Original Article

Influence of an 810-nm Diode Laser on the Temperature Changes of the External Root Surface: An *In Vitro* Study

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ABSTRACT

Background and Aims: Rising effects of temperature due to laser use during root canal disinfection may harm periodontium and alveolar bone. Therefore, the aim of this study was to estimate the surface root temperature of lower incisors throughout the application of different power levels and times of an 810-nm diode laser. **Materials and Methods:** Sixty single-rooted extracted human lower incisor teeth were selected and chemomechanical preparation was performed. Specimens were irradiated using 810-nm diode laser at 1.05, 1.5, and 1.95 W power settings and two periods of time 20 and 60 s, in a continuous wave (CW) mode, without water spray. Specimens were divided into three main groups (n = 20). Each group was subdivided into two subgroups (n = 10). Then, the peak temperatures at the middle and apical regions of the root surface were registered using a thermocouple. **Results:** Temperature rise of root surface at all the selected output powers was below 7°C. The highest temperature value was obtained in the apical region at 60 s when the root canal irradiated at 1.95 W output power. **Conclusion:** Diode laser is safe for use as a root canal disinfectant. Time of exposure to laser irradiation has an effect on the temperature difference at different output powers.

Keywords: *Diode laser, root canal surface, temperature, thermocouple*

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Introduction

Successful endodontic therapy requires proper disinfection by mechanical instrumentation and irrigation. But the microorganisms remain despite the process of root canal cleaning and shaping, due to bactericidal action of instrumentation modalities and irrigation regimens are through direct cell contact to the root canal system.[1]

New disinfection approaches by various lasers have been studied in detail by many researchers to improve the success of root canal treatments. Laser beam can be applied to narrow root canals using a thin fiber optic delivery system 200 µm.[2] Direct contact between target and fiber tip of laser light is not required.[3] Therefore, laser technology has gained the spotlight as an adjunct treatment in endodontics. Diode laser has optimal antibacterial properties. Because it has a direct thermal effect on the microorganism by photothermal interaction, it penetrates the dentinal tubules to the deep thickness and it is absorbed by water content the bacterial pigments, that is how bacteria in deeper layers are eliminated. In addition, laser light removes the smear layer and changes the surface morphology of dentin.[4]

The laser's type and radiation protocol can cause a temperature increase in laser-assisted root canal treatment. Heating in the root canal is a desirable effect, but overheating of the external root surface results in

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the injury of periodontal ligament and alveolar bone.[5] Laser irradiation can rise the temperature up to 7 to 10°C without producing any injury to periodontal tissues or ligaments.[6]

The temperature of the root canal surface should not overcome 7°C to avoid damage to bone regeneration or the periodontal ligament around the tooth.[7] This study aimed to detect the degree of temperature rise at the outer surface in the middle and apical regions of the root at different powers (1.05, 1.5, and 1.95 W) and times (20 and 60 s) using intracanal 810-nm diode laser irradiation.

Materials and Methods

Ethical statement

The protocol of this study was scientifically approved by Higher Scientific Researches Committee at Faculty of Dentistry, Mosul University, Iraq at clearance number (4C/74 in 13/1/2020).

Sample selection and preparation

Sixty extracted single-rooted teeth of lower incisors were used in this study. All the surface debris and residues were removed after extraction. At the level of cementoenamel junction (CEJ), each tooth was decoronated to a length of 15 mm from the apex using a diamond sectioning disc (Drendel, Zweiling Diamant GmbH in Berlin, Germany) for standardization. Patency was confirmed with No.15 K-type file (Dentsply-Maillefer, Ballaigues, Switzerland) and pulp tissue was removed with a barbed broach (Dentsply-Maillefer). Then the samples were prepared using 2Shape to the TS2 (25/.06) files (MICRO-MEGA, Besancon, France) at 250 rpm and 1.2 N/cm torque value using endodontic motor (Eighteeth, Changzhou City, China) according to the manufacturer's recommendations. Root canals were irrigated between each instrument change with 2 mL of 2.5% sodium hypochlorite (NaOCl) (Chloraxid, Medical Company, Poland) solution for 1 min. Then, the root canals were irrigated with a 5-mL final wash of sterile distilled water. After that, specimens were divided according to the output power of laser into three main groups (n = 20) as follows:

Group A: Irradiation at an output power of 1.05 W.

Group B: Irradiation at an output power of 1. 5 W.

Group C: Irradiation at an output power of 1.95 W.

Then, each group was subdivided according to the irradiation time into two subgroups (n = 10) as follows:

Group A1 (n = 10): 1.05 W, 5 s.

Group A2 (n = 10): 1.05 W, 15 s.

Group B1 (n = 10): 1.5 W, 5 s.

Group B2 (n = 10): 1.5 W, 15 s.

Group C1 (n = 10): 1.95 W, 5 s.

Group C2 (n = 10): 1.95 W, 15 s.

Laser irradiation

Diode laser at a wavelength 810 nm (Elexxion claros dental laser, Singen Deutschland, Germany) was applied in root canals after dryness with paper points. Irradiation of canals was performed with a continuous wave and the laser light was transferred through 200 µm flexible fiber optic tip which was inserted inside the root canal (1 mm from the apex) and continuously irradiated from the apical foramen to the canal access in a circular movement to treat all dentinal tubules at a speed of 2-mm/s by specially designed handpiece for endodontic application.

For each root canal, irradiation was repeated four times, with 10 s resting between each lasing cycle for each power. Thus, the total irradiation time was 20 and 60 s per root canal. No water spray or air was used, that mean, the root canal interior was dry at all times.

Temperature test apparatus and measurement

An acrylic-based material (Densply Limited, Germany) was developed to fix the roots and to standardize measurements of the temperature. Through the mold, two holes (1 mm in diameter) were drilled for thermocouple wire entrance at two points of the proximal root surface (middle approximately 6–7 mm from the working length and apical region 3 mm from the working length). Thus, standardization was ensured. Thermal changes were measured during continuous laser irradiation by a thermocouple (Digital Ki and BNT model: ST-1, Chania) and the experiment was measured at room temperature 23°C.[8]

Statistical analysis

The data were analyzed for temperature variation using the Statistical Package for the Social Sciences (SPSS) software program, version 24.0. Paired t test was applied to compare two points on the external root surface for each time at specific power at a significance level of 0.05.

A one-way analysis of variance (ANOVA) was applied for comparing the change in temperature rises at the external root surface in the middle and apical third each alone at each time among different output powers. The Duncan test was used to inspect discrepancy at a significance level of 0.05.

Independent t test was used to compare different times in the middle and apical third each alone at each output power at a significance level of 0.05.

Results

A comparison was done in temperature rises between the middle and apical regions at the external root surface of incisors for each level of time at the specific power using paired *t* test at $P \le 0.05$, as shown in Table 1 and Figure 1. The results revealed that at 20 s time no significant difference was observed in temperature rises between the middle and apical regions at an output power of 1.05 and 1.5 W. However, a significant difference was observed at an output power of 1.95 W. At 60 s time, there was a significant difference at an output power 1.05 W, although no significant difference was observed in temperature between middle and apical third at 1.5 and 1.95 W.

When a comparison was made among different output powers for each tooth segment alone at the selected time using ANOVA at $P \le 0.05$, at 20 and 60 s in the middle region, there was no significant difference in temperature rises between 1.05 and 1.5 W in which both of them were found to be significantly different from 1.95 W.

Further comparison was made among different output powers in the apical region for each level of time; the results showed that at 20 s there was a significant difference in temperature rises among them, whereas at 60 s no significant difference was detected. The results are shown in Table 2 and Figure 1.

Using independent *t* test for each output power in the middle and apical regions each alone at $P \le 0.05$, as shown in Table 3 and Figure 1, the results revealed that 810-nm diode laser at 60 s had significantly higher temperature rises than 20 s of exposure at all output powers in the middle third also in the apical third at the output powers 1.05 and 1.5 W. However, a nonsignificant difference was observed in temperature rises between both 20 and 60 s periods of time when the root canal irradiated at an output power of 1.95 W.

Discussion

In the latest years, lasers have been extensively used to attain ideal disinfection in infected root canals. Beer *et al.*[9] found a bacterial reduction of 98.8% with the 810-nm diode laser, describing laser as a modern state-of-the-art instrument for endodontics. Thermal changes because laser using in root canal disinfection depends on many factors such as laser wavelength, duration, power, and way of irradiation.[10]

The most commonly used wavelength in dentistry was 810-nm wavelength.[11] Therefore, it is selected for this study because this wave is highly absorbed in the bacterial pigmented proteins but it is poorly absorbed in water and hydroxyapatite of dental tissue[12] that leads to a higher penetration rate of laser irradiation deeply. This low absorption allows propagation, scattering,

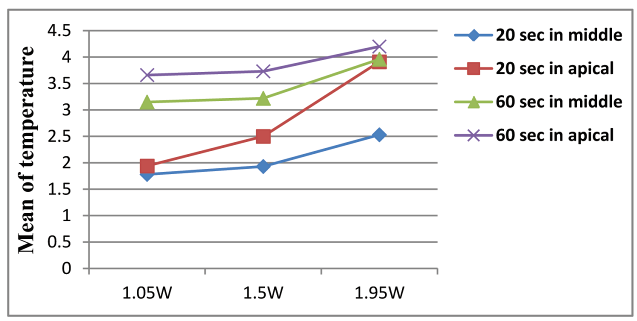

Figure 1: Thermal changes in the middle and apical regions at all output powers and times on the external root surface

Table 1: A comparison in temperature rises between middle and apical region of root surface at the selected time for each output power

Power (W)	Time (s)	Tooth segment	Mean (°C) ± SD	*P* Value
1.05	20	Middle	1.7800 ± 0.5206	NS
		Apical	1.9400 ± 0.7519	
	60	Middle	3.1500 ± 0.4424	0.014*
		Apical	3.6600 ± 0.4626	
1.5	20	Middle	1.9300 ± 0.6098	NS
		Apical	2.5000 ± 0.4163	
	60	Middle	3.2200 ± 0.5078	NS
		Apical	3.7300 ± 0.6292	
1.95	20	Middle	2.5300 ± 0.6738	0.003*
		Apical	3.9100 ± 0.5021	
	60	Middle	3.9600 ± 0.6299	NS
		Apical	4.2000 ± 0.8120	

SD = standard deviation, NS = not significant

Paired *t* test to compare between middle and apical segment of root surface for each level of time at each output power

*Significant difference existed at $P \le 0.05$

Table 2: A comparison of temperature (°C) rises at different output powers of 810 nm diode laser at the certain time

Time (s)	Tooth segment	Power (W)	Temperature rise Mean (°C) ± SD	*F* Value	*P* Value
20	Middle	1.05	1.7800 ± 0.52026 A*	4.314	0.024
		1.5	1.9300 ± 0.60928 A		
		1.95	2.5300 ± 0.67338 B		
	Apical	1.05	1.9400 ± 0.75159 A	31.215	0.000
		1.5	2.5000 ± 0.41633 B		
		1.95	3.9100 ± 0.50211 C		
60	Middle	1.05	3.1500 ± 0.44284 A	7.114	0.003
		1.5	3.2200 ± 0.50728 A		
		1.95	3.9600 ± 0.62929 B		
	Apical	1.05	3.6600 ± 0.46236 A	2.038	NS
		1.5	3.7300 ± 0.62902 A		
		1.95	4.2000 ± 0.81240 A		

SD = standard deviation, NS = not significant

* For each level of tooth segment, different letters vertically at each time have significant difference at $P \leq 0.05$ according to Duncan test

Table 3: Independent *t* test for temperature rises of 810 nm diode laser at specific output power between different times at each the middle and apical root surface

Tooth segment	Power (W)	Time (s)	Mean (°C) ± SD	*P* Value
Middle	1.05	20	1.7800 ± 0.5206	0.000*
		60	3.1500 ± 0.4424	
	1.5	20	1.9300 ± 0.6098	0.000*
		60	3.2200 ± 0.5078	
	1.95	20	2.5300 ± 0.6738	0.000*
		60	3.9600 ± 0.6299	
Apical	1.05	20	1.9400 ± 0.7519	0.000*
		60	3.6600 ± 0.4626	
	1.5	20	2.5000 ± 0.4163	0.000*
		60	3.7300 ± 0.6292	
	1.95	20	3.9100 ± 0.5021	NS
		60	4.2000 ± 0.8120	

SD = standard deviation, NS = not significant

*Significant difference existed at $P \leq 0.05$

and transmission, of the laser radiation through the dentin.[13] Thus, the absorption of laser light at deep layers will rise the temperature and cause photothermal results with harmful effects to the periodontal tissue.[6] Numerous studies reported irreversible damaged of periodontal tissues and the alveolar bone if temperature increased 10°C higher than body temperature for 1 min.[10,14] For that reason, analysis of temperature rises on the external root surfaces due to the use of 810-nm diode laser was appraised in root canals in this study.

To confirm the influence of the irradiation technique on the rate of disinfection, the procedure used in this research was taken from the studies of Shehab *et al.*[15] which evaluated the disinfection through 810-nm diode laser to be desirable and determined that using output powers (1.05, 1.5, and 1.95 W) had an efficient effect on reducing bacteria.

Different methods have been used for oral cavity simulation through many studies, for instance, in the study by Strakas *et al.*[16] who put the teeth in a bath containing hot water at 37°C to restore oral cavity. But Alfredo *et al.*[5] and Gutknecht *et al.*[10] thought that using the water bath was not appropriate because it allowed the water to flow and further cooling results than oral cavity. In the recent study, the canal was totally in dry environment to detect the effect of laser power and time alone on the temperature rises.[17]

Many studies investigated thermal changes in thick dentin walls of upper incisors and premolars during intracanal laser irradiation. However in this study, mandibular incisors were used and the root canals were enlarged to determine the temperature rises under the worst conditions. Mandibular incisors have thin root walls and become even thinner after endodontic preparation. Therefore, the same protocol of irradiation cannot be used for every type of teeth, owing to the extreme variation of thickness between them, particularly after endodontic enlargement procedures. Thus, if an irradiation protocol is safe in this study for this kind of teeth, it may be used for almost any teeth. Because of their thinner dentin walls of incisors, the total mass of dentine is fundamental to transmit higher temperatures to periodontal tissues.[10,18]

A study by Seraj *et al.*[19] reported that temperature rise was more than 7°C after 810-nm diode laser irradiation in 1.5-W continuous mode, whereas in our study at the highest output power (1.95 W/60 s) the mean temperature rise was 4.2°C at the apical third of lower incisors. Moritz *et al.*[20] assessed the influence of neodymium-doped yttrium aluminum garnet (Nd:YAG) laser in the upper middle third of root canal after 1-W power level of 5 s with 15 s intervals. The result showed that an average temperature rise was 3.8°C, whereas at 1.5 W power the temperature rise was 4.3°C. In an additional study, Zan *et al.*[21] reported that the highest temperature rise was at 4 W output power measured with two resting times (0.5–25 s) using Nd:YAG laser and potassium–titanyl–phosphate (KTP) laser and with 1 and 2 W powers, the threshold value was exceeded. The peak temperature rise was noted from the apical regions. In our opinion, these differences might be due to the difference in irradiation method, time of laser application, and number of measurement points.

Thus, the peak temperature in this study was below the critical value; the possible explanation of this result may be due to delivery fiber constantly moving within the root canal due to the temperature at the external root surface will rise if the fiber remains at a fixed position in the apical region.[22]

De Costa Ribeiro *et al.*[6] stated that brakes between irradiations were needed for inhibition of the cumulative influence of temperature rise. In this research, the selected interval was 10 s and the irradiation repeated four times, for every canal during irradiations. One possible explanation of this effect is that the breaks between the irradiation cycles are important to allow dissipation of the heat and cooling of the tissue, to prevent a temperature increase higher than the safety limit.

Results of this study found that mean temperature reaches the higher value in the apical segment of root surface of incisors compared with middle region, especially at 1.95 W/20 s. Difference in temperature may be due to dentinal root thickness differences.[19] This result is in accordance with the outcomes obtained by Gutknecht *et al.*[10] and Hmud *et al.*,[23] who showed that temperature at the apical region reaches higher values when the remaining dentine thickness of the root canal wall is thin compared with the middle region during irradiation. However at longer time (60 s) in this study the experiment showed different results with no significant variation between middle and apical regions at 1.5 and 1.95 W. This explains that there is no effect of root dentine thickness in the proximal surface of lower incisors on the temperature rises that reach external root surface at higher power and longer exposure time of laser because of its low thickness of dentine in this surface of the root compared with buccal and lingual surface.

In another study, Alfredo *et al.*[5] found the effect of diode laser after irradiation with 5 W power for 20 s in helicoidal movement in canines; the recorded temperature rise was 12°C, but at 1.5 W power the temperature was 4.2°C. Furthermore, Scaini *et al.*[24] evaluated the surface root temperature changes during erbium-doped yttrium aluminum garnet laser (Er:YAG) laser irradiation for 20 s. The maximum variations in the temperature were found in the apical sections and the lowest temperature changes were found in the cervical sections.

Furthermore, our results observed that effect of both output powers 1.05 and 1.5 W in the middle segment of the root in the incisors is the same. Also all output powers 1.05, 1.5, and 1.95 W are the same in the apical region at the exposure period 60 s. This may be due to point of temperature measurements in this study at the proximal surface as the thickness of the root at least on the proximal surface which is more critical to temperature changes.[18]

The results of this study showed that higher temperature rises at a longer period of exposure at 60 s than 20 s at all powers in middle third and apical third. The elevation in temperature is not only depended on the remaining dentin thickness, but also depended on the intensity output and time of irradiation.[10]

When thermocouple is used and 810-nm diode laser power in a continuous wave during this study, the maximum temperature did not overcome 10°C. If we added to that cooling effect of the body, the used powers (1.05, 1.5, and 1.95 W) and selected times (20 and 60 s) would be very secure. Hence, it was predictable that even more safety around the tooth in oral cavity would occur due to the effect of blood circulation cooling and the tissues surrounding the teeth, which have lower thermal conductivity than air. Therefore, thermal energy dissipates more rapidly.[18]

Conclusion

Within the limitation of present *in vitro* experiment, the result showed that diode laser at a 810-nm wavelength may be safely applied for endodontic uses at the studied parameters (1.05, 1.5, and 1.95 W) and application methods. In account of, the temperature will not rise higher than the protection limit (10°C) for the periodontal tissues with a 10 s resting time when used continuously in a circular activity for total irradiation time (20 and 60 s).

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Nil.

Conflicts of interest

There are no conflicts of interest.

Authors contributions

All the authors Njwan F. Shehab , Nawal A. Al-Sabawi, Emad F. Alkhalidi contributed equally in the preparation of the manuscript.

Ethical policy and institutional review board statement

Higher Scientific Researches Committee at Faculty of Dentistry, Mosul University, Iraq approved this study.

Patient declaration of consent

Not applicable because it's an *in vitro* study.

Data availability statement

The data of the study results are available from the author (Dr. Nawal A. Al-Sabawi, email: dr.n_a_khalaf@yahoo.com) on request.

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