J Endod* 1995;21:88–91.
11. Anić I, Tachibana H, Masumoto K, Qi P. Permeability, morphologic and temperature changes of canal dentine walls induced by Nd:YAG, CO_2 and argon lasers. *Int Endod J* 1996;29:13–22.
12. Zan R, Hubbezoglu I, Sümer Z, Tunç T, Tanalp J. Antibacterial effects of two different types of laser and aqueous ozone against *Enterococcus faecalis* in root canals. *Photomed Laser Surg* 2013;31:150–4.
13. Cheng X, Guan S, Lu H, et al. Evaluation of the bactericidal effect of Nd:YAG, Er:YAG, Er,Cr:YSGG laser radiation, and antimicrobial photodynamic therapy (aPDT) in experimentally infected root canals. *Lasers Surg Med* 2012;44:824–31.
14. Nammour S, Kowaly K, Powell GL, Van Reck J, Rocca JP. External temperature during KTP-Nd:YAG laser irradiation in root canals: an *in vitro* study. *Lasers Med Sci* 2004;19:27–32.
15. Moritz A, Jakolitsch S, Goharkhay K. Morphologic changes correlating to different sensitivities of *Escherichia coli* and *Enterococcus faecalis* to Nd:YAG laser irradiation through dentin. *Lasers Surg Med* 2000;26:250–6.
16. Lan WH. Temperature elevation on the root surface during Nd-Yag laser irradiation in the root canal. *J Endod* 1999;25:155–6.
17. Alfredo E, Marchesan MA, Sousa-Neto MD, Brugnera-Júnior A, Silva-Sousa YT. Temperature variation at the external root surface during 980-nm diode laser irradiation in the root canal. *J Dent* 2008;36:529–34.
18. Scaini F, Souza-Gabriel AE, Alfredo E, Da Cruz Filho AM. Temperature variation on the external root surface during intracanal Er:YAG laser irradiation. *Photomed Laser Surg* 2008;26:413–7.
19. Srimaneepong V, Palamara JE, Wilson PR. Pulpal space pressure and temperature changes from Nd:YAG laser irradiation of dentin. *J Dent* 2002;30:291–6.
20. He H, Yu J, Song Y, Lu S, Liu H, Liu L. Thermal and morphological effects of the pulsed Nd:YAG laser on root canal surfaces. *Photomed Laser Surg* 2009;27:235–40.