ORIGINAL ARTICLE

Effect of Er:YAG and Nd:YAG lasers on the mineral content of root canal dentin

Hüseyin Sinan Topçuoğlu · Mustafa Köseoğlu

Abstract The aim of this study was to assess the effect of two different laser systems on the mineral content of root canal dentin. Thirty-six single canal-extracted mandibular premolars were used in this study. The teeth were randomly divided into two groups of 18 teeth each and prepared with a master apical file #50. Dentin chips were obtained by Gates-Glidden burs and saved in Eppendorf tubes to serve as a control. Then, root canals were treated with a erbium:yttrium–aluminum–garnet or neodymium:yttrium–aluminum–garnet laser. Dentin chips were again obtained using Gates-Glidden. The levels of calcium (Ca), phosphorus (P), magnesium (Mg), sodium (Na), and potassium (K) in each specimen were measured by inductively coupled plasma-atomic emission spectrometry. Data were statistically analyzed by a Mann–Whitney U test. The changes in Ca, P, Mg, Ca, and K levels and the Ca/P ratio after laser irradiations were minimal and statistically not significant ($p > 0.05$). It was determined that the laser systems used in this study did not affect the mineral content of root canal dentin.

Keywords Laser · Root canal · Dentin · Mineral content

Introduction

Advances in technology have made it possible to use laser beams in dentistry, as well as in other areas of health care [1]. In recent years, the various applications of laser systems, including the removal of the smear layer, the melting of the dentin surfaces, root canal preparation, and antimicrobial effects, has gained popularity in endodontic therapy [2]. In particular, erbium:yttrium–aluminum–garnet (Er:YAG) and neodymium:yttrium–aluminum–garnet (Nd:YAG) lasers have been used for a broad range of applications [3, 4]. However, laser applications in root canals can cause some morphological and chemical changes on root canal dentin. The severity of these changes depends on the type of laser energy as well as the density and absorption characteristics of the tissue [5, 6].

Dentin composition has been defined based on its organic and inorganic components. Calcium (Ca) and phosphorus (P) elements present in the hydroxyapatite crystals are the major inorganic components of dental hard tissue. The Ca/P ratio of hydroxyapatite in the dentin, which implies the basic composition of dental hard tissue, has been shown to be 1.67 M, depending on variables such as the crystal type, the anatomical location, the availability of Ca, and the determination technique [7, 8]. Alterations in the Ca/P ratios of the dentin surface, as a result of operational procedures, may change the original ratio between the organic and inorganic components, which changes the permeability and solubility characteristics of the dentin and may affect the adhesion of dental materials to the hard tissues [9].

According to our data, the effects of the Er:YAG laser system on the mineral content of root canal dentin has not been studied yet. Therefore, the aim of this study was to evaluate the mineral content of root canal dentin after the application of two different lasers by using the inductively coupled plasma-atomic emission spectrometry (ICP-AES) technique. The null hypothesis was that Er:YAG and Nd:YAG laser irradiation would not affect the mineral content of the root canal dentin.

H. S. Topçuoğlu (✉)
Department of Endodontics, Faculty of Dentistry, Erciyes University,
Melikgazi, 38030 Kayseri, Turkey
e-mail: topcuogluhs@hotmail.com

M. Köseoğlu
Department of Endodontics, Faculty of Dentistry, Ataturk University,
Erzurum, Turkey

Materials and methods

Tooth selection and sample preparation

This study's protocol was approved by the Research Ethics Committee of Ataturk University. Thirty-six mandibular

premolar teeth collected from patients between 30 and 40 years old, freshly extracted for periodontal reasons, were used in this study. The soft tissues covering the root surfaces were removed, and the teeth were stored in distilled water. The crowns of all of the teeth were removed using a slow-speed diamond precision saw with water cooling (Isomet 1000; Buehler, Lake Bluff, IL, USA) to adjust the length of the roots to a standardized length of 15 mm. The pulp tissues were removed with barbed broaches (VDW, Munich, Germany). The working length of each root canal was determined by subtracting 1 mm from the length of an inserted #15 K-file (Dentsply, Maillefer, Ballaigues, Switzerland) with its tip visualized at the apical foramen. The canals were then prepared to a master apical size #50 with K-files (Dentsply) by using the balanced force technique as described by Roane et al. [10]. Step-back was performed by using K-files #55–80. The canals were irrigated with 2 mL 1 % sodium hypochlorite (NaOCl) between each file size by using a syringe and a 29-gauge needle (NaviTip; Ultradent, South Jordan, UT, USA). Twelve milliliters of NaOCl solution was used for each root. The final irrigation with 5 mL distilled water was performed. The canals were then dried with paper points (Dentsply). The teeth were randomly divided into two groups comprised of 18 teeth each. Before the laser application, dentin chips were obtained with Gates-Glidden drills (#2 and 3; Dentsply) from all of the teeth in both groups and saved in Eppendorf tubes. These dentin chips served as control.

Laser irradiation procedure

Group 1: The specimens were irradiated by an Nd:YAG laser (Smarty A10; Deka, Italy) using a fiber tip. The laser emits photons at a 1.064 nm wavelength, 1 W power output, 100 mJ energy, a 10 Hz repetition rate, a pulse duration of 150 μs, and a power density of 3,183.1 w/cm^2. A 200 μm fiber tip was placed just 3–4 mm shorter than the working length inside of the canal and then activated. Laser irradiation was performed in a spiral motion and in a noncontact mode from the apical region to the canal orifice. Each canal was irradiated four times for 10 s at 15-s intervals [11]. The movement speed of the laser tip was 1.2–1.3 mm/s. After the laser irradiation, the root canals were rinsed with distilled water and dried with paper points.

Group 2: The specimens were irradiated by an Er:YAG laser (Doctor Smile Erbium laser, Lambda Scientifica, Vicenza, Italy) with a wavelength of 2,940 nm, 1 W power output, 100 mJ pulse energy, a 10 Hz repetition rate, a pulse duration of 250 μs, and a power density of 795.7 w/cm^2. The laser energy was delivered through a sapphire tip terminal, 12 mm long and 400 μm in diameter. The tip was placed 3–4 mm shorter than the working

length inside of the canal and activated for 3 s in the apical region [12]. Following this process, four additional laser irradiations, each of which was 3 s, were performed in a spiral motion and in a noncontact mode from the apical region to the canal orifice. The movement speed of the laser tip was 4–4.3 mm/s.

In the experimental groups, water (2 cm^3/min) and air were sprayed through the handpiece at a 50 % level to prevent the dentin from overheating during the laser irradiation. After the laser irradiation, the root canals were irrigated with distilled water and dried with paper points. Dentin chips were obtained from the teeth by Gates-Glidden drills (#4 and 5) and preserved in Eppendorf tubes.

Measurement of mineral content

The dentin chips obtained from the teeth in both laser groups before and after laser treatment were stored in plates at 70 °C in a stove until they reached a fixed weight. Their weights were recorded with an electronic balance (Electronic Balance FA-1604B, E-Chrom Tech Corporation, Taiwan). Ten milliliter nitric acid and 15 ml deionized water were added to the samples, and they were burned at 170 PSI and 200 °C in a microwave until dissolved. Following the calibration of the ICP-AES instrument (Vista AX, Varian, Australia), 2 ml of the solution was taken and heated until it reached 10,000 °C, at which point the samples were completely atomized and energy was released. Every element was described according to its different wavelength. The levels of Ca, P, Mg, Na, and K in each sample were determined using the ICP-AES technique. The mineral contents were calculated as a percentage weight.

The differences between the values before and after laser irradiation were analyzed with a Mann–Whitney U test. The statistical differences were determined at a significance level set at $p < 0.05$ using SPSS software (SPSS Inc., Chicago, IL, USA).

Results

The mean percentage weights of the five elements (Ca, P, Mg, Na, and K) in the dentin before and after laser irradiation are shown in Table 1. The Mann–Whitney U test showed that there were no significant differences before and after laser treatment for Ca, P, Mg, Na, and K, as well as the Ca/P ratio ($p > 0.05$). Although the five element levels increased after Er:YAG laser irradiation, none of these changes were statistically significant ($p > 0.05$). The Ca, P, Mg, and K levels also increased after the Nd:YAG laser irradiation, but these changes were not statistically significant ($p > 0.05$) either. One exception was that the Na level decreased after the

Table 1 Mean levels and standard deviations of five elements in dentin before and after treatment with lasers

	Before Nd:YAG	After Nd:YAG	Before Er:YAG	After Er:YAG
Ca	30.2733±0.86835	30.5756±0.72768	30.4539±0.62190	30.5500±0.57731
P	12.3256±0.50837	12.5739±0.43981	12.6344±0.43424	12.8356±0.53654
Mg	1.3465±0.28725	1.3622±0.29170	1.2434±0.25250	1.2539±0.15462
K	0.0422±0.01555	0.0517±0.02307	0.0500±0.01495	0.0583±0.01505
Na	0.6811±0.05697	0.6661±0.05962	0.6233±03835	0.6261±0.04245
Ca/P	2.4596±0.12715	2.4476±0.09368	2.3998±0.09946	2.3840±0.11983

There was no significant difference between before and after laser irradiation ($p > 0.05$)

Nd:YAG application, but this decrease was not statistically significant ($p > 0.05$).

Discussion

Recently, laser technology has often been used in endodontic treatment. In investigating such treatment, numerous studies have used a variety of lasers: for example, diode, CO_2, Nd:YAG, and Er:YAG. Some studies have also researched whether Nd:YAG and Er:YAG lasers cause any change in root canal dentin, depending on various factors, such as their method of application, time, and the amount of energy released [13–16]. Few studies have addressed the effects of Nd:YAG laser irradiation on root canal dentin structure at the molecular level [11]. However, there are no studies about the effects of Er:YAG laser irradiation on the mineral content of root dentin. Therefore, in the present study, we examined changes in the mineral content of the root dentin after Er:YAG and Nd:YAG laser irradiation was applied using the same parameters.

In previous studies, the effects of lasers and irrigation solutions on the mineral content of the root canal dentin have been investigated. In most of these studies, teeth irrigated with distilled water or saline solutions were used as the control group [11, 17, 18]. In contrast, we used dentin chips obtained before the laser irradiation as the control. Thereby, given that each tooth has a different mineral structure, the effectiveness of the lasers on the mineral content of the root dentin can be assessed more objectively. In addition, in the present study, to achieve standardization, we used teeth obtained from patients who were similar in age because the mineral structure of teeth may change with aging.

Heat emerging during the laser systems' application to the hard tissues may cause changes to the structure and composition of the dentin tissue [19]. Nelson et al. [6] reported that dentin apatite crystals transform larger apatite crystals including the reduction of carbonate after a laser application. Dentin apatite crystals, like all other biological apatites (enamel, bone, and so forth), have been identified as carbonate hydroxyapatites containing minor elements like Mg, Na, and HPO_4. During a laser application, the tissue temperature

increases rapidly and quickly reaches up to 10,000 °C [20]. Dentin apatite crystals melt during laser pulses and recrystallize between consecutive pulses. As a result of rapid recrystallization, defects in apatite crystal structure occur. This change in the structure and content of apatite crystals may lead to an alteration in the Ca/P ratio. If the dentin temperature increases, water vaporization, protein decomposition, and the separation of carbonate from the apatite crystals occur [21]. The use of air and water cooling decreases heat generation by the absorption of excess energy in the region of the laser irradiation [22]. In the present study, to prevent heat increase, the laser irradiation for the experimental groups was performed via air and water cooling, and we observed that the Ca/P ratio of our experimental groups did not exhibit any significant changes.

In previous studies, scanning electron microscopy (SEM) and energy dispersive spectrometry were often used to determine the mineral content levels of dentin [18, 23]. However, it is impossible to repeat the measurements from SEM and energy dispersive spectrometry exactly [17, 24]. In addition, dentin porosity may produce secondary diffraction. Dentin surfaces must be polished perfectly for the correct measurements to be obtained. However, it has been stated that the smear layer produced by polishing may be responsible for different elements found in dentin surfaces [25]. For the determination of trace elements in dentin, the ICP-AES technique is one of the most attractive detection systems [17]. This technique allows the mineral content levels from dentin chips obtained with Gates-Glidden drills to be determined without polishing the dentin surface. SEM and energy dispersive spectrometry can measure dentin mineral content with amounts detectable at the parts per million (milligrams per liter) level. However, with the ICP-AES technique, trace elements can be detected at the parts per billion (micrograms per liter) level. Another main advantage of the technique is that multiple elements can be measured analysis at the same time by ICP-AES [24]. In contrast, the measurements in SEM and energy dispersive spectrometry should be repeated for each element [17]. In our study, we used the ICP-AES technique because of these advantages.

Previous studies have not evaluated the effects of the Er:YAG laser on the mineral content of the root dentin. In

the current study, we used the method of application and length of time of the Er:YAG laser similar to that used in the study of Takeda et al. [12]. They stated that Er:YAG irradiation for 15 s was the minimum time to obtain effective results in removing the smear layer because laser irradiation for a longer time may cause thermal damage to the periapical tissues. They activated the laser at the apical part for 3 s, and they determined that the smear layer in the apical region, which is described as the hardest area to clean during root canal treatment, was effectively removed. Thus, we aimed to determine the compositional changes of dentin after the use of the Er:YAG laser with this methodology. In the present study, the compositional changes of the dentin after Er:YAG or Nd:YAG laser irradiation during root canals were evaluated using the ICP-AES technique. The mean percentage weights of Ca, P, Mg, Na, and K, as well as the Ca/P ratio of the groups, were not affected by the laser irradiation. These findings are compatible with the results of a study reported by Gurbuz et al. [11], who demonstrated that the mineral content of root dentin was not affected significantly after Nd:YAG laser irradiation. Similarly, a recent study showed that the laser irradiation of dentin surfaces using Er:YAG, Nd:YAG, and KTP lasers did not change Ca, K, Mg, Na, or P concentrations, or the Ca/P mineral ratio of the dentin surface [25]. In contrast, Secilmis et al. [26] reported that Er:Cr:YSGG laser irradiation (1 W) increased the mean percentage weights of Ca, Mg, Na, and P, as well as the Ca/P ratios of their experimental groups. Soares et al. [27] showed that the Ca and P content of the dentin increased after Er:YAG laser irradiation with 220 mJ. They also determined that the Ca/P ratio decreased after Er:YAG laser irradiation with 100 mJ. The results of an in vitro study by Altundasar et al. demonstrated an increase in Ca, P, and Mg levels after Er:Cr:YSGG laser irradiation. In their study, they used an energy dispersive X-ray analysis to determine the compositional changes [22]. The differences between the results of these studies may be due to the laser system types or the detection method of the mineral content.

Conclusion

The null hypothesis was accepted by the results of the present study. Within the limitations of the present study, it can be concluded that Er:YAG and Nd:YAG laser irradiation did not affect the mineral contents of root dentin. In the present study, laser devices with the same parameters were used. Further studies must be conducted to determine whether different parameters and time intervals have an effect on the mineral content of root canal dentin.

References

1. Myers TD (2000) The future of lasers in dentistry. Dent Clin North Am 44:971–980
2. Sulewski JG (2000) Historical survey of laser dentistry. Dent Clin North Am 44:717–752
3. Kashima-Tanaka M, Tsujimoto Y, Kawamoto K, Senda N, Ito K, Yamazaki M (2003) Generation of free radicals and/or active oxygen by light or laser irradiation of hydrogen peroxide or sodium hypochlorite. J Endod 29:141–143
4. Kimura Y, Wilder-Smith P, Matsumoto K (2000) Lasers in endodontics: a review. Int Endod J 33:173–185
5. Fowler BO, Kuroda S (1986) Changes in heated and in laser-irradiated human tooth enamel and their probable effects on solubility. Calcif Tissue Int 38:197–208
6. Nelson DG, Wefel JS, Jongebloed WL, Featherstone JD (1987) Morphology, histology and crystallography of human dental enamel treated with pulsed low-energy infrared laser radiation. Caries Res 21:411–426
7. Cohen M, Garnick JJ, Ringle RD, Hanes PJ, Thompson WO (1992) Calcium and phosphorus content of roots exposed to the oral environment. J Clin Periodontol 19:268–273
8. Marshall GW Jr (1993) Dentin: microstructure and characterization. Quintessence Int 24:606–617
9. Rotstein I, Dankner E, Goldman A, Heling I, Stabholz A, Zalkind M (1996) Histochemical analysis of dental hard tissues following bleaching. J Endod 22:23–25
10. Roane JB, Sabala CL, Duncanson MG Jr (1985) The "balanced force" concept for instrumentation of curved canals. J Endod 11:203–211
11. Gurbuz T, Ozdemir Y, Kara N, Zehir C, Kurudirek M (2008) Evaluation of root canal dentin after Nd:YAG laser irradiation and treatment with five different irrigation solutions: a preliminary study. J Endod 34:318–321
12. Takeda FH, Harashima T, Kimura Y, Matsumoto K (1999) A comparative study of the removal of smear layer by three endodontic irrigants and two types of laser. Int Endod J 32:32–39
13. Camargo SE, Valera MC, Camargo CH, Fonseca MB, Menezes MM (2005) Effects of Nd:YAG laser irradiation on root canal dentin wall: a scanning electron microscopic study. Photomed Laser Surg 23:399–404
14. Khabbaz MG, Makropoulou MI, Serafetinides AA, Papadopoulos D, Papagiakoumou E (2004) Q-switched versus free-running Er:YAG laser efficacy on the root canal walls of human teeth: a SEM study. J Endod 30:585–588
15. Kivanc BH, Ulusoy OI, Gorgul G (2008) Effects of Er:YAG laser and Nd:YAG laser treatment on the root canal dentin of human teeth: a SEM study. Lasers Med Sci 23:247–252
16. Sousa-Neto MD, Silva Coelho FI, Marchesan MA, Alfredo E, Silva-Sousa YT (2005) Ex vivo study of the adhesion of an epoxy-based sealer to human dentine submitted to irradiation with Er:YAG and Nd:YAG lasers. Int Endod J 38:866–870
17. Ari H, Erdemir A (2005) Effects of endodontic irrigation solutions on mineral content of root canal dentin using ICP-AES technique. J Endod 31:187–189
18. Dogan H, Qalt S (2001) Effects of chelating agents and sodium hypochlorite on mineral content of root dentin. J Endod 27:578–580
19. He H, Yu J, Song Y, Lu S, Liu H, Liu L (2009) Thermal and morphological effects of the pulsed Nd:YAG laser on root canal surfaces. Photomed Laser Surg 27:235–240
20. Rohanizadeh R, LeGeros RZ, Fan D, Jean A, Daculsi G (1999) Ultrastructural properties of laser-irradiated and heat-treated dentin. J Dent Res 78:1829–1835
21. Hossain M, Nakamura Y, Yamada Y, Murakami Y, Matsumoto K (2002) Compositional and structural changes of human dentin following caries removal by Er, Cr:YSGG laser irradiation in primary teeth. J Clin Pediatr Dent 26:377–382

22. Altundasar E, Ozcelik B, Cehreli ZC, Matsumoto K (2006) Ultramorphological and histochemical changes after ER, CR:YSGG laser irradiation and two different irrigation regimes. J Endod 32: 465–468

23. Ballal NV, Mala K, Bhat KS (2011) Evaluation of decalcifying effect of maleic acid and EDTA on root canal dentin using energy dispersive spectrometer. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 112:78–84

24. Erdemir A, Eldeniz AU, Belli S (2004) Effect of gutta-percha solvents on mineral contents of human root dentin using ICP-AES technique. J Endod 30:54–56

25. Dilber E, Malkoc MA, Ozturk AN, Ozturk F (2013) Effect of various laser irradiations on the mineral content of dentin. Eur J Dent 7:74–80

26. Secilmis A, Altintas S, Usumez A, Berk G (2008) Evaluation of mineral content of dentin prepared by erbium, chromium: yttrium scandium gallium garnet laser. Lasers Med Sci 23:421–425

27. Soares LE, Martin OC, Moriyama LT, Kurachi C, Martin AA (2013) Relationship between the chemical and morphological characteristics of human dentin after Er:YAG laser irradiation. J Biomed Opt. doi: 10.1117/1.JBO.18.6.068001