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Diode Laser Irradiation in Endodontic Therapy through Cycles - *in vitro* Study

SUMMARY

Background/Aim: *The aim of this in vitro study was to investigate the influence of irradiation cycles and resting periods, on thermal effects on the external root surface during root canal irradiation of two diode laser systems (940 nm and 975 nm), at output powers of 1 W and 2 W in continuous mode. In previous studies the rising of temperature above 7°C has been reported as biologically accepted to avoid periodontal damage on the external root surface.* ***Material and Methods***: *Twenty human inferior incisors were randomly distributed into four groups, the 940 nm, and the 975 nm diode laser irradiation, both with an output power of 1 W and 2 W, in continuous mode. The thermographic camera was used to detect temperature variations on the external root surface. Digital radiography of the samples was made.* ***Results***: *After three cycles of irradiation, at apical third of the root, mean temperature variation by 940 nm diode laser irradiation was 2.88°C for output power of 1 W, and 6.52°C for output power of 2 W. The 975 nm laser caused a higher temperature increase in the apical region, with temperature variation of 13.56°C by an output power of 1 W, and 30.60°C at 2 W, with a statistical significance of $p \leq 0.0001$ between two laser systems compared for the same power. The resting periods of 20 s between cycles were enough to lower temperature under 7°C in the case of 1 W and 2 W for 940 nm diode laser, while for 975 nm laser, after three irradiation cycles overheating occurred at both output power rates.* ***Conclusion***: *Three cycles irradiation of 940 nm diode laser, with resting periods of 20 seconds, allowed safe usage of 1 W and 2 W in CW for endodontic treatment. For 975 nm at a power rate of 1 W, the last resting period drop the temperature near the safe limit and it came under 7°C in a period less than a minute, while at the power of 2 W the resting periods were not long enough for the safe temperature decrease.*

Key words: Diode Laser, Endodontics, Bactericidal, Temperature Variations, External Root Surface

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Introduction

Reduction of intracanal bacteria prior to obturation is the main goal of endodontic therapy. Microorganisms in the root canal and infected tooth structure have to be minimized, to create optimal conditions for periapical healing[1]. Chemomechanical instrumentation, with various concentrations of sodium hypochlorite as the most common canal irrigant, was the standard approach in elimination of bacteria biofilm, necrotic and vital tissue. Despite good instrumentation and intensive irrigation protocols, there was a lack of success in decontamination of root canal system[2,3].

Diode lasers caught the attention of the researchers in the past years for their antimicrobial abilities through thermal effect. Studies reported bacterial decontamination of root canals by the application of diode laser with different success rates[2,4]. Diode lasers have a direct thermal effect on the microbiota.

The effect depends on the irradiation mode and settings, and it is directly related to the amount of energy delivered. Heating in the root canal is a desirable effect, but it could also gain overheating of external root portions, causing injury of periodontal ligament and bone[5]. Temperature elevation on external root surface is dependent on dentine thickness, output power, and resting time between irradiation cycles[6]. In previous studies the rising of temperature above 7°C has been reported as biologically accepted to avoid periodontal damage on the external root surface during endodontic procedures[7,8].

The aim of our *in vitro* study was to investigate the influence of three irradiation cycles and following resting periods, on thermal effects on the external root surface during root canal irradiation of 940 nm and 975 nm diode laser systems, at output powers of 1 W and 2 W, in continuous mode.

Materials and Methods

Twenty lower permanent incisors were collected at the Clinic for Oral Surgery, Faculty of Dental Medicine, Belgrade, Serbia, with written consent from patients. Freshly extracted teeth were cleaned by removing organic residue tissue and calculus from the external root portion, and cross-sectioned at a cementoenamel junction in the cervical portion, using a double-sided diamond disk (NTI-Kahla GmbH, Kahla, Thuringia, Germany), standardizing the roots at a 13 mm length. Further, chemomechanical instrumentation was applied, and all the root canals were enlarged to an apical size of #40 by hand, using K-files, 1% sodium hypochlorite and 40% acetic acid. Teeth were stored in PBS at +4^{0}C, prior to use.

The Epic 940 nm diode laser (Biolase® Technology, Inc., San Clemente, CA, USA) and the LaserHF 975 nm diode laser (Hager & Werken, Germany) were used in the study, with optical fiber of 200 µm for 940 nm, and 320 µm for 975 nm laser, provided by the manufacturers. The prepared samples were randomly divided into 2 main groups, and subdivided into two groups depending on the output power - 1W and 2W, in continuous mode (CW), as shown in Figure 1.

Laser fiber was inserted into the root canal to the apex, approximately 1 mm from the anatomic foramen, and activated in the moment it was pulled from the apical end in helicoidal movements (~ 2 mm/s), three consecutive times, with resting periods of 20 seconds after each laser dose. Prior to irradiation, teeth were dried, set on the plastic holders in a vertical position, with a mesial side of the root directed toward thermographic camera Varioscan® high-resolution model 3021 (Jenoptik, Dresden, Germany). All the experiments were measured in the controlled environment, at room temperature 21 - 23°C. Thermographic camera detected infrared irradiation from the root surface and the lens system transformed energy into electrical impulses. Digital images of the root temperature variations were analyzed by IRBIS Professional 2.2. graphic-oriented software package (InfraTec GmbH, Dresden, Germany).

All teeth were radiographed by digital radiographic system Trophy RadioVisioGraphy (Trophy Radiologie, Croissy-Beaubourg, France). Dentin thickness of the mesial walls of the roots was measured in all thirds.

Statistical analysis was performed by the Prism software version 6 (GraphPad Software, San Diego, CA). Two-way ANOVA was used to compare values of temperature variations, and One-way ANOVA for comparing dentine thickness between the groups. The statistical significance was tested at $p < .05$.

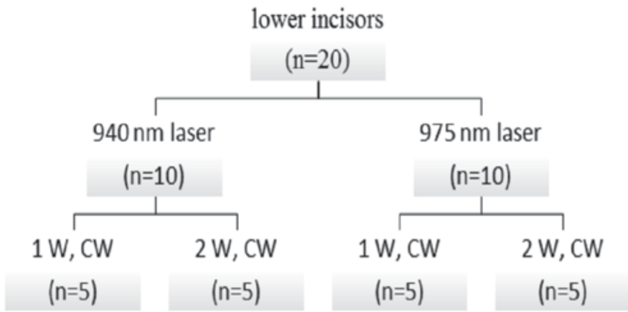

Figure 1. Teeth randomly assigned to the groups, depending on the treatment

Results

In Table 1. and Table 2. mean values of temperature variations (ΔT), regarding experimental groups, are represented. After three cycles of irradiation, at apical third of the root, mean ΔT by 940 nm diode laser irradiation was 2.88°C for output power of 1 W, and 6.52°C for output power of 2 W, in continuous mode. The 975 nm caused a higher temperature increase in the apical region, with ΔT variation of 13.56°C by an output power of 1 W, and 30.60°C at 2 W, with a statistical significance of $p \leq 0.0001$ between two laser systems compared for the same power. The trend continued in middle and cervical third of the root. There was not a statistical difference of ΔT between root thirds, for the same treatment, although temperature raised from cervical to apical third. Through irradiation cycles, and resting periods, ΔT values are represented in Figure 2. The resting periods of 20 s between cycles were enough to lower temperature under 7°C in the case of 1 W and 2 W for 940 nm diode laser, while for 975 nm laser, after three irradiation cycles overheating occurred at both output power rates.

Table 1. Mean and standard deviation (SD) values of the temperature variations ΔT (ºC) at external surface of the roots thirds, during irradiation cycles by 940 nm diode laser

	940 nm 1 W apical	940 nm 1 W middle	940 nm 1 W cervical	940 nm 2 W apical	940 nm 2 W middle	940 nm 2 W cervical
1. cycle	1.96 (0.65)	1.48 (0.53)	0.98 (0.30)	5.02 (2.23)	3.24 (0.84)	1.68 (0.37)
1. pause	1.18 (0.37)	1.08 (0.33)	0.88 (0.31)	1.72 (0.73)	1.64 (0.63)	1.22 (0.22)
2. cycle	2.34 (0.82)	2.04 (0.54)	1.72 (0.40)	5.98 (1.73)	4.54 (0.82)	3.26 (1.08)
2. pause	1.54 (0.38)	1.64 (0.40)	1.48 (0.36)	2.44 (0.79)	2.70 (0.53)	2.36 (0.25)
3. cycle	2.88 (0.82)	2.68 (0.68)	2.50 (0.58)	6.52 (1.65)	5.88 (1.17)	4.36 (0.69)
3. pause	1.98 (0.46)	2.18 (0.48)	2.06 (0.48)	3.52 (1.10)	3.82 (1.10)	3.24 (0.75)

Table 2. Mean and standard deviation (SD) values of the temperature variations ΔT (ºC) at external surface of the roots thirds, during irradiation cycles by 975 nm diode laser

	975 nm 1 W apical	975 nm 1 W middle	975 nm 1 W cervical	975 nm 2 W apical	975 nm 2 W middle	975 nm 2 W cervical
1. cycle	7.18 (2.78)	8.94 (2.52)	8.36 (3.29)	16.60 (6.19)	17.92 (3.92)	19.60 (6.65)
1. pause	3.82 (1.27)	4.18 (1.57)	3.32 (0.62)	7.62 (1.40)	8.06 (1.42)	7.28 (1.40)
2. cycle	13.02 (2.27)	13.86 (3.00)	11.26 (2.31)	20.30 (4.94)	24.82 (5.36)	27.52 (6.69)
2. pause	6.54 (1.08)	6.82 (1.44)	5.68 (0.40)	10.80 (2.17)	12.30 (1.86)	11.22 (1.51)
3. cycle	13.56 (2.30)	15.66 (3.06)	14.34 (2.09)	30.60 (2.50)	32.42 (5.20)	31.22 (7.14)
3. pause	8.02 (1.00)	8.80 (1.31)	7.56 (0.68)	14.80 (2.25)	14.00 (3.22)	14.98 (1.81)

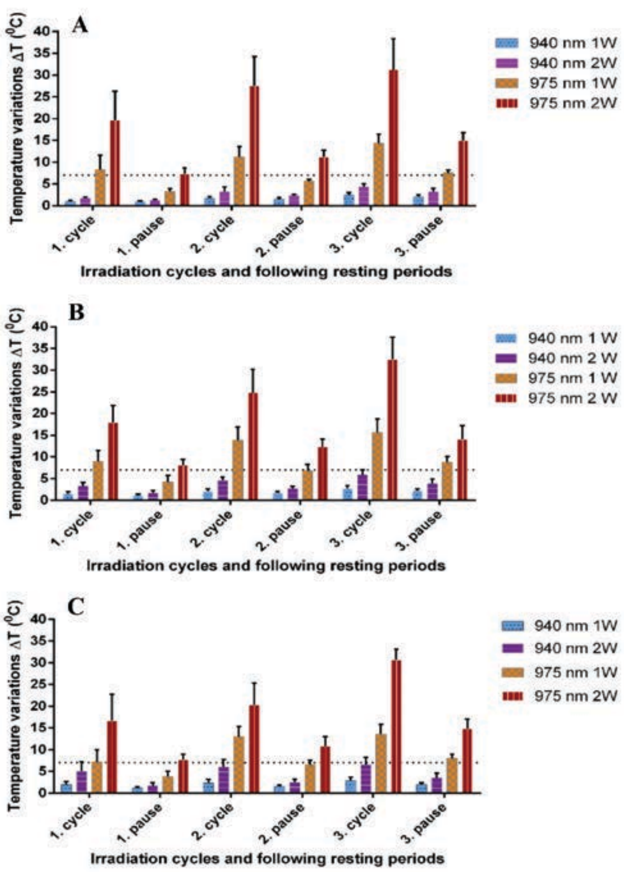

Figure 2. Temperature variations ΔT (ºC) through cycles and resting periods, for 940 nm and 975 nm laser systems, at output powers of 1 W and 2 W. A - cervical third, B - middle third, C - apical third. The recommended safe temperature rising limit of 7 0C is represented by horizontal bar.

Differences in ΔT values were significant at third cycle point between the laser systems in all thirds and between output powers ($p < .0001$), except between 1 W and 2 W in 940 nm group ($p > .05$). For 975 nm at a power rate of 1 W, the last resting period drop the temperature near the safe limit and temperature further lowered under 7 °C in a period less than a minute. Statistical analysis of dentine thickness showed no statistical differences between groups ($p > .05$), which suggested that the results from the groups were comparable.

Discussion

Healing of the tissue after endodontic treatment directly depends on successful disinfection of root canal system. Chemical disinfection can reach bacteria only at 0.1 mm in dentin canaliculi[9], while microbiota is found at 1.1 mm deep into dentine[10]. It has been shown that the wavelengths of 940 nm and 980 nm diode lasers had high penetration into the dentine tissue with bactericidal effect[11], which justify the usage of high-power diode lasers as adjutant in endodontic therapy. In *in vitro* study, Schoop et al.[12] showed significant reduction of *Enterococcus faecalis* and *Escherichia coli* after diode laser irradiation. They concluded that diode laser could be successfully applied for disinfection in deep layers of dentin. On the other hand, it has been shown that during diode laser irradiation thermal stress on the external root surface could occur, if the safe temperature rising of 7°C last over one minute[7,13].

In our study, 940 nm laser with output powers of 1 W and 2 W, in continuous mode, remained in the safe limit through three irradiation cycles. Contrary to these results, 975 nm laser came into the safe zone after two irradiation cycles at output power of 1 W, and only after first irradiation cycle for output power of 2 W. Hmud et al.[14] found statistically significant higher increase of temperature on external root surface at apical third when 980 nm laser was used, in comparison to 940 nm laser, which is consistent with our results. These results could be explained by the stronger absorption of the 980 nm wavelength in water[15]. Also, in the study of Alfredo et al.[5] with 980 nm diode laser in CW, they concluded that during one cycle of irradiation at higher power rate, rising of temperature over safe limit occurred.

The previous study, conducted in dry root canals, suggested 20 seconds of resting time between irradiation cycles, to provide time for the temperature to came into the safe limit[6]. Since irradiation of root canals for antimicrobial effect is recommended to be provided in cycles[16,17], we investigated the variation of temperature during three irradiation cycles followed by 20 seconds of rest after each cycle. The resting periods allowed temperature decrease at the external root surface in all experimental groups. For 940 nm laser resting periods were long enough to provide safe roots irradiation through all irradiation cycles, with both power rates. For 975 nm laser, temperature decrease during resting periods was significant. Unfortunately, at a higher power rate of 975 nm diode laser, resting periods were not long enough to decrease temperature into the safe limit. A new protocol for irradiation with 975 nm laser should be provided, for safe endodontic usage, since the antimicrobial effect is more efficient at higher power rates[17].

Conclusions

The results of this *in vitro* study showed that three cycles irradiation of 940 nm diode laser, with following resting periods of 20 seconds, allowed safe usage of 1 W and 2 W in CW for endodontic treatment. For 975 nm laser application at 1 W in CW, during the last resting period temperature drop near safe limit and came into the safe zone under the minute. At the power of 2 W of the 975 nm laser, resting periods were not long enough for ΔT to decrease into the safe limit.

Note: The results of this paper were awarded for the oral presentation at the 22nd BaSS Congress.

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