Study of the ablative effects of Nd:YAG or Er:YAG laser radiation

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Abstract

The use of pulsed lasers in such applications as surgical tissue ablation has motivated investigative works to better understand the laser ablation mechanisms in several tissues types. Understanding the mechanisms involved in the laser ablation allows reduced tissue damage and better surgical results when a high energy laser is used. Thirty-two human molar teeth were used in this in vitro *study to evaluate the ablative effects of Nd:YAG or Er:YAG laser radiation on dental tissue presenting occlusal caries. The samples were randomly divided into 3 groups. Group I was irradiated by Nd:YAG laser at 1064 nm, 30 Hz repetition rate and under the energy density of 95 J/cm^2, 127 J/cm^2 or 191 J/cm^2. Group II was irradiated by Er:YAG laser at 2940 nm, 10 Hz repetition rate and under the same energy densities as in group I. Each group was represented by 15 specimens (5 samples for each energy density). The control group was represented by a decayed tooth and a sound one removed for orthodontic purposes. The morphologies of the irradiated tissues allowed a deeper penetration of the laser beam, representing a low resistance to its propagation. The decayed tissue presented a branny aspect and a fibrous structure on the bottom of the cavities. The caries removal by laser under these experimental conditions were not completely efficient. Depending on the energy density applied, the laser removed not only caries but also the healthy tissue. In other cases, the decayed tissue was still found after the laser ablation. The temperature on the pulp chamber was monitored during the experiments and the thermal damage threshold for the pulp (5 ℃) was never reached for all samples.*

Introduction

The use of pulsed lasers in such applications as surgical tissue ablation has motivated investigative works to better understand the laser ablation mechanisms in several tissues types. An application for laser ablation that gains new adepts each year is its use for the removal of caries in dental tissue [1]. The traditional procedure to remove the decayed tissue is carried out by high speed air turbine handpiece which causes pain due to the vibration and a possible heating transmitted to the pulp. The use of the laser to the same procedure offers improvements to the patient perception [2].

Experimental Setup

In this *in vitro* study thirty-two human molar teeth were used to evaluate the ablative effects of Nd:YAG or Er:YAG laser radiation on dental tissue presenting occlusal caries. For the experiments using the Nd:YAG laser (Spectra Physics – Quanta Ray Lab170 model), the samples were randomly divided into three groups with 5 samples for each one in a total of 15 specimens. The laser parameters used was 1064 nm wavelength, 30 Hz repetition rate and energy densities of 95 J/cm^2, 127 J/cm^2 or 191 J/cm^2.

For the experiments using the Er:YAG laser (571A model, BSL Tech. Inc.), another three study groups were prepared, also with 5 samples each. The laser parameters used was 2940 nm wavelength, 10 Hz repetition rate and the same energy densities mentioned before.

The control group was represented by two samples: a decayed tooth and a sound one removed for orthodontic purposes. The samples were analyzed under Scanning Electron Microscopy (SEM) at the Brazilian Synchrotron Light Laboratory to investigate the efficiency of the carie removal process. The electron microscopy were performed with a JSM-5900 LV microscope (JEOL) under 10 kV. All the samples received a thin layer of gold coating. The samples were also submitted to Energy Dispersive Spectroscopy (EDS) to differentiate the tissue on the bottom of the irradiated area from healthy or caried one.

Results and Discussions

The decayed tissue presented a branny aspect and a fibrous structure on the carie cavities, presenting a biofilm in some samples (figure 1a). We can observe the EDS results for this biofilm and how it differs from the EDS results for a sound dentin region (figure 2). The caries removal by laser under these experimental conditions were not completely efficient, depending on the energy density applied to the sample (see figure 1b).

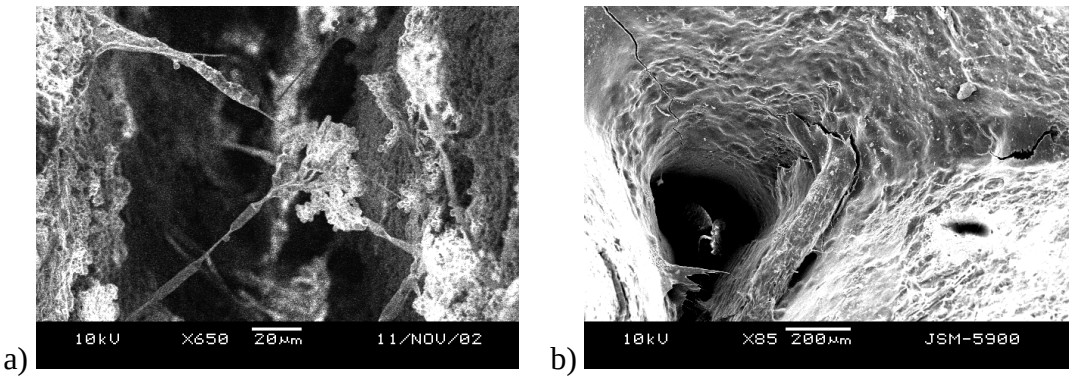

Figure 1: (a) SEM micrograph of the biofilm inside a carie cavity (10 kV, x 650, 20 µm bar); (b) SEM micrograph of the carie cavity irradiated with 127 J/cm^2 Er:YAG laser radiation (10kV, x 85, 200 µm bar);

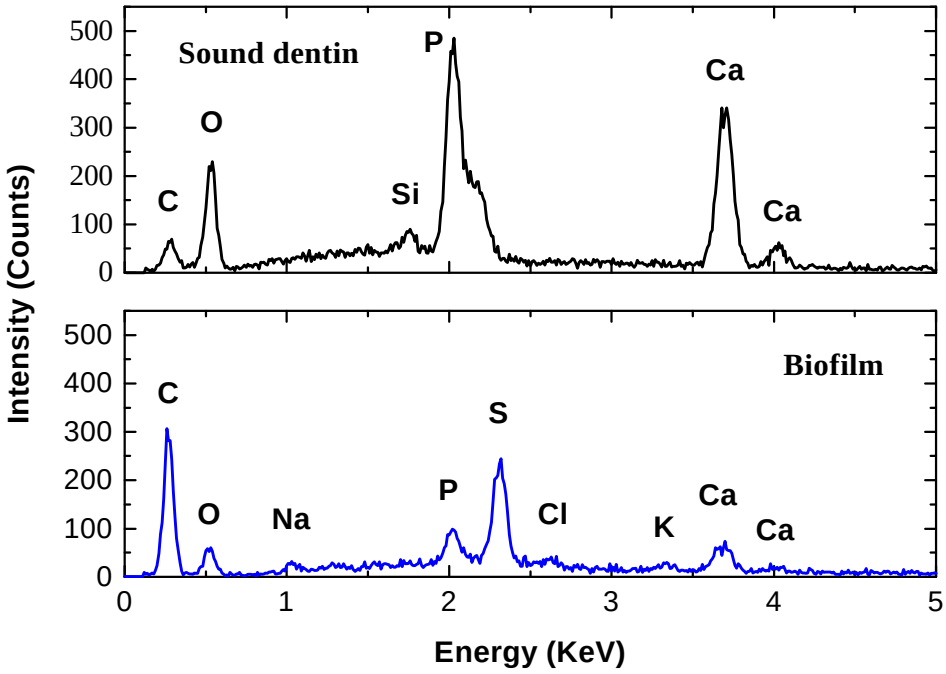

Figure 2: EDS analysis of the sound dentin and the biofilm;

In this case, only the highest energy density that was used removed all the carie tissue but invading the sound dentin for some samples. For the other energy densities applied the decayed tissue was still found after the laser ablation. The temperature on the pulp chamber was monitored during the experiments and the thermal damage threshold for the pulp (5 ºC) was never reached for all samples. Due to the strong optical absorption at the infrared wavelengths even the small amount of water found in hard tissue has a significant role in the laser-tissue interaction [3]. The ablation initialization process is the vaporization of the water increasing the pressure inside the tissue leading to local micro-explosions that will cause the material ejection. The higher etch rates for carious material than sound material allows a more efficient removal of decayed tissue.

Conclusions

The caries removal by laser under these experimental conditions were not completely efficient. Depending on the energy density applied, both lasers removed not only caries but also the healthy tissue. In other cases, the decayed tissue was still found after the laser ablation. The temperature on the pulp chamber was monitored during the experiments and the thermal damage threshold for the pulp (5 °C) was never reached for all samples.

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