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Research Article

The Effect of Two Lasers, Lx16, and Denlase on the Rise of Temperature on the External Root Surface of the Root Canals: An *In Vitro* Study

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Abstract

Aim: The aim is to assess the impact of LX16 and DENLASE lasers on the increase in temperature on the external surface of root canals.

Materials and Methods: The selected sixty single-rooted extracted teeth were chemomechanically prepared. The specimens were then irradiated using LX16 and DENLASE lasers at power settings of 1.15, 1.45, and 1.85W, and two application times of 20 and 60 seconds, in continuous wave (CW) mode. The specimens were divided into two main groups: Group A, which received LX16 laser irradiation, and Group B, which received DENLASE laser irradiation. Each group was further subdivided into subgroups based on the irradiation power level and application time. The peak temperatures at the middle and apical regions of the root surface were measured using a thermocouple and a digital thermometer.

Results: The results showed that the temperature rise on the root surface, at all the tested output powers, was below 7°C. The highest temperature value was observed in the apical region when the root canal was irradiated for 60 seconds at an output power of 1.85W.

Conclusion: Based on these findings, it is concluded that, within the limitations of the in vitro experiment, LX16 and DENLASE lasers with wavelengths of 976 and 810 nm, respectively, can be safely used for endodontic purposes using the studied parameters of 1.15, 1.45, and 1.85W power levels and application times.

Keywords: Continuous Wave (CW); Temperature; Thermometer

Introduction

Effective endodontic therapy is crucial for preserving nonvital teeth in the long term. However, conventional root canal procedures have limitations in effectively eliminating bacteria from dentinal tubules, as irrigation solutions can only penetrate a limited depth due to their surface tension [1]. This necessitates additional cleaning procedures to improve the success rates of root canal treatments [2]. Laser systems, which emit nonionizing light with high energy concentration, have been studied as a therapeutic tool in endodontics [3]. Lasers are used in endodontics, specifically in root canal procedures, to address potential issues such as pain, vital pulp remnants, rest pulpitis, and bleeding [5]. Diode lasers, which emit light in the visible (mainly 660 nm) and infrared (810 to 980 nm) ranges of the electromagnetic spectrum, are commonly used for root canal disinfection [6]. These lasers are accessible in many dental clinics, affordable, and have experienced rapid technological advancement [7]. Based on a thorough investigation, it was found that utilizing a diode laser in conjunction with sodium hypochlorite and/or oxygenated water produced positive outcomes [8].

The thermal impact of lasers on teeth is a subject of investigation in the current study mentioned. Factors such as laser wavelength, power level, and pulse repetition rate can concentrate laser light and potentially result in thermal damages. The extent of thermal damage is largely controlled by the photo-absorptive characteristics of the tissue being exposed to the laser [4].

The aim of the investigation is likely to assess the potential thermal effects of using lasers in endodontics and to determine their role in root canal procedures [9]. This research may provide insights into the safe and effective use of lasers for disinfection and treatment purposes in endodontics. The thermal effects of laser irradiation on the external root surface are a concern, as they can result in temperature increases that may cause damage to the surrounding tissues, including the cementum layer, periodontal ligament fibers, alveolar bone, and induce pain. The severity of these effects depends on the amount of heat produced and the duration of exposure. It is crucial to consider the thermal effects of laser root canal irradiation, as excessive temperature increases can have harmful consequences. While periodontal tissue can withstand temperature increases of up to 10°C above body temperature for less than a minute, temperatures exceeding 60°C can obstruct blood flow and lead to bone necrosis.

LX16 LASER (650nm, 976 nm) is a high-power dental diode laser used in endodontic sterilization, dental soft tissue surgery, periodontal sterilization, peri-implantitis, low-intensity laser therapy, oral ulcer treatment, and teeth whitening [10].

DENLASE LASER (810nm) is a diode laser-based surgical device designed for minimally invasive soft tissue procedures, providing control over the depth and width of target areas through a flexible optical fiber [11].

The conversion of light energy into heat energy during laser contact with dentinal structures can lead to temperature increases in the external root surface and surrounding tissues. Concerns about the thermal effects include damage to the cementum layer, which can result in root reabsorption, necrosis of periodontal ligament fibers, alveolar bone necrosis, and pain. The severity of these effects depends on the amount of heat produced and the duration of exposure [3]. Thermal effects are crucial considerations in laser root canal irradiation, as excessive temperature increases can have detrimental effects on the surrounding tissues. While periodontal tissue can tolerate temperature increases of up to 10°C above body temperature for less than a minute, temperatures exceeding 60°C can obstruct blood flow and lead to bone necrosis [6].

Materials and Methodology

The materials and methodology of the study involved the following steps:

- **Tooth Selection and Preparation:** Sixty extracted single-rooted teeth were selected and cleaned to remove surface debris and residues. The teeth were decoronated using a diamond sectioning disc (Drendel, Zweiling Diamant gmbh in Berlin, Germany) for standardization to a length of 15 mm from the apex at the cementoenamel junction (CEJ). Patency was confirmed using a No. 15 K-type file (Dentsply-Maillefer, Ballaigues, Switzerland), and pulp tissue was removed with a barbed broach (Dentsply-Maillefer). After calculating the working length and subtracting 1 mm from the canal length, all of the roots were sterilized for 15 minutes at 121 °C in an autoclave. SuperEndo Blue Files were used for shaping the root. Expanding the coronal third with B Safe (Size 17/100, 0.08taper) rotary file. The glide path was achieved till working length using B Path (Size19/100, 0.02taper) rotary file, and the working length was reached after the final preparation with B1(Size20/100, 0.04taper), B2(Size25/100, 0.04taper), B3(Size25/100, 0.06taper), and B4(Size35/100, 0.04taper) rotary files. In the given information, during the root canal procedure, a 1 ml irrigation solution containing 3% sodium hypochlorite (NaOCl) was used between each instrument change. Sodium hypochlorite is a commonly used irrigant in endodontics due to its antimicrobial properties. After the irrigation with NaOCl, a final irrigation was performed using 10 ml of saline water. Saline water is used to rinse the canals and remove any remaining traces of the sodium hypochlorite solution. Once the irrigation process was completed, paper points were used to dry the canals. Paper points are small absorbent cones made of paper or similar material, which are used to remove excess moisture from the root canal system.
- **Test Apparatus:** The roots were fixed in self-curing acrylic resin blocks. Two holes, 1 mm in diameter, were drilled in the test device at 2 mm (apical third) and 5 mm (middle third) from the apex to accommodate the thermocouple wire.
- **Grouping and Subgrouping:** The specimens were divided into two main groups: Group A (LX16 LASER) and Group B (DENLASE LASER). Each group was further divided into subgroups based on the irradiation power level. The subgroups were as follows: A1 (1.15 W), A2 (1.45 W), A3 (1.85 W) for Group A, and B1 (1.15 W), B2 (1.45 W), B3 (1.85 W) for Group B.
- **Laser Irradiation:** Before laser irradiation, each root canal was filled with 1 ml of distilled water. The continuous wave method was used to irradiate the canals, with a 200µm flexible fiber optic tip inserted 1 mm from the apex. The laser was irradiated from the apical foramen to the canal access in a circular motion at a speed of 2 mm/s. Each root canal was irradiated three times with a ten-second break between each cycle for each power level.
- **Temperature Measurement:** The temperature at the middle and apical regions of the root surface was measured using a digital thermometer at two time intervals: 20 seconds and 60 seconds.

Statistical analysis

The data were analyzed using the One-way ANOVA F test followed by Tukey's post hoc test for pairwise comparisons. An unpaired t-test was used to compare the rise in temperature between the middle third and apical third of the root surface between Group A (LX16 LASER) and Group B (DENLASE LASER), irrespective of power levels and times.

Results

The results of the study comparing Group A (LX16 LASER) and Group B (DENLASE LASER) on the rise of temperature on the external root surface of the root canal of permanent teeth between the middle third and apical third showed a significant difference in temperature between the middle and apical third in both groups A and B. This comparison was done using an unpaired t-test at a significance level of $P \leq 0.05$. The specific values and statistical details can be found in Table 1 and Figure 1.

saIn degree celcius	Middle Mean (SD)	Apical Mean (SD)	Unpaired t-test	P value, Significance
Group A(LX16)	2.77 (0.9)	3.33 (0.91)	t = -1.858	p = 0.072
Group B (Denlase)	2.67 (0.9)	3.32 (0.98)	t = -2.066	p = 0.046*

Table 1: Comparative statistics in Group A (LX16) and Group B (Denlase) on the rise of temperature on the external root surface of the root canal of permanent teeth between the middle third and apical third irrespective of power and time using unpaired t-test.

P > 0.05 – no statistically significant difference *p < 0.05 – significant difference.

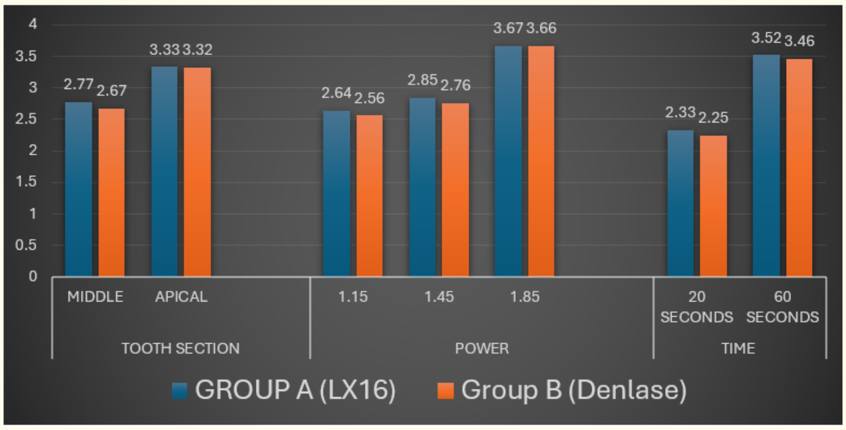

Figure 1

Another comparison was made among different power levels (watts) within Group A and Group B, regardless of location and time. This comparison used a One-way ANOVA F test followed by Tukey's post hoc test for pairwise comparisons, with a significance level of P≤ 0.05. The results showed a significant difference in temperature between the output power levels of 1.15W, 1.45W, and 1.85W in both groups A and B. However, there was no significant difference observed in temperature between the power levels of 1.15W and 1.45W in Group A. Additionally, there was a significant difference between the power level of 1.15W and 1.85W in both groups A and B. In Group B, there was a significant difference between the power levels of 1.45W and 1.85W, while no significant difference was observed in temperature between these two power levels in Group A. The specific values and statistical details can be found in Table 2 and Figure 1.

Furthermore, a comparison was made among different application times within Group A and Group B, irrespective of location and power. This comparison was done using an unpaired t-test at a significance level of P≤ 0.05. The results showed a significant difference in temperature between the application times of 20 seconds and 60 seconds in both groups A and B. The specific values and statistical details can be found in Table 3 and Figure 1.

Overall, the study revealed significant differences in temperature based on location (middle third vs. apical third), power levels (1.15W, 1.45W, and 1.85W), and application times (20 seconds and 60 seconds) within the two laser groups (Group A and Group B).

In degree celcius	Group A(LX16)	Group B (Denlase)
1.15	2.64 (0.93)	2.56 (0.99)
1.45	2.85 (0.82)	2.76 (0.82)
1.85	3.67 (0.77)	3.66 (0.82)
One way Anova F test value	F = 4.899	F = 5.267
P value, Significance	p = 0.014*	p = 0.01*
1.15 W vs 1.45 W^	p = 0.822	p = 0.845
1.15W vs 1.85 W^	p = 0.015*	p = 0.012*
1.45 W vs 1.85 W^	p = 0.061	p = 0.046*

Table 2: Comparative statistics of different power (watts) of Group A (LX16) and Group B (Denlase) on the rise of temperature on the external root surface of the root canal of permanent teeth irrespective of location and time using One-way Anova F test followed by Tukey's posthoc test for pairwise comparison.

P > 0.05 – no statistically significant difference.

*p < 0.05 – significant difference ^ p-value (pairwise) calculated using Tukey's post hoc test.

Discussion

In recent years, lasers have been extensively utilized to achieve highly effective disinfection in infected root canals. A study conducted by Beer., *et al*. demonstrated the remarkable capability of the 810-nm diode laser in reducing bacteria by an impressive 98.8%. This finding establishes the 810-nm diode laser as an advanced and innovative tool in the field of endodontics [1]. Thermal changes can occur during the disinfection of root canals using la-

In degree celcius	20 secondsMean (SD)	60 secondsMean (SD)	Unpaired t-test	P value, Significance
Group A(LX16)	2.33 (0.74)	3.52 (0.28)	t = -3.759	p = 0.001*
Group B (Denlase)	2.25 (0.77)	3.46 (0.45)	t = -3.623	p = 0.002*

Table 3: Comparative statistics of different application times of Group A (LX16) and Group B (Denlase) on the rise of temperature on the external root surface of the root canal of permanentteeth irrespective of location and power using unpaired t-test.

*p < 0.05 – a significant difference.

sers due to various parameters involved in the process. These parameters include the wavelength of the laser, the duration of laser exposure, the power or strength of the laser, and the method of irradiation. Each of these factors can contribute to the generation of heat, leading to thermal effects within the treated area. Controlling and adjusting these parameters is crucial to ensure that the temperature remains within safe limits and prevents any potential harm to the surrounding tissues during laser disinfection [12].

The wavelengths of 976 nm and 810 nm have been widely used in dental procedures. These particular wavelengths are commonly employed in various dental applications [13].

The LX16 and DENLASE lasers were selected for this study based on their lower absorption rate in water and hydroxyapatite, which allows for a higher penetration rate of laser irradiation. This characteristic is crucial in achieving a more profound effect of laser treatment on dental tissues [14].

Due to its low absorption, laser radiation has the ability to pass through dentin and undergo processes such as transmission, scattering, and propagation. However, it is important to note that when laser light is absorbed in the deeper layers [15], it can generate heat and trigger photothermal reactions that may cause injury to the periodontal tissue [6]. Care must be taken to regulate laser parameters and ensure appropriate cooling measures to minimize the risk of thermal damage to the surrounding tissues during dental procedures.

Several studies have reported that an increase in temperature of 10°C above body temperature for a duration of 1 minute can lead to irreversible damage to periodontal tissues and the alveolar bone [12]. Considering this critical threshold, the present study aimed to analyze the temperature changes resulting from the application of 976 nm and 810 nm diode lasers in root canals. By evaluating the temperature increases caused by these specific wavelengths, the study aimed to assess the potential thermal impact of these lasers on the surrounding tissues during the root canal procedure.

In an *in vitro* investigation conducted by Shehab., *et al.* it was determined that the use of output powers of 1.05, 1.5, and 1.95 W had a significant impact on effectively eliminating pathogens. The study concluded that the disinfection achieved by employing the 810-nm diode laser was desirable. This finding highlights the influence of the irradiation method on the speed and effectiveness of disinfection in the context of the study [16].

Several studies have utilized different techniques to simulate the conditions of the oral cavity in research settings. One example is the work conducted by Strakas., *et al.* where the teeth were immersed in a bath of hot water heated to 37°C to replicate the temperature of the oral cavity. This method aimed to create an environment similar to the oral cavity for conducting experiments or investigations related to dental procedures or treatments [17].

In contrast to the approach taken by Strakas., *et al.* researchers such as Alfredo., *et al.* and Gutknecht., *et al.* expressed concerns regarding the use of a water bath for simulating the oral cavity. They believed that this method was inappropriate as it allowed for the flow of water, leading to excessive cooling of the oral cavity. Their perspective highlights the need for careful consideration of simulation techniques to ensure a more accurate representation of the oral environment during experimental studies.

In contrast to the approach taken by Strakas., *et al.* researchers such as Alfredo., *et al.* [3] and Gutknecht., *et al.* expressed concerns regarding the use of a water bath for simulating the oral cavity. They believed that this method was inappropriate as it allowed for the flow of water, leading to excessive cooling of the oral cavity. Their perspective highlights the need for careful consideration of simulation techniques to ensure a more accurate representation of the oral environment during experimental studies [12]. In a recent study, the root canal was deliberately kept completely dry to investigate the impact of laser power and duration on temperature increases [18].

When it comes to temperature increases over the root surface, it is important to consider their potential harm to the surrounding periodontium. The widely accepted threshold for bone is considered to be a temperature increase of 47°C sustained for 1 minute. This indicates that a temperature increase of approximately 10°C during a minute is generally well-tolerated [17,19].

However, the crucial threshold for the periodontium differs slightly. For the periodontium, a temperature increase of 11°C sustained for 5 minutes or 13°C sustained for 1 minute is considered to be the critical threshold beyond which damage may occur. This suggests that the periodontium is more sensitive to temperature changes compared to the bone [19,20].

In the study conducted, two lasers, LX16 and DENLASE, were used at different power levels to assess their temperature effects in different areas of the root canal.

When the LX16 laser was used at power levels of 1.15, 1.45, and 1.85 watts, the highest temperature rise observed at the apical area was 3.26°C, 3.84°C, and 4.31°C, respectively. On the other hand, when the DENLASE laser was used at the same power levels, the highest temperature rise was measured as 3.87°C, 3.77°C, and 4.41°C.

In the middle third of the root canal, using the LX16 laser at power levels of 1.15, 1.45, and 1.85 watts resulted in temperature increases of 3.26°C, 3.34°C, and 4.12°C, respectively. Similarly, when the DENLASE laser was used at the same power levels, temperature rises of 3.05°C, 3.21°C, and 4.08°C were observed.

It is worth noting that all temperature increases recorded in the test groups remained below the critical thresholds of 11°C for 5 minutes and 13°C for 1 minute. Therefore, from a thermal standpoint, the temperature rises observed during the study were considered safe and did not exceed the critical thresholds for potential damage.

In contrast to the findings of Seraj., *et al.* who reported a temperature rise of over 7°C with 810-nm diode laser irradiation in continuous mode at 1.5W, our investigation yielded different results. In our study, the mean temperature rise at the apical third of the teeth was measured as 4.41°C at the highest output power of 1.8W for a duration of 60 seconds. These results indicate that our investigation observed a lower temperature increase compared to the previous study by Seraj., *et al.* [20].

Indeed, according to De Costa Ribeiro., *et al.* the intervals between irradiation cycles play a crucial role in allowing heat to dissipate and tissues to cool, thus preventing excessive temperature rises. In their study, an interval of 10 seconds was chosen between each irradiation cycle, and each canal was exposed to radiation four times. This chosen interval allows for thermal relaxation and ensures that the overall impact of temperature rise remains within safe limits. The breaks between irradiations enable sufficient time for heat to dissipate, tissue to cool, and minimize the risk of exceeding the safety temperature threshold [6].

The study's findings indicate that the apical portion of the tooth's root surface tends to have higher temperatures, especially at 1.85 W/20 s, compared to the middle region. This temperature disparity may be attributed to variations in the thickness of the dentinal root. These results align with previous studies conducted by Gutknecht., *et al.* [6] and Hmud., *et al.* which also demonstrated that temperature levels in the apical region increase when the residual dentine thickness of the root canal wall is relatively thinner compared to the central region during laser irradiation [22]. However, when the experiment was extended to a longer duration (60 s) in this study, different results were observed. There was no significant variation in temperature between the middle and apical regions at 1.15 W and 1.85 W. This suggests that the thickness of the root dentine does not play a substantial role in the temperature rises reaching the external root surface when higher laser power and longer exposure times are used.

Furthermore, our study revealed that the middle section of the root demonstrated similar temperature responses to both the LX16 and DENLASE lasers at output powers of 1.15 W and 1.45 W. At an exposure time of 60 seconds, there was no significant difference in temperature rise among the output powers of 1.15 W, 1.45 W, and 1.85 W at the apical area for both the LX16 and DENLASE lasers. This observation could be attributed to the diminishing thickness or tapering of the root at the apex, making it more sensitive to temperature fluctuations compared to other measurement points in this study.

According to our findings, the middle third and apical third of the root exhibited greater temperature increases at exposure times of 60 seconds compared to 20 seconds for both the LX16 and DENLASE lasers. The temperature increase was influenced by the remaining dentin thickness as well as the intensity and duration of the laser radiation [12].

In this investigation, the maximum temperature recorded did not exceed 10°C when utilizing thermocouples in conjunction with continuous-wave LX16 and DENLASE diode lasers. The chosen power levels (1.15, 1.45, and 1.85 W) and durations (20 and 60 s) were deemed safe, especially when considering the cooling effects of the body. The presence of blood circulation and the surrounding tissues around the teeth, which have lower thermal conductivity compared to air, further contribute to the safety of laser treatments in the oral cavity. This enhanced cooling effect allows thermal energy to dissipate more rapidly, ensuring an even higher level of safety around the tooth during laser procedures [23].

Conclusion

Within the limitations of the *in vitro* experiment, both the LX16 and DENLASE lasers at the studied parameters and application methods can be safely used in endodontic procedures. The temperature increases remained below the protection limit for periodontal tissues, especially when considering the cooling effect of the body and the surrounding tissues in the oral cavity.

It's important to note that this conclusion is specific to the conditions and parameters of the study. Further research and clinical trials may be necessary to validate these findings and evaluate the long-term effects of laser irradiation in endodontics.

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