



Temperature rise on external root surface during 810- and 970-nm diode laser application in endodontic treatments

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Received: 17 October 2023 / Accepted: 16 January 2024
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Abstract

Purpose The aim of this study was to evaluate the temperature rise on the external root surface during 810- and 970-nm diode laser application.

Methods Thirty-six single-rooted mandibular premolar teeth were employed. All of the root canals were prepared at 1 mm short of the apical foramen; after working length determination, each root canal was prepared using ProTaper Universal instruments. The roots were randomly divided into 2 groups of 18 specimens in each. A 810-nm diode laser in group 1 and 970-nm diode laser in group 2 were used with continuous mode and 1.5 W parameters. The temperature elevations were measured with an infrared thermographic camera during 810- and 970-nm diode laser irradiation. Data were analyzed statistically using Kruskal–Wallis and Tukey’s tests.

Results No significant difference was obtained among the 810- and 970-nm diode laser groups according to the temperature changes ($P > 0.05$). Temperature rise values in all the teeth were detected below 10 °C.

Conclusion Within the limitations of this in vitro study, the 810- and 970-nm diode laser irradiation is a safe supported treatment option when considering the temperature elevation on the external root surface and these lasers can be safely used for endodontic treatments at the investigated parameters. The peak temperature was below the critical value.

Keywords Diode laser · Temperature · Infrared thermographic camera · Wavelength

Introduction

In order to perform a successful root canal treatment, it is necessary to reach the entire root canal system successfully [1]. Chemomechanical preparation plays a key role in achieving debridement and eliminating vital and necrotic tissue, debris, and microorganisms [2]. However, the power of conventional methods may be insufficient to achieve complete debridement and disinfection due to the complexity of root canal morphology, which includes lateral canals, isthmuses, complex branching, and deltas [3]. In addition while bacterial colonies can settle and multiply at a depth of 1100 µm, the cleaning effects of chemical agents used in

the canal remain limited to 100 nm and these compromise the long-term success of root canal treatment [4].

The contributions of laser systems to the conventional root canal treatment system in antibacterial, debris, and smear removal and irrigation activation have been demonstrated by many studies [5]. The effectiveness of lasers depends on many factors, including wavelength [6]. Diode lasers, which are applied in a range of wavelengths between 600 and 980 nm, have come to the fore in laser-assisted endodontic treatments due to their low cost, more useful device size compared to other laser systems, and thin fiber tips that carry the light to the root canal [7]. Especially the antibacterial ability of 810–980 nm has been extensively investigated [8–10]. The newest laser system named Siro-Laser Blue provides three different forms of lasers working at three different wavelengths: blue (445 nm), infrared (970 nm), and red (660 nm). The infrared diode was designed by the manufacturer to reduce bacterial levels from the root canal even up to 1000 µm in the dentinal tubules using with EasyTip 200 µm Endo [11, 12].

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The most important side effect of lasers to be considered is the increase in temperature on the dentin surface. According to Eriksson and Albrektsson, 10 °C temperature increase in the tissue for 1 min is sufficient to cause irreversible tissue damage [13]. Moreover, when the tissue temperature rises above 60 °C, blood flow is interrupted, resulting in bone necrosis and protein denaturation in hard tissues [14]. For the safe use of diode lasers, a number of studies have been conducted examining the temperature increase that occurs during the use of diode lasers to support root canal treatment. In these studies, the classical thermocouple device was often used. In addition, infrared thermal cameras, which allow us to examine a common area on the tooth and make detailed examinations at the desired point, have also been used, although they are less in number. In the literature, there is no study examining the thermal side effects of SiroLaser Blue [6, 10, 15].

Therefore, the purpose of the present study is to evaluate the temperature rise on external root surface using 970-nm and 810-nm diode lasers using an infrared thermographic camera. The null hypothesis is that there is not any significant difference between 970- and 810-nm diode lasers on the temperature rise.

Material and methods

The study was approved by the Ethics Committee of the University of Istanbul Aydın (202373). Informed consent was obtained from all individual participants included in the study.

Selection and preparation of the teeth

Power was performed to calculate the sample size. G*Power 3.1 program and analysis indicated that the sample size for each group should be at least 14. The number of groups was determined as 18 at a test power of $P > 80\%$, an error of 0.05, and an effect size of 0.98.

Thirty-six single-rooted mature mandibular premolars were used in this study. All teeth were extracted for periodontal reasons. They were examined, and the teeth with single and straight canals without calcification were included in the study. Selected teeth were cleaned of tissue debris with ultrasonic scalers, and then, they were stored in physiological saline solution at +4 °C until use. The access cavities were made using round diamond burs and an Endo Access Bur (Dentsply Sirona, Ballaigues, Switzerland). A size ISO #15 K-type file (Dentsply Maillefer, Ballaigues, Switzerland) was inserted into the root canal until visible at the apical foramen. The working length of each root canal was then established 1 mm short of the apical foramen. All canals were prepared using ProTaper Universal (Dentsply Maillefer,

Switzerland) instruments up to F3. The canals were irrigated with 1 mL of 2.5% NaOCl between each file. For the final irrigation, 2 mL of 2.5% NaOCl and 2 mL of 17% EDTA for 2 min and 2 mL of distilled water were used. The root canals were dried with absorbent paper points. Then, the teeth were randomly divided into two experimental groups with 18 specimens in each (Fig. 1).

The irradiation of root canals was achieved with the following:

Group 1 (n , 18): cheese (GaAlAs) diode laser 810 nm + 200 μ m fiber optic cable.

Group 2 (n , 18): SİROLaser Blue, Sirona, Germany, 970 nm + EasyTip Endo 200 μ m (SiroLaser Blue, Sirona Dental Systems GmbH, Germany)

In groups 1 and 2, specified diode lasers were used with continuous mode and 1.5 W parameters. The fiber was inserted into the working length, and irradiation was started. The fiber was moved in a coronal direction, at a rate of approximately 2 mm/s, utilizing a spiral movement to avoid hot spots. This cycle was repeated 3 times with a

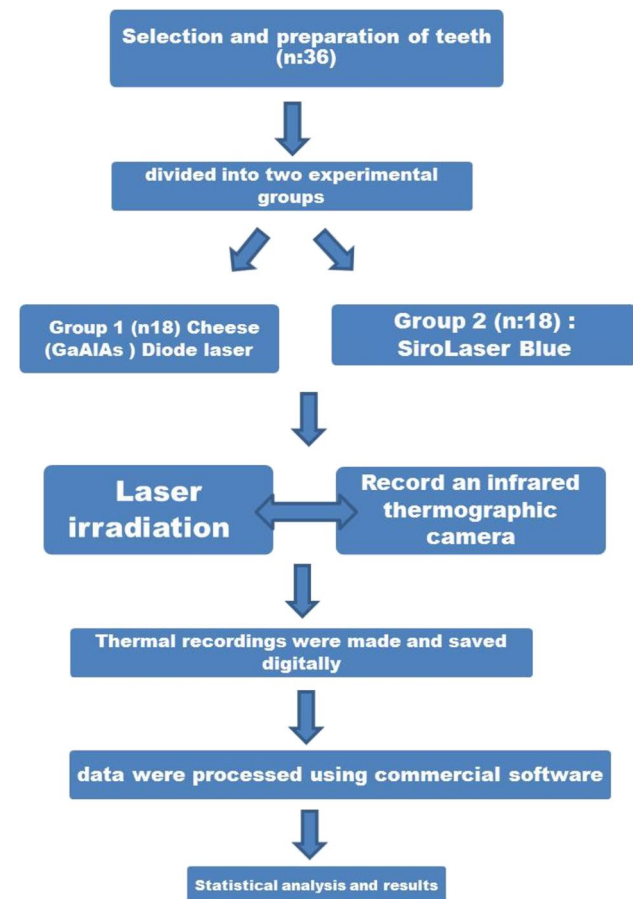


Fig. 1 Flowchart of the study process

break of 20 s. During irradiation, the teeth were mounted in a holder [15] (Fig. 2A).

The temperature changes on the root surface were measured as dynamic shot by using an infrared thermographic camera (FLIR T650sc camera, FLIR Systems AB, Taby, Sweden) at the room temperature of 21 °C. The camera was calibrated considering the dentin emissivity to be 0.91 within the temperature range of −40 to +120 °C with data acquisition of 50/60 Hz. The teeth were mounted in a holder and were placed 15 cm from the camera, corresponding to the lens focal length. During the applications, a type of mechanism made of insulative materials was designed in order to minimize the reflection of external factors to the thermal recording/video (Fig. 2B). The whole application was completed in the same day in order for the results not to be negatively affected. Thermal recordings were made and saved digitally, and the data were processed using commercial software to determine the temperature change at the apical and coronal thirds.

Scanning electron microscopy

The roots were split along the longitudinal axis into two halves, and the each half section was dehydrated in an ascending alcohol series for 24 h each (70%, 80%, 90%, and absolute), sputter-coated with gold, and then examined with an SEM (LEO 440 Computer Controlled Digital; Leica Zeiss, Cologne, Germany). SEM photomicrographs were taken at $\times 2000$ magnifications at the coronal and apical thirds of the root canals only representative (Fig. 3).

Statistical analysis

IBM SPSS Statistics 22 program was used for statistical analysis. Normal distributions for temperature rise values were tested using the Shapiro–Wilk test. As the values were normally distributed, *t*-tests were then carried out to analyze

between groups. Statistical significance was accepted at the alpha level of 5% ($P < 0.05$).

Result

Table 1 presents the results of the mean, maximum, and minimum temperature rise for each of the groups and the thirds. It was determined that the increase in temperature values in both groups was below 10 °C during the entire laser application. A maximum temperature increase of 0.8 °C was recorded in the apical thirds on group 1, and a minimum temperature increase of 0.12 °C was obtained in the coronal third on group 2.

Statistically, in apical and coronal thirds, no significant difference was obtained among the 810- and 970-nm diode laser groups according to the temperature changes ($P > 0.05$).

Discussion

Since there is no difference in the temperature rise on external root surface using 970-nm and 810-nm diode lasers, the null hypothesis tested in the present study was accepted.

When working with conventional methods, large areas remain untouched in the root canal system, especially due to the complexity of the root canal anatomy, regardless of the instrumentation technique used [16]. Smear and organic tissue residues left in areas that are not cleaned mechanically and chemically will be the ideal storage and reproduction area for surviving bacteria such as *E. faecalis* [17, 18]. Consequently, laser applications using different wavelengths have also been proposed to support conventional techniques. Diode lasers, which have proven effects on bacteria, are frequently preferred in endodontic applications compared to other laser systems due to their

Fig. 2 **A** Tooth mounted on a holder during laser treatment. **B** Position of the camera, tooth, and a type of mechanism for minimize the reflection

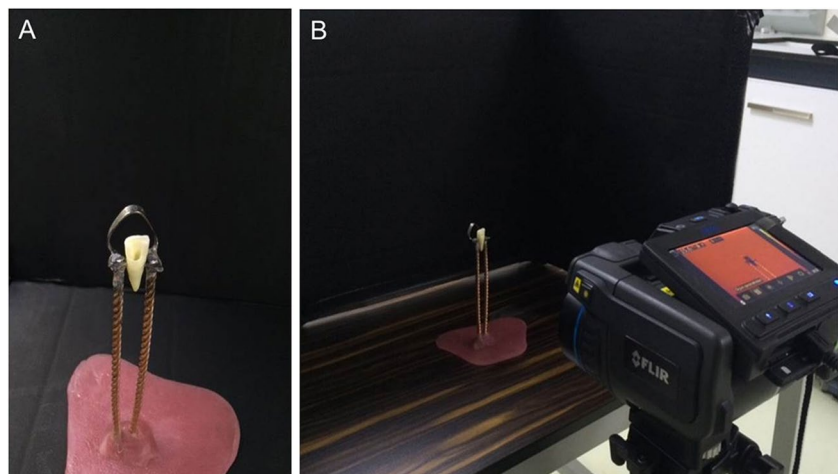


Fig. 3 Representative SEM image showing melting and fusion at the apical region in 810- and 970-nm diode laser. Dentin tubules appeared open at the coronal region especially SiroLaser Blue laser (magnification $\times 2000$)

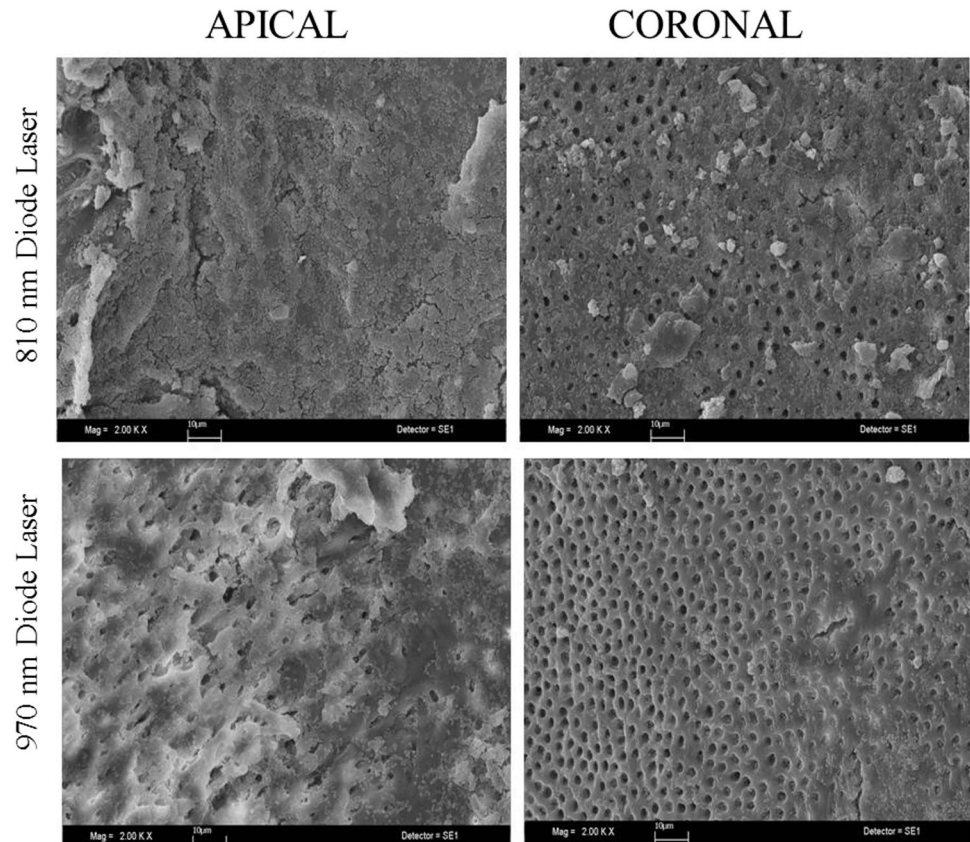


Table 1 Result of temperature rise measurements ($\Delta T/^\circ\text{C}$)

Groups (<i>n</i> , 18)	Apical ($\Delta T/^\circ\text{C}$)			Coronal ($\Delta T/^\circ\text{C}$)		
	Mean \pm SD	Max	Min	Mean \pm SD	Max	Min
810 nm (cheese)	0.48 \pm 0.17	0.80	0.20	0.38 \pm 0.20	0.80	0.06
970 nm (SiroLaser Blue)	0.39 \pm 0.10	0.60	0.12	0.33 \pm 0.08	0.50	0.12

easy portability and low cost [19–21]. Therefore, diode lasers with wavelengths of 810 and 970 nm (SiroLaser Blue), which are highly absorbed in bacterial pigmented proteins and poorly absorbed by water and hydroxyapatite in dental tissue, were preferred for this study [22]. When the literature is examined, it is seen that there are very limited studies on SiroLaser Blue. In fact, there is no study examining the effect on the temperature increase created in the tissues.

Because of in the thermographic method, the temperature can be analyzed over a large surface area, the maximum and minimum temperature change can be monitored at any point of interest in the adapted software program, and the entire camera recording can be analyzed graphically [23, 24]. Infrared thermography systems were preferred instead of the thermocouple method to monitor the temperature increase in our study. Nammour et al. [25] and da Costa Ribeiro et al. [23] reported that it is necessary to leave time intervals that allow the tissues to cool between irradiations

in order to prevent the cumulative effect of the temperature increase. In our study, this interval was accepted as 20 s.

Alfredo et al. [10] and Gutknecht et al. [26] believed that using water bath was not suitable because of free flow of water and more cooling effect of water than oral cavity. In this study, the teeth were mounted in a holder and were placed 15 cm from the camera, corresponding to the lens focal length. During the applications, a type of mechanism made of insulative materials was designed in order to minimize the reflection of external factors to the thermal recording/video (Fig. 2B).

Although lasers interact directly with the root canal dentin tissue, if they are not used carefully, thermal side effects such as root resorption, ankylosis in the affected tooth, or tissue necrosis occur depending on the type of laser, wavelength, application parameter and procedure, and the existing dentin thickness [10, 15]. Before clinical applications, it is extremely important to know the estimated temperature increase as information is important.

During laser application, the root surface temperature change should remain within the known safe limit of 10 °C above the core body temperature [13, 14]. Otherwise, irreversible tissue damage may occur. Alfredo et al. [10] found the temperature increase of 6.06 °C in their work for 980-nm diode laser at 1.5 W. In the work of Hmud et al. [27], the thermal changes of the inner and outer root surfaces of 980-nm (25 Hz, 2.5 W) and 940-nm (10 Hz, 4 W) diode lasers were investigated and it has been shown that both wavelengths do not cause a temperature increase in the thermal threshold and can be used safely in endodontic applications. Beer et al. [15] showed that the highest temperature increase was measured 5.7 °C in their work for 980-nm diode laser. Similarly, in our study, the maximum recorded temperature increase was detected below the safe thermal threshold level of 10 °C.

According to the modified Beer-Lambert law and diffusion theory, the intensity of a laser decreases as it moves toward deep layers of tissue. So, the level of the temperature that arises in the internal of the root canal walls is higher than that of the external, and the dentin thickness plays an important role in temperature increase [23]. Kreisler et al. [28] reported the impact of increased thickness on temperature rise and stated that the temperature of external root surface was reduced with an increase in dental thickness. This also explains consistent with other studies, why the highest temperature rise is observed in the apical part of the root, where the root has the narrowest thickness in this study [26, 29]. In addition, the low temperature increase values detected on the external surface of the root in our study can be explained by the minimum internal shaping and the high remaining dentin thickness. Moreover, blood circulation will increase the thermal conductivity of periodontal tissue in vivo; it has also been shown that the temperature drop is faster in vivo than in vitro studies [30].

The SEM images revealed melting and fusing at the apical regions and dentin tubules appeared open at the coronal region (Fig. 3). This can be explained by the fact that the apical third diameter of the canal is narrower compared to other regions. In this region, the fibers contacts the dentin wall more, resulting in more energy accumulation on the apical dentin surface. These results agree with da Costa Ribeiro et al. [23] who revealed closed dentin tubule, especially at the apical regions for used diode laser. In our study, 17% EDTA solution used for final irrigation describes the open dentinal tubules seen coronally.

To mention the limitations of this study, this study was designed on mandibular premolar teeth. Future studies should be conducted on the teeth with different anatomical features, for example, lower incisors. In addition, the bactericidal effect of these lasers and different parameters needs to be evaluated before adaptation in any clinical protocol.

Conclusion

Within the limitations of this in vitro study, the 810-nm diode laser and SiroLaser Blue (970 nm) can be safely used for endodontic treatments at the investigated parameters. The temperature will not increase above the safety limit (10 °C) for the periodontal tissues; the peak temperature was below the critical value. In laser-assisted root canal treatments, especially, the apical area where the dentin is thin, a 20-s resting time should be considered to prevent an excessive temperature rise in the tissue. Further studies especially about SiroLaser Blue (970 nm) are needed to examine before this procedure can be clinically applied.

Author contribution DA presented the idea and contributed in study design and data analysis.

FK presented the idea and contributed in study design, data analysis, and manuscript writing.

KS carried out the experiment and contributed in data analysis.

MD carried out the experiment and methodology.

All authors read and approved the final manuscript.

Declarations

Ethics approval This article does not contain any studies with human participants or animals performed by any of the authors.

Consent for publication All authors agree with submitting the manuscript to the journal of "Lasers in Dental Science."

Conflict of interest The authors declare no competing interests.

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