http://dx.doi.org/10.21611/qirt.2004.076

Thermographic assessment of thermal effects during laser sterilisation of pathological periodontal pocket

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Abstract

This article evaluates thermal effects during laser-assisted curettage of pathological gingival pocket. The use of thermal imaging camera and a real time recording software allowed to qualify the maximum increases of tissue's temperature as well as to estimate the safe time of laser irradiation on surgical area for selected laser parameters. The main goal of investigation was to evaluate if there is possibility of hard dental tissue damage during laser sterilization. Two kinds of dental lasers were tested: Er:YAG and Nd:YAG. To ensure conditions similar to those occurring in the patient's mouth the investigations was performed using special experimental stand.

1. Introduction

Periodontal disease is one of the most common bacterial conditions affecting mankind. The earliest clinical sign of periodontal disease are inflammatory conditions of the pockets around the tooth. Conventional treatment plan consists of scaling and a root planing. Advanced disease when pockets are deeper than 5 mm requires subgingival curettage. It involves the removal of all subgingival calculus, epithelial lining of the pocket as well as necrotic and granulation tissues. As a result of sulcular debridement a fresh wound forms. It is increases risk of bacterial infection and may extend the period of treatment. To prevent post-operative complications antibiotics will be necessary. Conventional methods of treatment appear to demand considerable clinical skill, time and may be limited by the root anatomy and often preclude the achievement of the desired clinical effects. More recently it has been suggested that laser-assisted curettage may be a useful adjunct to mechanical debridement in the treatment of inflammatory periodontal diseases. The laser has been reported to reduce the amount of subgingival bacterial flora, to cause less postoperative pain and less bleeding as well as to reduce oedema [1]. After laser-assisted treatment the gingival tissues heal without incident. Subgingival curettage, contrary to the traditional instrumentation with curettes is considered to be less traumatic and painful thus local anaesthesia is usually not needed.

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One of the earliest reports that suggested the efficacy of the laser in the field of periodontal surgery was presented in the late1980s. As a number of clinical experiments have been devoted to confirm advantages of laser in dentistry, the use of lasers in periodontal therapy become more popular. The most generally used instruments for subgingival curettage of pathological periodontal pocket are the Nd:YAG and the most recent Er:YAG lasers. For a laser to have a biological effect, the energy must be absorbed. As a result of absorption, the increase in temperature of subjacent tissue occurs. Thus the laser-assisted therapy will produce undesirable and uncontrolled thermal effects and may cause irreversible damage to biological tissues [2, 3]. Variables inherent to both Nd:YAG and Er:YAG laser systems include first of all wavelength, which determines how deep the laser radiation will penetrate (thus defines the extent of laser/tissue thermal reaction). The paper presents the results of comparison of the thermal effects in human tooth during laser-assisted subgingival curettage with Nd:YAG and Er:YAG lasers. Direct, in vivo experimental investigations of temperature changes in tissue (will the temperature exceed acceptable level) are very difficult because of many instrumental and methodological limitations. For these reason investigations have been conducted on experimental stand designed to ensure thermal conditions as close as possible to those “in vivo”. Temperature changes were measured by thermovision camera allowed precise control of operation site [4].

2. Experimental investigations

Measurements have been conducted on experimental stand, which schematic diagram is depicted in Fig. 1. A Single rooted human teeth, extracted because of hopeless prognosis were used for this study. Teeth were cut in coronal plane to expose root canal dentin and placed in the handle. To ensure conditions similar to those, occurring in the patient’s mouth during a real dental procedure the investigated tooth was immersed in a special moisturized cotton-wool imitating thermal properties of marginal gingiva. Evaporated water was supplemented to keep constant level of humidity during the whole measurement cycle. The optical fibre was fixed in the handle and positioned parallel to the tooth surface, like during real “in vivo” curettage.

The external surface of tooth, in the cervical region was irradiated with the 320 μm optical fibre of Nd:YAG laser for 15 sec. The time of laser application was

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matched to prevent thermal damage of the specimen, obtaining simultaneously the temperature increases high enough to perform analysis. So the experimental conditions can be interpreted as extremely unfavourable and impossible to accomplish in clinical practice unless the procedure isn't obey by the dentist. Although the real, in vitro Nd:YAG laser curettage last from 30 to 60 seconds, the real temperature increases as a result of irradiation on the tissue's surface are significant lower, than in presented study. It is because in vivo the fibre is moving horizontally around the tooth and simultaneous cooling of operation site is applied.

The average laser power was constant (1,5W) in each measurement cycle due to proper combinations of laser energy and pulse frequency settings. To increase accuracy of measurements, each cycle for each combination of parameters was repeated three times. The combinations of laser parameters are listed in table 1.1.

Table.1. *The combinations of laser parameters, used in experiment*

Er:YAG	Energy [mJ]	500	250	150	100	60
	Pulse frequency [Hz]	3	6	10	15	25
Nd:YAG	Energy [mJ]	150	100	83	75	60
	Pulse frequency [Hz]	10	15	18	20	25

Temperature changes at the time of laser irradiation were measured on the internal surface of the tooth by means of thermal imaging camera ThermaCam SC1000 with its dedicated software package Thermal Studio, allowed continuous registration as well as analysing the stored images. Results of measurement were corrected taking into account the real coefficient of emissivity for surface observed [5]. An example thermal image, registered during measurements is presented in Fig. 2.

3. Results

Temperature changes on the surface of teeth were analysing after all measurement cycles were completed. Results are presented on the Fig. 3 and Fig. 4.

For the Er:YAG laser (Fig. 3) one can see that the lowest increase of temperature was of 17.9°C, and the highest reached value was of 24.3°C in relation to initial temperature of the surgical field. The graphs shows the consistent increase

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of temperature when the increase of pulse energy occurs. The growth of energy from 60 mJ to 500 mJ when using the same average laser power causes increase of maximum temperature of 6.2°C, that is over 15% in relation to maximum temperature got for the lowest energy applied.

For the Nd:YAG laser using radiation power identical to compared the Er:YAG laser the graphs of maximum temperature changes do not show (in the tested energy range) the influence of increase the value of impulse energy on temperature changes of the specimen (Fig. 4). The differences of maximum values of temperatures did not cross 2.4°C, which made up of about +2% of the average temperature value. In this case the regularity in temperature changes was not observed. The increases of maximum temperature in reference to initial temperature of the surgical field during 15 second laser application exceed value of 35°C.

4. Discussion and conclusions

Results of this study indicate that application of laser irradiation at the same energy setting results in much faster growing of tissues temperature when Nd:YAG laser is used compared to Er:YAG laser. The increase of the maximum temperature, observed for Er:YAG laser was about 11°C higher. This phenomenon probably results from the minor width of pulses of the Er:YAG laser and more favourable heat transfer effects in tissues. The use of Er:YAG laser during periodontal soft tissue surgery seems to be safer for patients. One should keep in mind the fact that temperature gradients registered during experiment for both Nd:YAG and Er:YAG lasers significantly exceed the critical value of 5,5°C for dental pulp survival [6, 7]. To prevent undesirable thermal side effects the dentists should rigorously obey treatment procedure, including total irradiation time and laser parameters. Cooling of the surgical field is essential condition for this operation to be safe.

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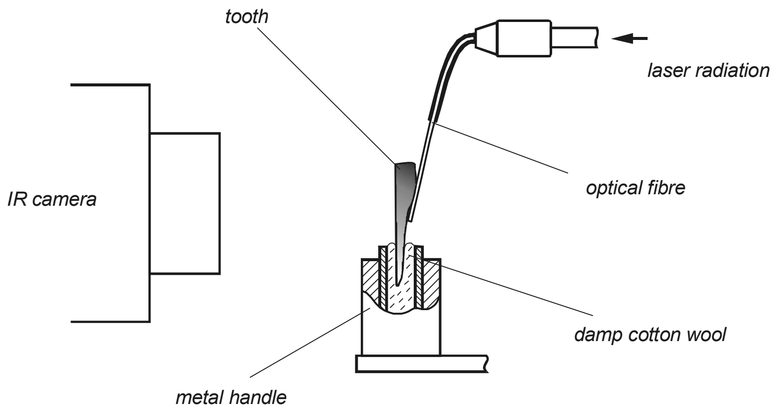

Fig. 1. *The schematic diagram of experimental stand*

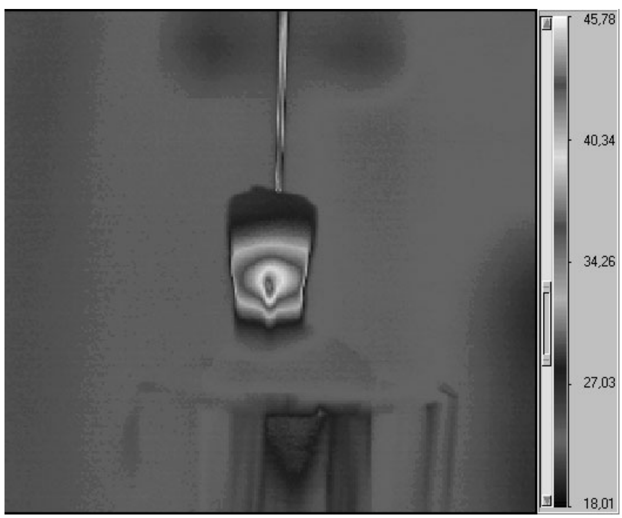

Fig. 2. *An example thermal image of the specimen surface during laser irradiation*

http://dx.doi.org/10.21611/qirt.2004.076

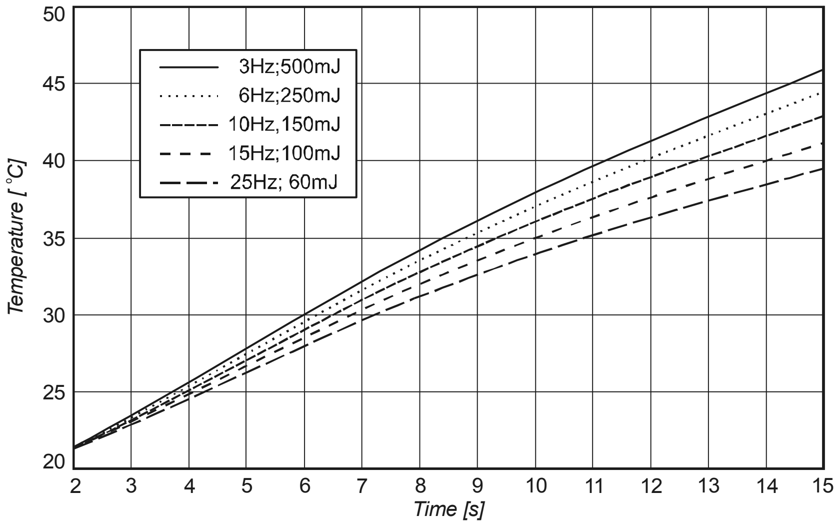

Fig. 3. *The changes of maximum temperature of the specimen for Er:YAG laser at 1,5W and different energy and repetition rate settings*

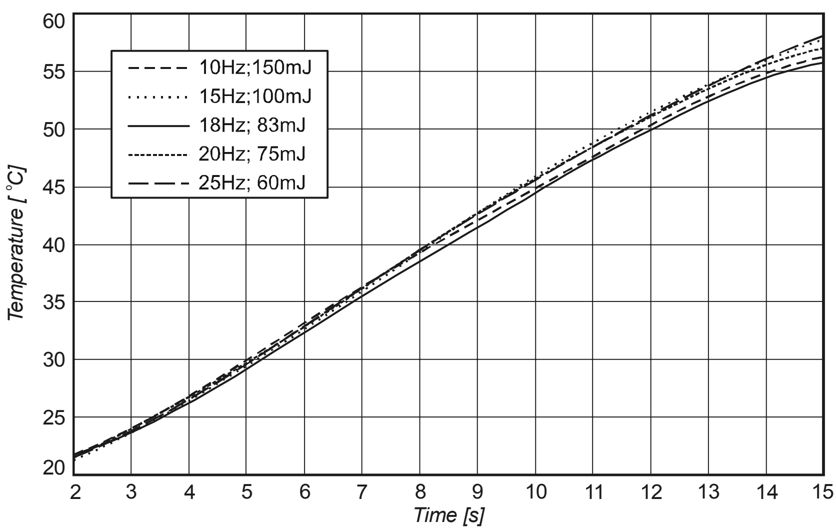

Fig. 4. *The changes of maximum temperature of the specimen for Nd:YAG laser at 1,5W and different energy and repetition rate settings*