

Temperature Changes in Periodontal Tissues

Root canal treatment under irradiation with Diode Laser of 980 nm in sheep teeth

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_Abstract

The aim of this study is to examine if two different modes (CW-Chopped) with different power settings and irradiation time can rise the temperature of the periodontal tissues above 47 °C under root canal irradiation with diode laser of 980 nm and also see if the temperature rising has any correlation to the root length.

40 single root sheep teeth (the two lower central incisors) were endodontically treated with the step back technique. The root canal length was controlled with Schick 2.6 digital intraoral X-ray system. The 40 teeth were divided in two groups with 20 teeth in each group; one was irradiated with CW (Continuous wave) and the other one with chopped mode. The irradiation of the root canal was done with a 200 µm

optical fiber. The power and irradiation time was different in both emission modes. In order the start temperature to be the same as the normal living tissue temperature, a warm bath was used with temperature in 37 °C checked with an inbuilt quicksilver thermometer. The temperature in the periodontal tissues was registered by a thermocouple in three different areas of the root length (1/3 coronal, 1/3 middle, 1/3 apical). The results were statistically analyzed with SPSS 13 statistical package.

The results have shown that the temperature never went above the 47 °C, temperature threshold for bone necrosis. There was a very strong correlation between the root length, the total irradiation time and the temperature rising in the CW mode and a weak correlation in the chopped mode. As a conclusion we can say that the diode laser 980 nm can be used for endodontic treatment without any risk for periodontal tissue damage with the power and irradiation time settings used above.

_Introduction

The history of observations on the pulp biology and the dental procedures to relieve the patient from the pulp pain is going back to ancient times. The relation between caries and pulp pain from the inflamed pulp is recognized in very old writings.

Since these old days reports have been found that ancient Greeks were trying to performed root canal treatments in order to relieve the patient from the pulp pain by hermetically sealing the root canal system of the tooth after disinfecting it with cauterization, by putting small trephines of very hot iron in to it.

In the modern days root canal treatment is achieved by removing the pulp from the root canal with different files (K-files, H-files) and different

Table 1 _Descriptive statistics of the temperature results.

VARIABLES	MISSING	VALID	MEAN	MEDIAN	STD. DEV	MIN.	MAX.
CW. APICAL	0	20	41.66	41.10	1.61	40.00	46.70
CHOPPED, APICAL	0	20	38.99	38.90	0.43	38.30	39.90
CW. MIDDLE	0	20	41.34	40.85	1.65	39.70	46.30
CHOPPED, MIDDLE	0	20	38.78	38.70	0.40	38.30	39.70
CW. CORONAL	0	20	41.13	40.60	1.69	39.60	45.80
CHOPPED, CORONAL	0	20	38.67	38.65	0.39	38.00	39.50
ROOT CANAL LENGTH – CW	0	20	17.49	16.05	3.20	14.00	28.00
ROOT CANAL LENGTH – CHOPPED	0	20	17.49	16.05	3.20	14.00	28.00

techniques. At the same time disinfection of the root canal and the dental tubuli can be achieved with a lot of different solutions such as NaOCl, Chlorhexidin, H₂O₂, Iodine, EDTA, or pastes such as Ca(OH)₂ with some times good and some other times not so good results.^{1, 2, 6, 11, 12, 16} It seems that some of the bacteria are penetrating deeper in the dental tubuli making more difficult for the chemical solutions or pastes to penetrate that deep to kill them or that the bacteria itself is resistant to these solutions and pastes such as the bacteria *Enterococcus Faecalis* is, presenting a reservoir for future infections and risk for failure of our treatment.^{1, 2, 5, 6, 8, 11, 12, 14, 16, 17}

An answer to this problem could be the different Laser systems which have given good results in disinfecting the deeper layers of the dentin.^{5, 8, 13, 14, 17}

One of the ways that the Laser works on the tissues and on the bacteria is by being absorbed by them. The photons of the laser beam are absorbed from the bacteria or the tissues, giving their high kinetic energy to them which is transformed to thermal energy. In this way, temperature in the tissues and/or in the bacteria rises and kills the bacteria. The question which always comes up is if this temperature rising in the tissues is big enough to be transmitted to nearby tissues and create thermal damage to them.

During the recent years research was done with different types of Lasers (Nd:YAG, KTP, Diode 810 nm, Er:YAG, Ho:YAG, Er,Cr:YSGG) in order to answer this question. These research projects have shown no damaging thermal effect in the periodontium when different types of Lasers are used for disinfection of the root canal during the root treatment.^{4, 7, 9, 10, 13, 14, 15}

The aim of this study is to investigate in vitro if the temperature changes in the periodontal tissues of sheep teeth exceed the thermal bone necrosis threshold³ of 47 °C or not when we use a Diode 980 nm Laser for the disinfection of the root canal.

Materials and Methods

Forty sheep teeth, the central incisors of the lower jaw, were drilled and endodontic treated with H-files up to nr. 50. The teeth were rinsed with NaOCl solution following the root treatment procedure for the human teeth in order to remove the smear layer as much as possible¹¹, and dried out with paper points. X-rays were taken from all the teeth involved with the Schick 2.6 digital X-ray system in order to control and measure the root canal length and also to control the placement of the electrodes from the thermocouples which were used to measure the temperature rising inside the periodontium. The electrodes of the thermocouples were placed in three different places in the periodontium in the vertical dimension (1/3 apical, 1/3 medial, 1/3 coro-

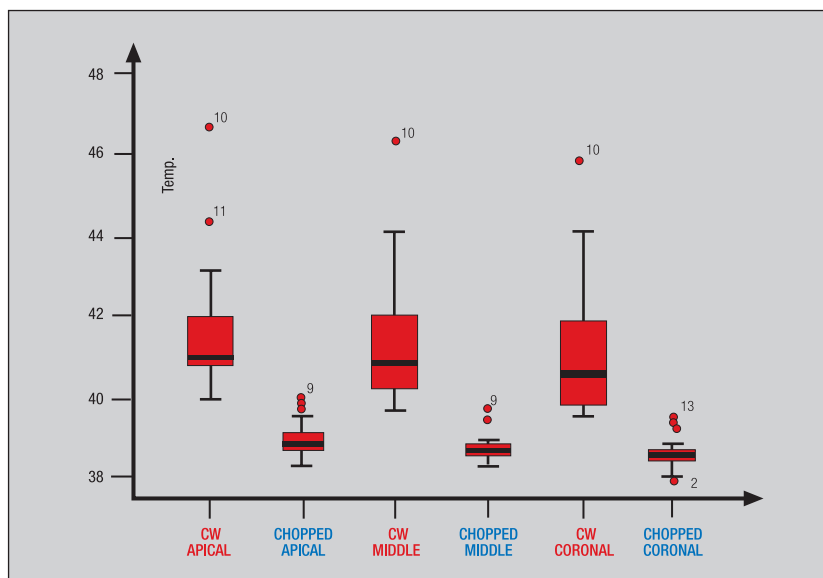


Diagram 1 _The temperature rising in all the measurement places in CW and Chopped mode

nal). The front section of the sheep jaw with the treated teeth involved in the study was stabilized in a gyps base. The forty teeth were divided in two groups of twenty teeth in each group. The two central incisors in each jaw were used in the study. The first group (the right one) was irradiated with a power of 2 Watt in continuous wave (CW) and the second group (the left one) with a power of 3 Watts in Chopped mode with 10 ms the Laser radiation on and 10 ms the Laser irradiation off. Before the irradiation the section of the sheep jaw with the root treated teeth was put in a warm bath in order to simulate the normal tissue temperature of 37 °C as a start temperature for our experiments. The temperature was double checked with the thermocouples and an inbuilt quicksilver thermometer in the warm bath. In order to have a dry root canal even inside in the warm bath a rubber dam cover was used to insulate the opening of the root canal from the water. A diode 980 nm laser was used in the study with an optical fiber of 200 µm in diameter. Before every irradiation a calibration of the output power was done with an inbuilt calibration device in the Laser instrument.

The optical fiber was inserted into the root canal until the root apex was reached. Then the optical fiber was moved 1 mm back from the apical contact and the irradiation started with circular movements in contact to the root canal wall from the apical to the coronal area. The irradiation time was for CW mode 2 mm/sec while for the Chopped mode was 5 sec.

Results and statistical analysis

The results of the temperature measurements during the experiments were registered in tables and a statistical analysis was done with the use of SPSS 13 statistical package. The differences in temperature between results of the irradiations in the two emis-

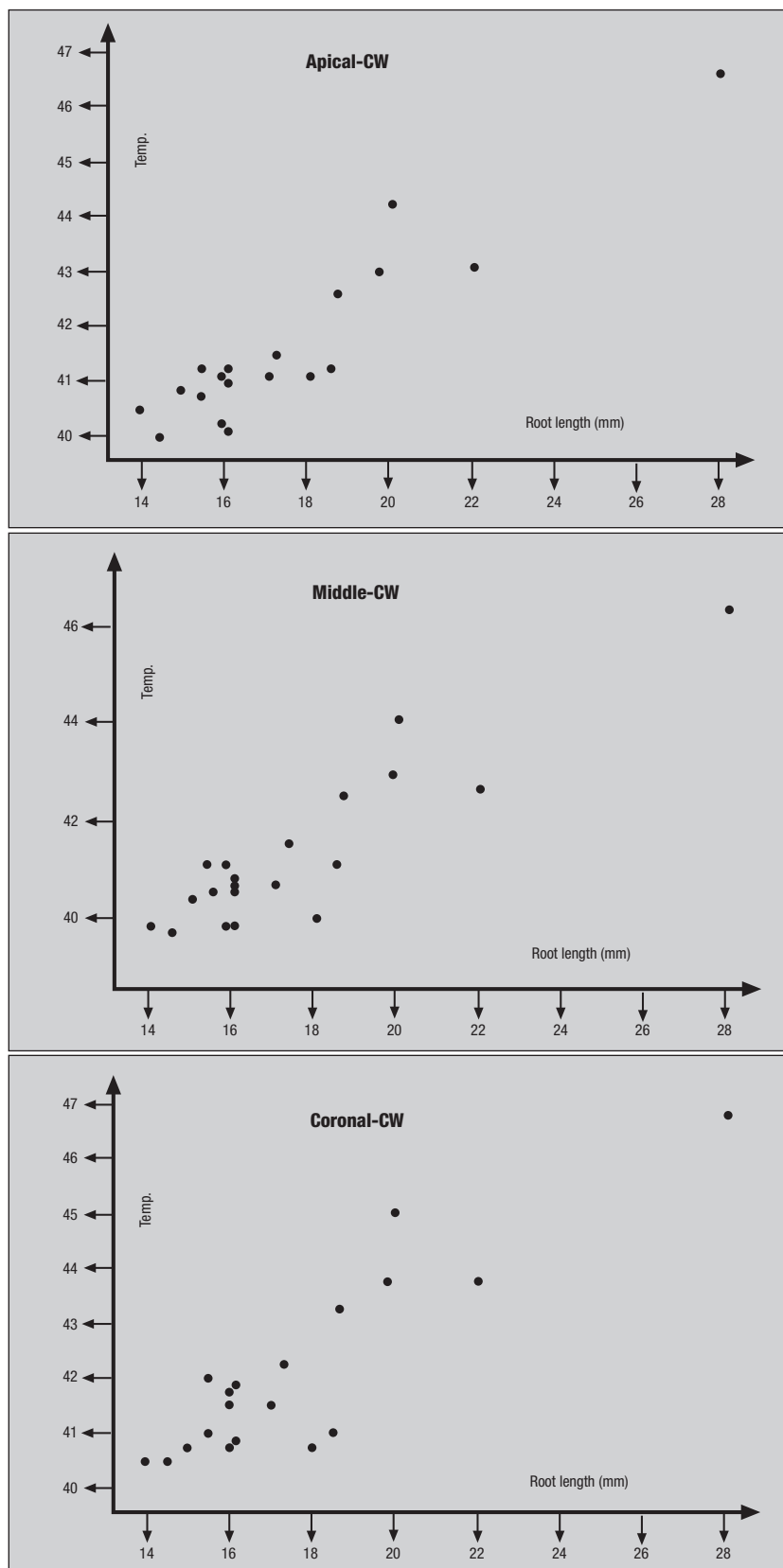


Diagram 2_ The correlation between the root length and the temperature rising in CW mode in all the measurement places in periodontium.

sion modes and the three measurement places in the periodontium were tested with the Wilcoxon test. The relation between the total root length and the temperature was controlled with the Pearson's correlation coefficient.

The descriptive results for the temperature found in all the measurement places in the periodontium in both emission modes (CW, Chopped) are given in table 1.

It is obvious, from table 1 that in all the places in the periodontium in both emission modes the temperature rising does not exceed the temperature threshold point of 47 °C. The distribution is better seen in the box plot in the diagram 1 where it becomes obvious that the temperature rising is much higher for the CW-mode than for the Chopped mode. We can also see that the highest temperature is present in the apical area for both the CW and Chopped mode and the lowest in the coronal area.

The formal analysis shows that the value of 47 °C is not possible for the temperature rising in all the measurement places in the periodontium in both the emission modes.

The temperature, three times the typical divergence for the mean value of every measurement place in the periodontium for both the CW and Chopped mode was calculated and found to be:

_ For the CW mode: 46.5 °C in the apical 1/3, 46.3 °C for the middle 1/3, 42.2 °C for the coronal 1/3.

_ For the chopped mode: 40.3 °C in the apical 1/3, 40.0 °C in the middle 1/3, 39.8 °C in the coronal 1/3.

These temperatures can be considered the logical upper limit of the distribution of the temperature and the possibility to find, in such experiments, temperature values above these limits are 0.13 %.

Especially for the temperature value of 47 °C the possibility to have such a temperature rising is:

_ For CW mode: 0.046 % in the apical 1/3, 0.030 % in the middle 1/3, 0.026 % in the coronal 1/3.

_ For the Chopped mode is 0% in all the three measurement places.

The differences between the CW and Chopped mode in the temperature rising was found to be statistically significant for all the measurement places.

The mean differences were:

_ For the apical 1/3: 2.67 (sd = 1.562, t = 7.651, p < 0.001)

_ For the middle 1/3: 2.57 (sd = 1.707, t = 6.719, p < 0.001)

_ For the coronal 1/3: 2.46 (sd = 1.777, t = 6.191, p < 0.001)

There was a very strong correlation between the root length and the temperature rising in all the three measurement places in the periodontium for CW mode. For the Chopped mode the correlation was weak.

The Pearson's correlation coefficient between the root length and the temperature rising for the CW mode was:

_ For the apical 1/3: 0.932 (p < 0.001)

_ For the middle 1/3: 0.907 (p < 0.001)

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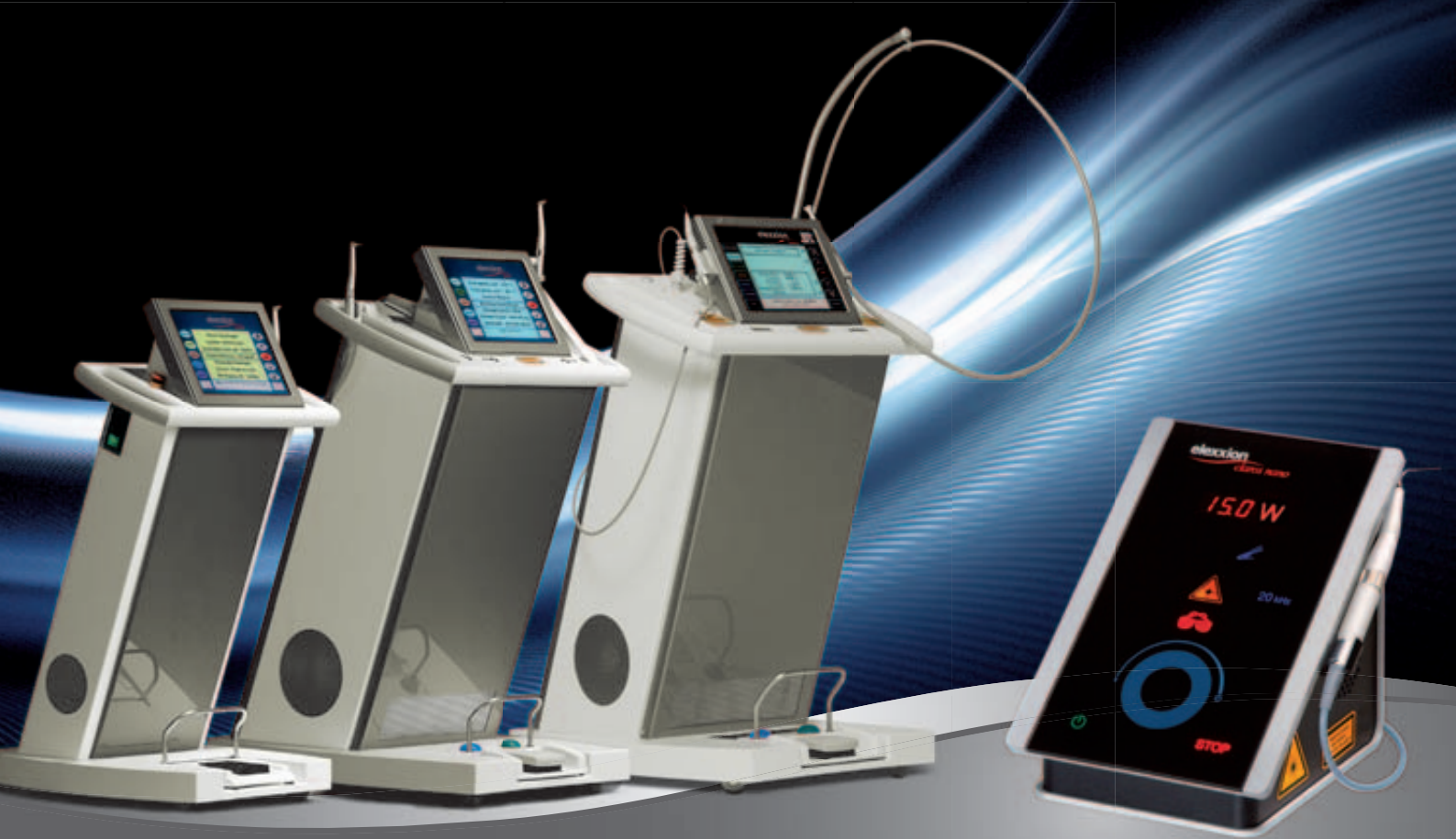
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For the coronal 1/3: 0.886 ($p < 0.001$)

The Pearson's correlation coefficient between the root length and the temperature rising for the Chopped mode was:

For the apical 1/3: 0.393 ($p = 0.086$)

For the middle 1/3: 0.211 ($p = 0.371$)

For the coronal 1/3: 0.113 ($p = 0.634$)

The correlation between the root length and the temperature rising in all the three measurement places in the periodontium are better visualized in the graphs in diagram 2.

The graphs in diagram 2 make obvious that the longer the root length is the higher the temperature rising. This happens because the longer the root length is, the longer is the irradiation time in the CW mode.

The correlation between the root length and the total irradiation time in CW mode was also very strong. This correlation was:

For the apical 1/3: 0.930 ($p < 0.001$)

For the middle 1/3: 0.910 ($p < 0.001$)

For the coronal 1/3: 0.895 ($p < 0.001$)

That is the reason why it is expected to find a very strong correlation between the temperature and the total irradiation time in CW mode.

Discussion

Based on the established practice, it could be easier or more difficult to disinfect the root canal, depending on the type of the bacteria and their location in the root canal and the dentinal tubule.^{1, 2, 5, 6, 11, 12, 16}

During the years different methods were tried in disinfecting the root canal and the deeper layers of the root canal walls with Ca(OH)_2 pastes, or NaOCl, H_2O_2 , EDTA, Iodine solutions with different success rate.^{1, 2, 6, 11, 12, 16} Some bacteria, e.g. *Enterococcus Faecalis*, can not be killed or are imbedded far away from the reach of the disinfecting solutions deep inside the dentinal tubuli. An answer to the problem of reaching out and killing these bacteria is to use different Laser systems.^{5, 8, 13, 14, 17}

In this study we tried to find out if the temperature in the periodontium rises in such a high temperature that exceeds the threshold point of bone thermal damage while using a diode 980 nm Laser with different power settings in the two modes (CW and Chopped) for disinfecting the root canal.

In 1983 Eriksson and Albrektsson reported in their article in the Journal of Prosthetic Dentistry that the temperature threshold for bone necrosis is 47 °C for 1 min.³

Researchers were trying to find the answer to this question using different types of Lasers such as diode 810 nm Lasers, Nd:YAG Lasers, Er,Cr:YSGG Lasers, Er:YAG Lasers and 2 Ω Nd:YAG (KTP) Lasers. All of these different research projects gave differ-

ent results not only because of the different Laser types which have different absorption in the root canal walls but also because of the different power settings used in these projects. In all of these projects the temperature rising was ≤ 10 °C. That means ≤ 47 °C which is the temperature threshold for bone necrosis.^{4, 7, 9, 10, 13, 15}

Looking at these projects separately we can see that in 1997 Klink, Klimm, and Gutknecht, reported that during irradiation of the root canal with an Nd:YAG Laser, the temperature rising was kept locally in the root canal wall and was not transmitted into the deeper layers of the dentin.

At the same year, (1997) Moritz, Gutknecht, Gorbarkhay, Shoop, Wernish, and Sperr, had irradiated root canals with diode 810 nm Laser with power of 4 watts in Chopped mode 10 ms on and 10 ms off, with irradiation time in 5 seconds. They found out that the maximum temperature rising on the root surface was 6 °C when the fiber was used with circular movements in the root canal. In 1999 Wan-Hong Lan had irradiated root canals with Nd:YAG laser in order to see the temperature elevation on the root surface. He found that the temperature never exceeded the 10 °C if the energy was 100 mJ/pulse, the pulse rate 20 pulses/sec and the irradiation time of 15 sec. The increase of irradiation time resulted in increased temperature elevation which is in agreement with our results and conclusions. In 2004 Ishizaki, Matsumoto, et al., have shown that the average temperature rising on the root surface during root canal irradiation with Er,Cr:YSGG Laser was less than 10 °C.

In 2004 Shium Lee et al., have shown that the temperature rising on the root surface, was not only depended on the shape of the tip (flat or conical) but also to the dentine's conductivity, diffusivity and heat capacity. During the same year (2004) Namour, Kowaly, Van Reck, Rocca, were measuring the thermal elevation on the root surface during root canal irradiation with a 2 Ω Nd:YAG (KTP) Laser and found that the temperature rising never exceeded the 7 °C. In 2005 Gutknecht, Franzen, Meister, Vanweersch, Mir were investigating the temperature rising on the root surface during the root canal irradiation with a diode 810 nm Laser. They found out that with the power of 4 Watts and irradiation time of 5 sec., the thermal elevation in the apical 1/3 was 7 °C.

During our study we investigated the thermal elevation in the periodontium in sheep teeth in vitro during root canal irradiation with diode 980 nm Laser. The results of temperature rising can be correlated with the root length and the irradiation time.

The measurements and the statistical analysis have shown that no elevation of the temperature in the periodontium exceeded the threshold level of 47 °C a result that is in agreement with earlier studies with different types of Lasers. Looking at table 1

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of our experiments it becomes obvious that the temperature elevation in the periodontium has always been less than 10 °C in all the measurements places, both for the CW and Chopped mode, even if the maximum temperature registered in the CW mode was very near to that point. The statistical analysis has shown that it is very unlikely to have temperature elevation above the temperature threshold point of 47° C in the Chopped mode with the possibility being 0, while for the CW mode this possibility is very small.

The differences between the measurement places in CW and Chopped mode separately, were also significant with the highest temperature being in the apical 1/3 and the lowest in the coronal 1/3.

The total root length had a very strong correlation with the temperature elevation in CW mode. The total irradiation time had also very strong correlation with the temperature rising in CW mode which was in agreement with an earlier study.⁹ The same correlation for the Chopped mode was very weak because the total irradiation time had a standard value of 5 sec. The study has shown that the longer the irradiation time or the longer the root length, the higher the thermal elevation is in the periodontium in CW mode.

Conclusions

As it is mentioned in earlier studies, also in our study, the temperature elevation in the periodontal tissues during the root canal irradiation with 980 nm Laser was never greater than the thermal bone necrosis threshold point of 47 °C. It is expected to have lower temperature elevation in living tissues due to the blood circulation in the periodontal tissues.

More research has to be done concerning the effect of dentine's conductivity, diffusivity, and heat capacity in order to understand better the temperature transportation between the dental and oral tissues.

Finally as a conclusion we can report that there is no risk for thermal bone damage in the periodontium under irradiation of the root canal with diode 980 nm Laser, as long as we do not exceed the working parameters of this study.

The literature list can be requested from the editorial office.

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