Temperature changes under Ho:YLF irradiation

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ABSTRACT

A prototype of Er:Tm:Ho:$LiYF_4$ (Ho:YLF) laser, emitting at 2,065µm, 1,25J 5 Hz, with pulsewidth of 250µs was developed for biomedical applications. In order to verify the possibility of using this laser for cavities preparation *in vivo*, temperature rise in the pulp chamber must be known. Temperature changes were measured during Ho:YLF irradiation with 500mJ/pulse, 30 pulses/position with energy density of 2079 J/cm^2 /pulse. Two groups of teeth were used: group I with pulp chamber empty and group II with pulp chamber filled with phase change material. In both cases, there were no temperature rise above 3,8°C in the pulp chamber.

Key words: Holmium laser, irradiation of enamel and dentine, heat effect in the pulp, preparation of cavities

1- INTRODUCTION

Benefits of holmium laser in dentistry are mainly associated with its wavelength emission, absorbed into water with shallow depth of tissue penetration. The 2,065µm can be delivered through flexible quartz fiber and as a solid state laser, flashlamp pumped, the holmium laser is versatile and rather robust.

The pulsed holmium laser prototype developed at IPEN emits high energy densities, allowing ablation of both soft and hard tissue.

The holmium laser has been used in several applications in biomedical areas, like orthopedics, ophtalmology, cardiology and urulogy. Soft tissue aplications in dentistry includes excisional biopsy of fibrolipoma, benign tumor, traumatic fibroma, etc.[1], and hard tissue applications promisses to be effective for artroscopy of temporomandibular joint, for etching of dental enamel, treatment of dental caries and for cavities preparation for endodontic and restorative purposes [2, 3, 4, 5, 6, 7, 8, 9, 10].

1.1- Consequences of laser irradiation in pulp

In order to evaluate the effects of laser irradiation in dental tissues, the different structures of the tooth must be considered, such as the enamel, dentin and pulp tissue. The later is connective tissue highly vascularized, which is responsible for formation of dentin, nutrition, defense and sensory functions. The

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knowledge of the effects of laser irradiation in these tissues, even indirectly, is very important when establishing patterns of irradiations with no damaging effects on dental tissues.

The most significant effects on pulp tissue are the rise of temperature in the pulp chamber, the rise of microvascularization in this tissue, the formation of mineralized dentine(activation of odontoblasts), as well as the formation of a barrier to the external stimulus on the tissue (reduction of dentin hypersensitivity).

1.2- Rise of temperature in pulp chamber

Incidence of laser light with relatively high density of energy raises the temperature in the focus area and in its neighborhood. It is desirable to minimize the heat flux to decrease thermal injury, delivering enough energy in less time than it takes to the heat to diffuse to the tissue by conduction (thermal relaxation is inversely proportional to square diameter of the irradiated volume).

Hard dental tissues are poor conductors of heat, i.e., they act like true thermal insulators. The parameters for the conductivity and thermic diffusion of enamel an dentin are shown in table 01 [11,12].

Table 01- Thermal Parameters

	Density (g/cm^3)	Thermal Conductivity (cal/s.cm.°C)	Thermal Diffusion (cm^2/s)
Enamel	2,8	2,23 10^{-3}	4,69
Dentin	1,96	1,39 10^{-3}	1,87

From these parameters it can be deduced that thermal conduction is faster in enamel than in dentin. A tooth exposed to low temperatures will suffer an intense stress due to contraction of dentin. If the change of temperature is very big, there can be fissure and cracks in the enamel.

Studies which verified the rise of intrapulp temperature showed that with an increase of approximately 2,2°C, the pulp tissue remains histologically identical to the control (normal). With a thermic rise of 5,5°C, the destruction of odontoblasts is initiated, causing necrosis in 15% of the pulp tissue. If the temperature is risen to 11°C, a great destruction of odontoblast is obtained, with 60% of necrosis. A 100% of necrosis in the pulp tissues occurs at a rise of temperature of around 17 °C [13, 14, 15]

Considering that the pulp is surrounded by hard tissue, with a limited diffusion of heat, the histopathological changes in pulp tissue differs from those in mucous tissue and skin.

The rise of temperature in the pulp chamber is directly proportional to the amount of energy applied, consequently the exposure time is of fundamental importance. High energy densities for short periods of time cause smaller damage in the pulp.

The thickness of enamel and dentine tissues must also be considered. Teeth with smaller dentin remaining show a higher rise of temperature in the pulp tissue [16 17, 18, 19].

In clinical treatments, to minimize thermal rise in teeth avoiding injury to the pulp, air and water spray are used during laser irradiation.

Therefore, temperature field established during the application will define the safe operational conditions and its proper determination helps to know the extension of the thermal injury. The aim of this work is to investigate the temperature rise inside the pulp chamber, when holmium laser is used to cut hard tissue *in vitro*. Morphological changes on enamel and dentine and the ratios of the concentration of calcium atoms to phosphorous ones in the area of laser incidence were carried out in previous works [2, 3, 4].

2- MATERIALS AND METHODS

The study was performed in two groups of freshly extracted human teeth which had been stored in saline solution. The root apexes were resected and the root channel reaimed and widened to allow insertion of a termocouple. Group I had the pulp chamber empty and group II had the pulp chamber filled with a fase change material, to simulate blood fluency in the pulp.

A termocouple type-T (Cooper-Constantan, Omega Eng.), with 0,0013 mm in diameter was inserted in the root channel, in contact with the upper part of pulp chamber. The output voltage of termocouple was amplified (800X) and registered in a H 17501A.

It was used a prototype of flashlamp pumped, pulsed Er:Tm:Ho:$LiYF_4$ (Ho:YLF) laser, emitting at 2,065μm, energies up to 1,25 J/pulse with pulsewidth of 250μs, single pulses to 5 Hz, developed at IPEN for biomedical applications. Group I and Group II were irradiated with 500 mJ/pulse, 30 pulses in the same position, through a quartz biconvex lens of f = 4 mm. Energy density was 2.079 J/cm^2.

3- RESULTS AND DISCUSSION

The results of monitoring temperature rise inside the pulp chamber are shown in figure 01 for group I (pulp chamber empty) and in figure 02 for group II (pulp chamber filled with phase change material).

The temperature rise in the different dental structures as a consequence of laser irradiation is very important to determine morphological changes and chemical changes in the target tissue. Enamel and dentin weakly absorbs energy in the visible and near infrared wavelenghts, causing energy distribution in a large volume of tissue.

Temperature rise *in vivo* are expexted to be lower than *in vitro* experiences due to soft tissue surrounding the tooth and the bloof flow through the pulp tissue in vital teeth.. Irradiating teeth with Ho:YLF with high energy densities (2.079 J/cm^2) caused maximum temperature rise of 3,8 °C in the pulp chamber filled with a phase change material and a maximum temperature rise of 2 °C.

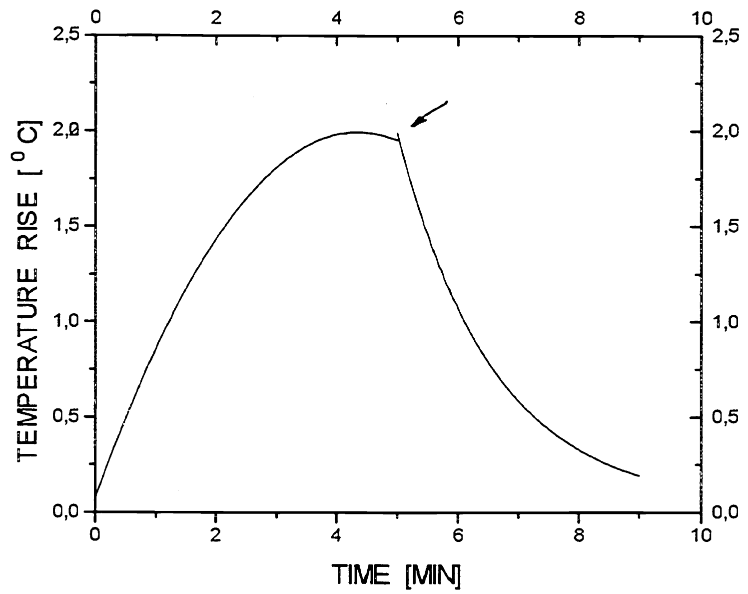

Figure 02- Temperature rise inside the empty pulp chamber of freshly extracted human molar (500mJ/p, 30 pulses). The arrow indicates the end of laser irradiation.

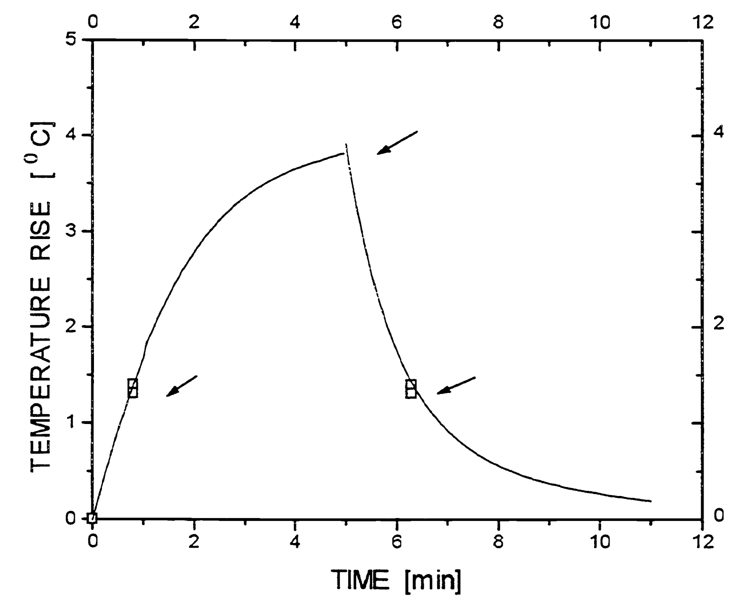

Figure 03- Temperature rise inside the pulp chamber filled with a phase change material of freshly extracted human molar (500mJ/p, 30 pulses). The arrows indicates the end of laser irradiation and the points of paste phase change.

This qualitative results suggests the possibility of using holmium laser for cavities preparation for endodontic and restorative purposes.

Before testing the Ho:YLF laser clinically, further investigation on temperature rises, incorporation of water flow on the teeth, and experiments *in vivo* must be carried out.

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