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Short Communication

Measurement of Nd:YAG laser-induced pulpal damage in dental treatment

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Abstract

Thermal-induced destruction of the pulpal material due to prolonged exposure of tooth to laser radiation is an important complication during the application of lasers in dentistry. The temperature rise in the pulp chamber due to the exposure of tooth samples to a Q-switched Nd:YAG laser producing 8 ns pulses at 10 Hz repetition rate is reported here. Experimental results indicate that the pulpal damage can be avoided by choosing appropriate exposure time for a given laser energy level. For laser energy greater than 100 mJ exposure time longer than 5 s will lead to irreversible damage of the pulp. These results are useful for dentists to select appropriate laser energies and the exposure times for safe application of Nd:YAG laser in dentistry.

Keywords: Laser-induced pulpal damage, laser radiation, and dentistry.

1. Introduction

Human tooth consists of enamel, the hardest material in the human body, dentin and pulp, which contains blood vessels, nerve fibers and different types of cells like odontoblasts and fibroblasts. The pulp is connected to peripheral blood vessels by root canal, which is protected by gingiva from external bacterial attack. Commonly used mechanical tools employed in dentistry evoke pain due to induced vibrations and temperature rise produced due to friction during the drilling process. Hence efforts are being made to develop laser-based systems as alternative dental tools without accompanying pain and injection of anaesthetic. However, although the application of lasers in dentistry in place of mechanical drill eliminates the problems associated with vibrations, thermal complications remain. In particular, CW and long-pulse lasers induce extremely high temperatures in the pulp. Even cooling by air-assisted operation does not reduce the temperature rise.

The problem of pulpal damage due to rise in temperature during laser treatment has been widely investigated. The penetration of ruby laser beam through enamel is substantial at higher power densities and the absorption of laser light is higher in blackened enamel surface which may occur due to caries [1]. A threshold value of 2100 J/cm^2 for the initiation of histological or morphological changes by laser irradiation was reported in dog's teeth [2]. The steep rise in temperature at the site of interaction of the laser beam melts and vaporizes the enamel and creates

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craters on the tooth surface. Vaporization and crater formation can be eliminated by operating the laser in pulsed mode [3]. The study of thermal effects of CW Nd:YAG laser radiation on enamel, dentin and dental pulp showed that although the fluences in the range 190–2228 J/cm^2 do not produce enough heat to lead to hydroxyapatite melting have resulted in overheating of the pulpal material [4]. In the case of CO_2 laser irradiation, the pulpal damage due to the laser beam is dependent on energy used with exposure time playing a crucial role [5]. Exposure of higher laser intensity for shorter time causes less damage. Hence, the amount of heat transferred to the pulp chamber during the curing of resins used during fabrication of provisional crowns may be damaging the dental pulp [6].

Highly flexible fiber-based beam delivery system for oral use has made the Nd:YAG laser the most widely used laser in dentistry [7]. Its applications include vaporization of caries tissue, cutting dentin, sterilization of tooth surfaces, removal of extrinsic stains and preparation of pits and fissures for sealants [8]. The temperature rise in the pulp chamber during laser etching using Nd:YAG laser has been investigated recently [9]. It is found that laser power above 1 W causes irreversible pulpal damage since the rise in the temperature is above 6°C. The damage threshold can be increased by using water or air-cooling during laser treatment [10]. In addition, the Nd:YAG laser system has effect on the bacterial activities of the pulpal material [11], [12].

Although the literature on the thermal effects of laser treatment on the pulpal material is significant, more studies are needed to quantify the safe levels of laser power that could be used before accepting the laser treatment procedure. We have undertaken one such study to determine the rise of temperature at the dentinopulpal junction due to the etching of premolar teeth using Q-switched Nd:YAG laser. The important results of this study are reported in the present communication.

2. Experimental

The study was conducted using 24 approximately identical first maxillary premolar human teeth. The teeth samples were extracted over two weeks prior to the study and cleaned free of saliva and debris like blood. The samples were also free of caries and had no visible fracture lines in enamel. The samples were stored in distilled water and the water was changed every day to avoid bacterial accumulation. Each of the samples was cleaned with liquid soap and washed under running water before exposing to laser radiation. Occlusal access cavity was prepared with more of lingual extension and very minimal buccal side involvement using straight fissure dental bur. The pulp chamber was exposed and nonvital pulp and other debris was cleaned from this chamber using a water syringe. The tooth sample was dried before laser treatment.

A Q-switched Nd:YAG laser operating at 1.06 μm producing 8 ns pulses at 10 Hz repetition rate was used in this study. The specifications of the laser are identical to the typical laser system used in dental applications. The diameter of the laser beam was 6 mm and a 50% beam splitter was used to divide it into two equal parts. One portion of the beam was used to monitor the laser power simultaneously while the other was used to expose the tooth sample mounted on a special mount. Because of the affinity of Nd:YAG laser radiation to the pigmented tissue the etching area on the tooth sample was painted with Indian ink. This was done essentially to increase the coupling efficiency of the laser radiation with the tooth material and also as a marker to focus the beam on the sample. However, it was found that the ink evaporated at early stages of exposure of the tooth sample to laser radiation and hence its effect on the end result was negligible. The temperature rise in the pulpal chamber was monitored using a thermocouple. The thermocouple was inserted such that it touched the dentinopulpal junction on the side facing the laser beam. The temperature rise in the thermocouple was due to heat transfer from the exposed area through the tooth material during laser irradiation.

3. Results and discussion

The tooth samples were divided into four groups of six each and the first group was treated with 50 mJ, the second with 75 mJ, the third with 100 mJ and the last with 150 mJ of laser energy. The samples were exposed to laser radiation for a period of 45 s and the rise in temperature in the pulp chamber was recorded at 5 s interval.

The increase in temperature for different exposure times and laser energies is shown in Fig.1. It is seen that the temperature rise in the group of tooth samples exposed to 50 mJ of laser energy is less than 5.6°C, the damage threshold of the pulpal material, even after 45 s exposure time. Since the initial pulpal reaction occurs at a temperature rise of 5.6°C [13], it can be concluded that it is safe to use the lower energy laser for dental applications even if the exposure time is longer. The results presented in the figure for various energy levels indicate that as the laser energy increases, the safe level of exposure time reduces drastically. For energy levels beyond 100 mJ, exposing the tooth more than 5 s is fatal to the pulp. Also, at higher laser energy, a faint chalky spot appears on the exposed area due to the reaction of the enamel induced by steep rise in temperature at the interaction site of the laser pulse.

The measured temperature rise presented in Fig. 1 is not identical to the corresponding temperature rise in actual practice as the heat removed by the blood flow during exposure to laser radiation is not taken into consideration [14]–[16]. In order to make realistic measurements we need to fill the pulpal chamber of the experimental specimen with some material with appropriate thermal absorption characteristics to compensate for the cooling effects of blood circulation. However, since the aim of the present study is only to emphasize the importance of the heating effects of laser radiation, we have not made any attempt to incorporate this effect in the experimental results.

4. Conclusions

The experimental results prescribe the safe energy levels and exposure times for Q-switched

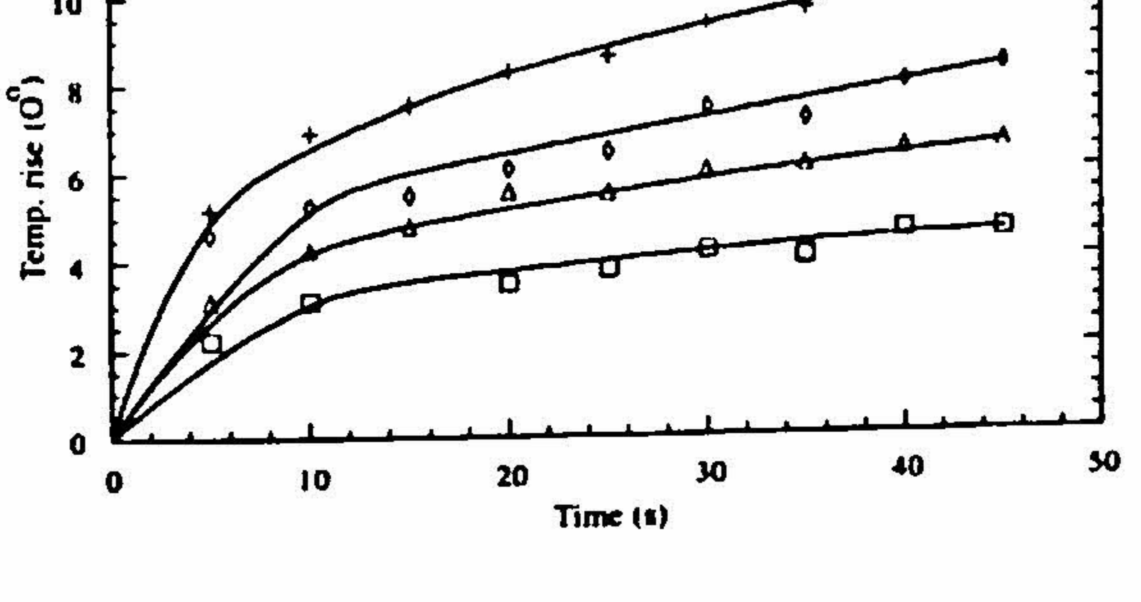

Fig. 1. Mean temperature rise in the pulp chamber during exposure to a Q-switched Nd: YAG laser producing 8 ns pulses at 10 Hz repetition rate for different energy levels (□□□□ 50 mJ, ΔΔΔΔ 75 mJ, ◊◊◊◊ 100 mJ and ++++ 150 mJ).

Nd:YAG laser which is commonly used for laser etching. The results are useful to set guidelines for safe application of Nd:YAG laser in dentistry. The effect of pulse length and pulse repetition time on the temperature rise in the pulpal chamber is not investigated in this experiment. Also, the results cannot be generalized because the teeth vary in thickness and thermal conductivity of enamel and dentin. A detailed investigation is needed to further quantify the safe operating parameters of Nd:YAG dental laser.

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