

## Effect of 940 nm Gallium Arsenide Laser on dental hard tissues temperature propagation

Influência do laser de arseneto de gálio (940 nm) na propagação da temperatura em tecidos duros dentais

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### ABSTRACT

Despite the extensive literature available on laser at the present, there are few articles about the temperature of laser radiation and its propagation on dental hard tissues. The present study general objective is to evaluate in vitro the effect of temperature increase produced by the laser radiation of 940 nm on the dental hard tissues and, as specific objectives a) analyze current parameters using 940 nm laser on dental hard tissues b) assess the most appropriate criteria for this wavelength on dental hard tissues. 4 groups of 5 teeth each (lower incisors, upper incisors, canines and molars) were irradiated with 6 powers and frequencies (0.1 to 0.4 W, in continuous or pulsed mode). The results of this study allow us to ensure that, in the chosen parameters, major powers, but delivered in pulsed manner, generate less temperature rise. Extremely significant differences were found between groups of lower incisors and molars. 0.1 W power, pulsed mode for 20 ms, with 20 millisecond intervals, generated less than 4 Celsius degrees of temperature increase in all the cases studied. In conclusion, the use of powers of up to 0.4W, in pulsed mode, generated thermal effects of less than 4 Celsius degrees.

### KEYWORDS

Temperature; Low level laser; Tooth.

### RESUMO

Apesar da extensa literatura disponível sobre o laser na atualidade, há poucos artigos sobre a temperatura da radiação laser e sua propagação nos tecidos duros dentais. O presente estudo teve por objetivo geral avaliar in vitro o efeito do aumento da temperatura produzida pela radiação laser de 940 nm sobre os tecidos duros dentais e, como objetivos específicos a) analisar os parâmetros atuais utilizados para o laser de 940 nm nos tecidos dentais duros b) avaliar o parâmetro mais adequado para esse comprimento de onda sobre os tecidos dentais duros. Quatro grupos de 5 dentes cada (incisivos inferiores, incisivos superiores, caninos e molares) foram irradiados com 6 potências e frequências (0,1 a 0,4 W, em modo contínuo ou pulsado). Os resultados deste estudo permitem afirmar que, nos parâmetros escolhidos, as potências mais altas, mas entregues em forma pulsada, geram menos aumento de temperatura. Diferenças significativas foram encontradas entre os grupos de incisivos e molares inferiores. A potência de 0,1 W, modo pulsado para 20 ms, com 20 milissegundos de intervalo, gerou menos de 4 graus Celsius de aumento da temperatura em todos os casos estudados. Em conclusão, o uso de potências de até 0,4 W, no modo pulsado, gerou efeitos térmicos de menos de 4 graus Celsius.

### PALAVRAS-CHAVE

Temperatura; Laser de baixa potência; Dente.

### INTRODUCTION

Dental procedures involve heat generation. Pulp is very sensitive to temperature increase. Tissue can suffer irreversible damage

to its structure and composition if certain temperature thresholds are exceeded. Zach and Cohen investigated the pulp temperature increase of healthy teeth in Rhesus Monkeys [1]. These authors observed that a temperature

increase of 5.5 °C generated pulp necrosis in 15% of cases, in 60% of cases at 11 °C and 100% of necrosis at 16 °C. Ericsson and Albrektsson determined that a temperature of 5.5 °C is critical when it's maintained constantly for 1 min [2]. For these reasons, clinical treatments are considered completely safe when the pulp temperature increase does not exceed 4 °C [1,2].

Since it was discovered by Theodore Maiman [3], lasers have evolved. In dentistry, they are in the visible and infrared spectrum, are non-ionizing and unable to damage nucleus cell. This means that its use is completely safe for health and that can be used in dentistry without risks.

Within the different light sources used in dentistry, lasers have been proven to be the most innocuous tool to minimize temperature increase in pulp [4].

Important progress has been made in controlling the temperature of the pulp. In the case of lasers, it has always been present this situation. Niccoli et al. have already established the importance of pulp temperature increase by using a CO2 laser in continuous mode [5].

Dental lasers can be pulsed to control the temperature rise on tissue. In Restorative Dentistry and Endodontics this control is mandatory. Continuous movement of laser fiber and correct parameters laser can minimize the risks and are preconditions for successful endodontic treatment [6].

Through the years, it has been used less power and time of laser exposure. Despite the extensive literature available (more than 248,000 articles in PubMed only on laser from 1970 to the present), few articles talk about the spread of the pulp temperature to 940 nm laser application. It's very important to establish the best possible exposure dose of radiation to maximize the benefits generated by laser action on tissues of the oral cavity, making it necessary to know the exact temperature spread of dental hard tissues.

### **General objective:**

Assess the effect of temperature increase produced by laser radiation of 940 nm on dental hard tissues.

### **Specific objectives:**

Analyze current parameters using 940 nm laser on dental hard tissues.

Evaluate the most appropriate criteria, according to the temperature rise of dental hard tissues, with the power and frequency of the laser radiation of 940 nm.

## **MATERIALS AND METHODS**

For this study, 20 fresh extraction teeth were divided into 4 groups:

Group 1: Lower incisors (n = 5).

Group 2: Upper incisors (n = 5).

Group 3: Canines (n = 5).

Group 4: Molars (n = 5).

In each group the same power and frequency variables were used, using known parameters laser [7] with the wavelength of 940 nm:

Power 1: 0.1 Watts (W), continuous wave (CW) (0.1W CW).

Power 2: 0.1 W, 20 ms of pulse duration, 20 ms of pulse interval (0.1W 20 ms).

Power 3: 0.2 W, 20 ms of pulse duration, 20 ms of pulse interval (0.2W 20 ms).

Power 4: 0.3 W, 20 ms of pulse duration, 20 ms of pulse interval (0.3W 20 ms).

- Power 5: 0.4 W, 20 ms of pulse duration, 20 ms of pulse interval (0.4 W 20 ms).

- Power 6: 1 W, 20 ms of pulse duration, 20 ms of pulse interval (1 W 20 ms).

To measure the temperature, a digital thermometer with a flexible dual thermocouple input was used, with a measuring range of -50 to 1300 °C with a resolution of 0.1 °C, with an accuracy of + 0.5% + 1 °C (Figure 1).

The laser used for this study was a 4 W laser of 940 nm, programmable 0.1 to 4 W, in the range of microseconds/ms, with an optical fiber of 400 microns (Figure 2).



Figure 1 - Digital thermometer with double entrance thermocouple Model CEM DT-610B).



Figure 2 - 4 Watts, 940 nm Laser, Medelux Co. Ltd.

The thermocouple was placed in all the irradiated samples 5 mm away from the tip of the fiber, both in contact with the enamel of the irradiated part [8].

To ensure constant contact between laser and enamel and in order to maintain the distance between thermocouple and laser, an ad hoc device was designed to prevent direct manipulation, preventing accidental alteration of the temperature of the experiment (Figure 3).

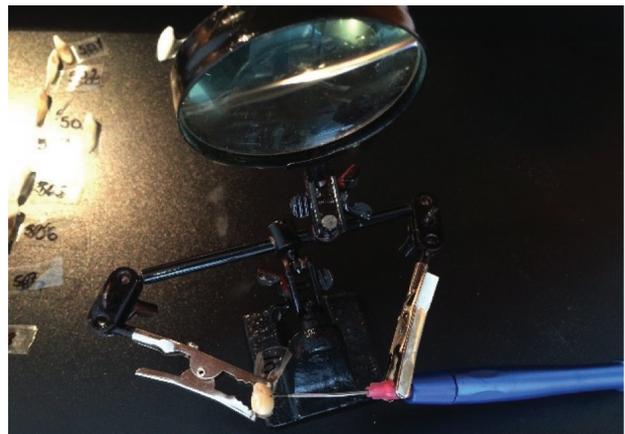


Figure 3 - Ad hoc device to keep optic fiber position perpendicular to the irradiated surface).

Laboratory temperature was kept constant for all samples, checking that the temperature was the same before and after every experience.

Power and wavelength were controlled, ensuring that the delivery was correct, using a power meter. This was done before each experiment.

Temperature was measured every 40 s through 200 s and until 4 degrees were reached, generating a curve of temperature increase. After 200 s, the laser was turned off and let the tooth cool, also measuring, in this case, the temperature every 40 s, to establish a cooling curve of the tooth (Figure 4).

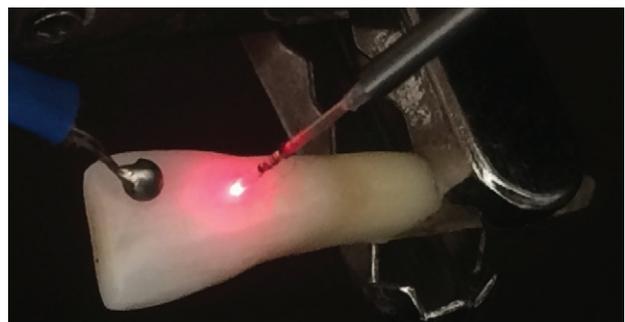


Figure 4 - Final position of 5 mm distance between thermocouple and optic fiber).

**RESULTS**

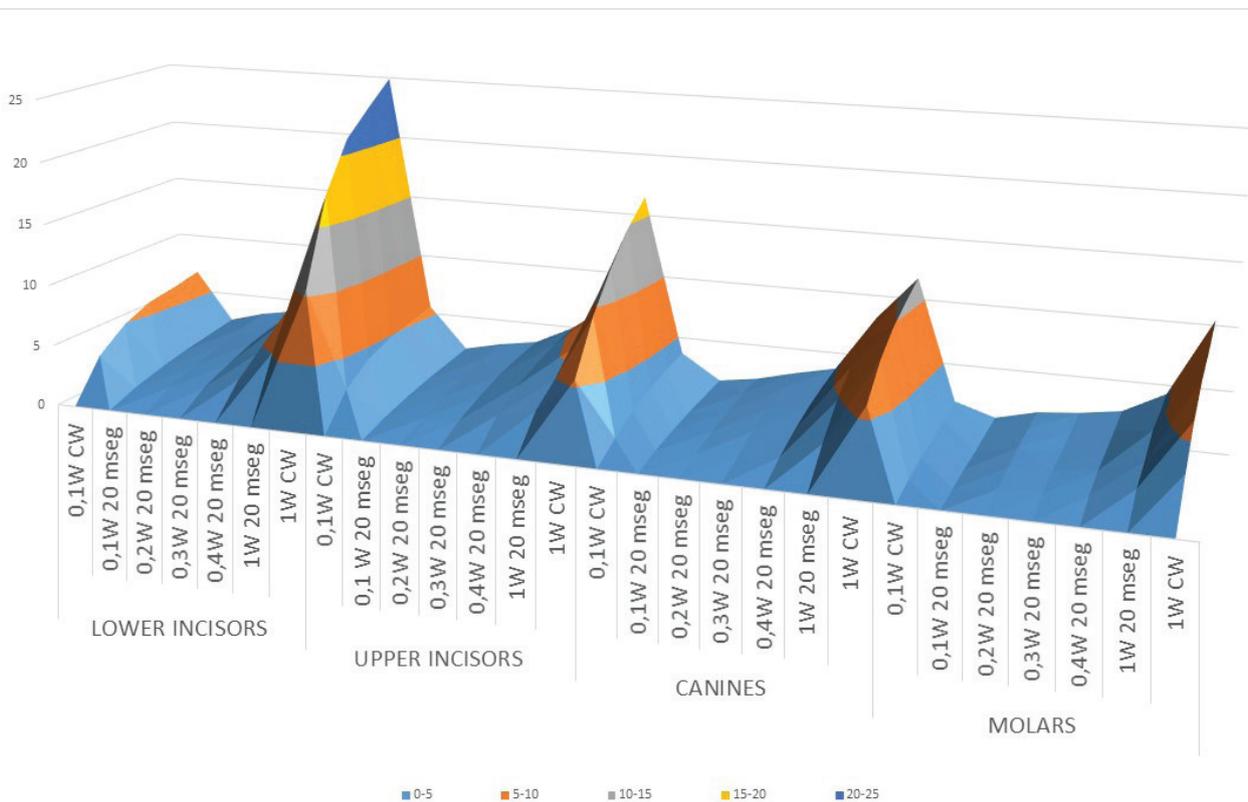
The results of all groups showed an increase of higher temperature at the highest power of smaller surface teeth (Group 1 lower incisors) and lower values for lower powers in the largest surface teeth (Group 4 molar) (Graph 1).

It is also noteworthy that the continuous power generated greater increase in temperature than the same powers in pulsed mode, as 0.1 W of power occurs in all groups, with extremely

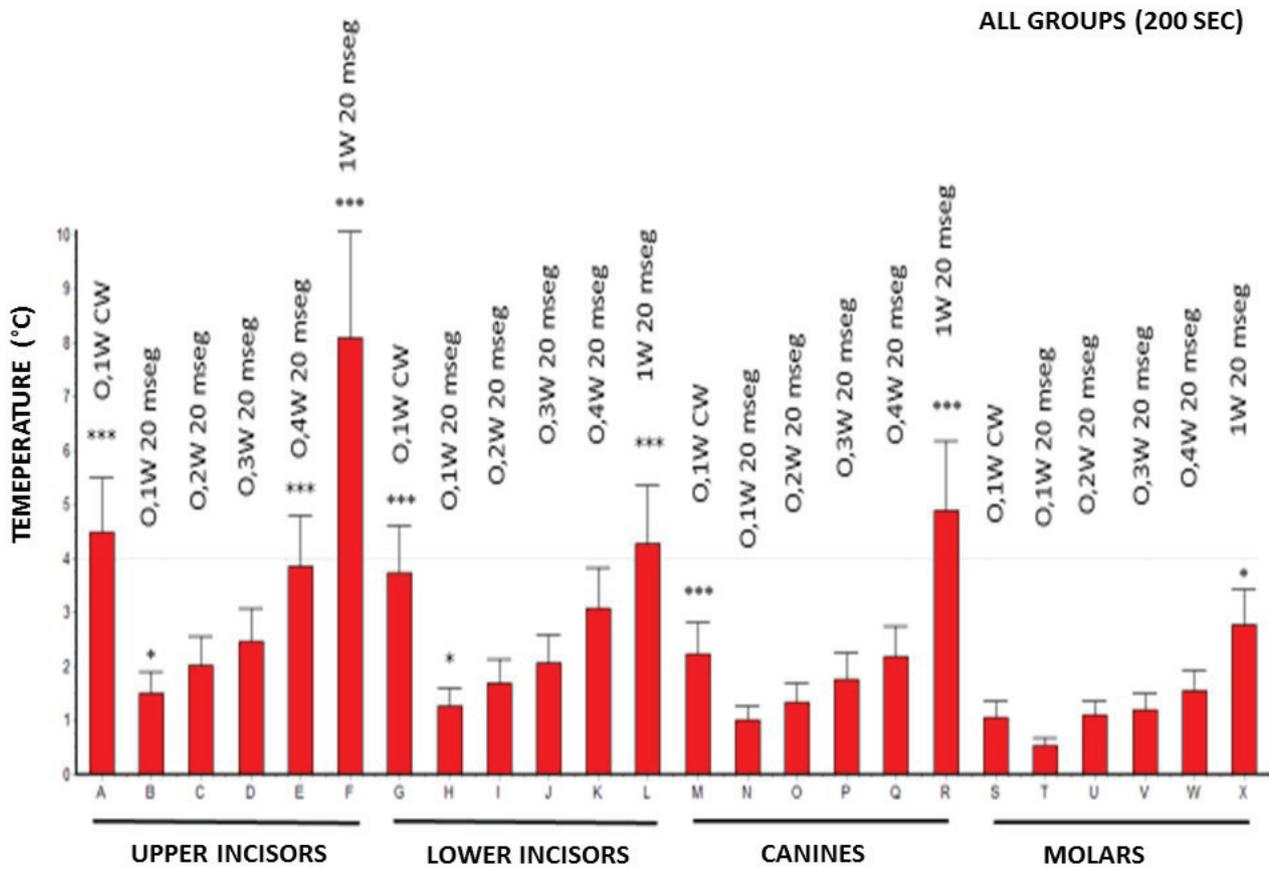
significant differences ( $P < 0.001$ ) in all groups, except for molars (Graph 2).

*Statistical analysis of the results*

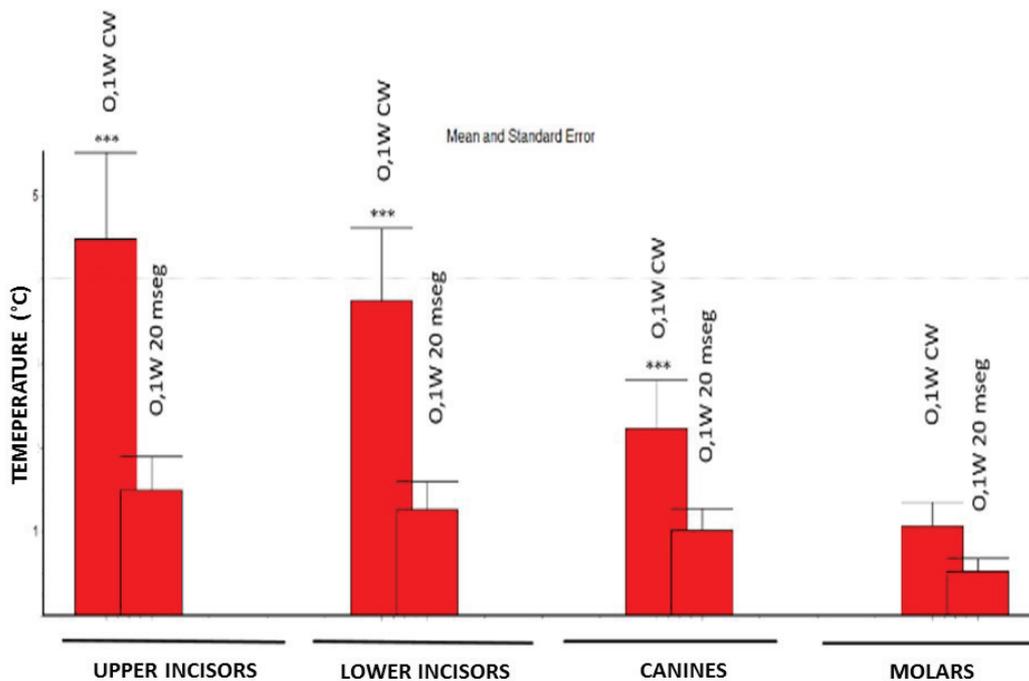
An ANOVA was conducted to see the normality of the data and determined that  $P < 0.0001$ . To evaluate the results statistically the Tukey-Kramer test was used for multiple comparisons. Samples of the first 200 s (six samples for each group and for each power) were chosen to evaluate the warming of dental hard tissues (Graph 3).



**Graph 1** - All groups with Power and Temperatures.



Graph 2 - Temperatures of all groups at 0,1W continuous wave vs. pulsed mode.



Graph 3 - Every group at 1W 20 msec and 0,1W 20 msec, pulsed mode, with extremely significant difference (P < 0.0001). Molar group, with all values below 4 °C, with significant difference (P < 0.05) in the 1W 20 msec group.

## DISCUSSION

While studies of Schulz [7,9] on toxicology opened a horizon on the concept of small stimulations that contribute to homeostasis, known first as “hormesis” by Stebbing [10], was Mester who [7], only seven years after Maiman created the laser [3], discovered the potential modulation of the cellular response for the stimulated radiation at low intensity.

Find the ideal dose of energy for each treatment in every patient was, since then, a challenge that revealed to scientists and clinicians from different areas of health in the application of low intensity laser. Neither too weak not to achieve any biological effect and not too strong to generate cell damage.

The bio modulation of laser is really impressive: Karu [11] raised a pattern functioning through activation of cytochrome c oxidase which would explain the increase of ATP intracellular. Arany et al. have suggested, in vitro, that TGF- $\beta$ 1 activated with laser is able to differentiate human dental stem cells [12].

Higuera, in clinical trials, has shown extremely significant difference and instantaneous increase of Interleukin 8 after application of therapeutic laser in the periapical area teeth chronically infected [13]. Tunér has described the laser action as an analgesic and anti-inflammatory effect that can be as beneficial as these but without the side effects. [14]

Valério et al. (remineralized teeth with laser and acidulated phosphate fluoride, concluding that this type of radiation can be a very effective resource in the control and progression of caries in primary teeth enamel [15].

Laser, at low doses, can also treat herpes in oral cavity and mucositis caused by chemotherapy. In these cases, De Paula et al. and Schubert et al. implemented treatment protocols without adverse effects and successfully for both diseases, reducing recurrences and improving the quality of life of these patients [16,17].

In words of Tunér, “Wrong parameters can give just any results” [14]: one of the least studied and most important parameters to laser dentistry is the propagation of temperature on dental hard tissues. Zach and Cohen, estimated at 5.5 Celsius degrees a critical temperature, in which 15% of the dental pulps generated necrosis [1]. For this reason it's used as a measure of security that any treatment on the teeth must not generate more than 4 Celsius degrees in dental hard tissue to work in a safe area of treatment [4,18-20].

In the present study, parameters normally recommended in dentistry were applied (0.1 W in continuous mode) and used others with lower intensity, such as 0.1 W with 20 ms pulse every 20 ms interval, but the vast majority were of greater intensity, but in pulsed mode.

Major power, but delivered in pulsed mode, generated less temperature increase. This fact is of great interest from a clinical point of view to provide more energy for a longer amount of time in the treatment without risk of heating.

The importance of temperature propagation through the tooth surface is evident with an extremely significant difference ( $P < 0.0001$ ), found between the groups of lower incisors and molars. With the current protocols, it must be differentiated power delivered to lower or upper incisors, canines and molars.

Another fact of this study is that power usually used in dentistry directly on the teeth, as 0.1 W in continuous mode, were excessive in upper and lower incisors. On the other hand, the use of powers up to 0.4 W, but applied in a pulsed mode on canines and molars, resulted in temperature increase below 4 °C, including standard error.

For these reasons, for safety, bio modulator effect, analgesic, and anti-inflammatory, antibacterial and its proven efficiency and effectiveness, it is considered laser as an extraordinary therapeutic tool that has a great present and a promising future in the health sciences, of which dentistry is an important part.

## CONCLUSIONS

Power of 0.1 W, continuous wave, has generated increases in temperature higher than 4 Celsius degrees, when applied for 200 s on selected teeth for this study.

Using parameters up to 0.4 W in pulsed mode, for 200 s, has produced lower thermal effects than 4 Celsius degrees.

Finally, the use of selective parameters, depending on the type of dental piece to be treated, must be taken into account when establishing clinical treatment protocols with low power lasers directly on teeth.

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