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Infrared spectroscopy of dentin irradiated by erbium laser

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Abstract

The erbium laser has a great affinity with water molecule, which present in great quantity in biological hard tissues. The objective of this work was to identify by infrared spectroscopy the chemical composition of dentin tissue induced by the irradiation with subablative energy densities of Er:YAG laser with emission at 2.94 μm. The fluencies used were between 0.365 and 1.94 J/cm^2. A Fourier transform infrared spectrometer was used, and the analyzed region was between 4000 and 400 cm^{-1}. After the laser irradiation, two main alterations were observed in the analyzed spectral region: loss of water and changes in the structure of organic matrix. The observed effects depend on the applied laser fluency, and it suggests a correlation between the temperature produced with irradiation and those effects.

Keywords: Erbium; Dentin; Water; Organic material; Infrared spectroscopy

1. Introduction

The absorption of the erbium laser radiation by the water molecules [1] produces thermal effects that can be divided in: ablative regime which produces material removal and a subablative regime that produces a controlled heated process in the irradiated area and neighborhood. The objective of this work was to identify changes in the tissue

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chemical composition when the erbium laser with subablative fluencies was irradiated on dentin. The results of this study and the morphological information produced after the laser irradiation could have great importance in the development of clinical erbium laser applications [2,3].

2. Materials and methods

The samples used in this work were bovine incisors prepared in slices with the purpose to preserve the natural characteristics of a tooth in an oral cavity and to permit the laser irradiation. The slices were sanded with a diamond paste to a thickness below 50 μm, and the samples' irradiation was accomplished with an Er:YAG laser with emission at 2.94 μm. The spectral acquisition was alternated with the sample irradiation. First, the spectrum of the nonirradiated sample was acquired; sequentially, the minor fluency (0.365 J/cm^2) was applied to the sample, successively up to 1.94 J/cm^2. A Fourier transform infrared spectrometer was used in transmission mode to identify changes in band characteristics.

3. Results

The absorption spectra of irradiated dentin with different fluencies is visualized in Fig. 1. In this region, the intensive water band and some other bands with low intensity

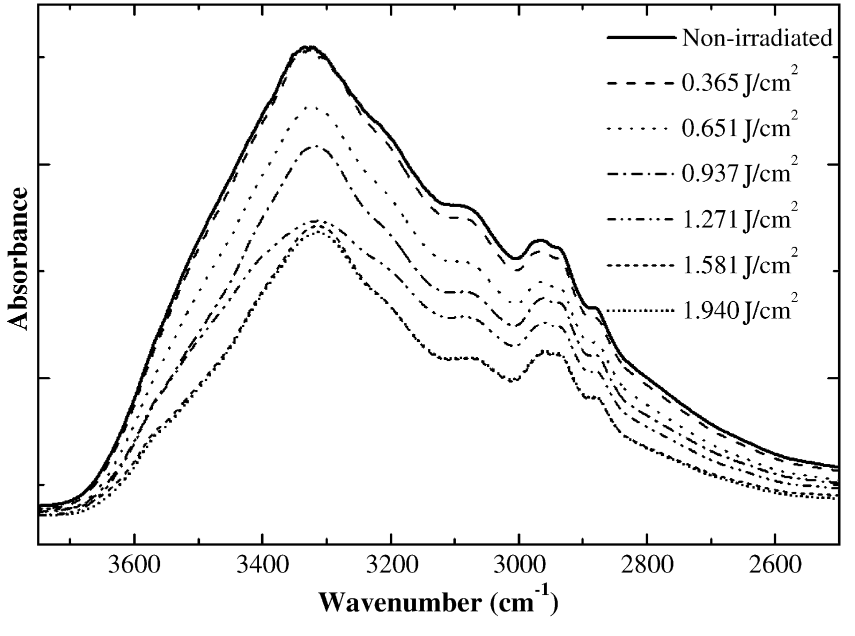

Fig. 1. Absorption spectra between 3600 and 2500 cm^{-1} for natural dentin and irradiated with an erbium laser for different energy densities.

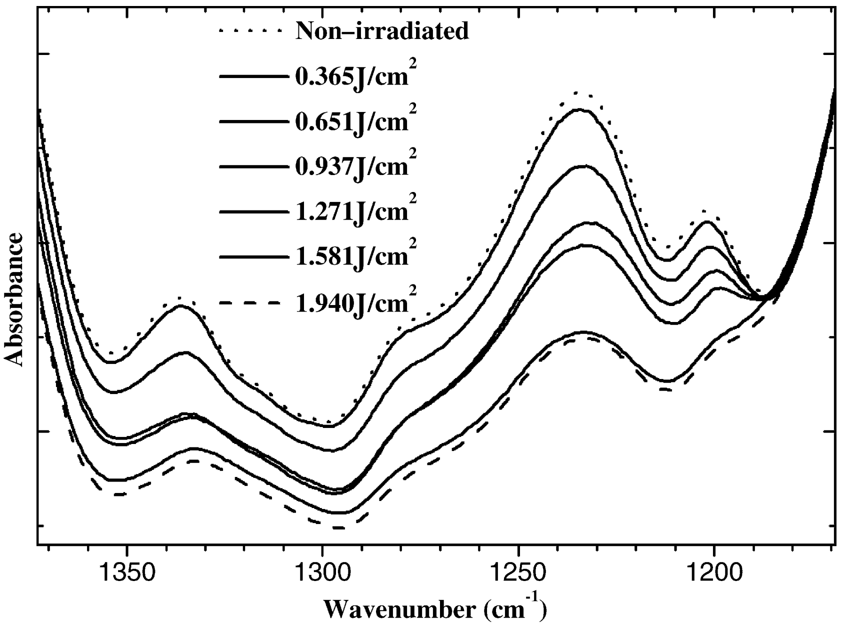

Fig. 2. Absorption spectra between 1400 and 1100 cm^{-1} for natural dentin and irradiated with an erbium laser from minor to highest fluencies.

associated to C—H stretching, amide A and amide B are present [4]. The bands associated to the amide A, amide B and C—H stretching presented in this region are part of the organic matrix of the dentin tissue. Besides this spectral region, the organic matrix absorbs between 1700 and 1100 cm^{-1}. In this region, different bands are present: amide I at 1655 cm^{-1}, amide II at 1532 and 1510 cm^{-1}, amide III at 1228 cm^{-1} and C—H bending at 1445 and 1310 cm^{-1} [4]. The amide I overlaps with a water band, resulting in a common band at 1645 cm^{-1}. Carbonate bands at 1435 and 1463 cm^{-1} associated to the type A and at 1456 and 1422 cm^{-1} associated to the carbonate type B [5] also overlap with organic matrix bands. The second region where alterations are observed are presented in Fig. 2, spectra of the irradiated dentin with different fluencies can be visualized between 1370 and 1170 cm^{-1}. In this spectral region, amide III and C—H bending absorption bands are present as stated in the literature [4].

4. Discussion

After the irradiation with the erbium laser on the dentin, a reduction of the band intensities was observed in two regions. The first region was between 3600 and 2500 cm^{-1}, associated to the water band and another between 1400 and 1100 cm^{-1}, associated to organic components. The effects produced with the laser irradiation were restricted to the water, which absorbs the laser light, and some chemical compounds present in the organic matrix, probably weak chemical bonds that are more sensitive to temperature variation. In the spectral region between 1400 and 1100 cm^{-1}, the literature does not show absorption bands associated to the mineral matrix or water; also, all the bands in this range are associated only to the organic matrix. The bands in this region are associated by the literature to amide III and C—H bending [4]. A precise recognition of bands association is difficult because changes in the position can occur among different organic matrix of calcified tissues. The bands presented in the literature for this region was observed in bone tissue, which has an organic matrix comparable to the dentin organic matrix.

With erbium irradiation, there is a temperature gradient in the tissue with maximum values registered in the central region of the beam incidence [6]. Temperature reduction is a function of the distance from the irradiated local. A same comportment is expected for the results observed here: the water release and organic matrix alterations. The effects will be more intense on the tissue surface and minimal in the deeper tissue layer. In experiments carried out here, it was not possible to distinguish the signal resulting from the surface and from other layers of the bulk.

Using energy densities under the ablation threshold, the erbium laser irradiation at 2.94 μm reduces the water band intensities between 3800 and 2800 cm^{-1}, and the bands of the organic material between 1400 and 1100 cm^{-1}.

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