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Early screening of dentin caries using the methods of Micro-Raman and laser-induced fluorescence spectroscopy

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ABSTRACT

The work presents microspectroscopic studies of the caries development and phase formation in dentin tissues using the methods of laser-induced fluorescence (LIF) and Raman spectroscopy. The results show that the data obtained near the boundary of intact and infected dentin by these two methods under simultaneous scanning from micro-regions confirm and complement each other. The analysis of the LIF spectra proves that the detected bands in Raman spectroscopy can be referred to the porphyrins, amino acids and DNA/RNA of microorganisms. In the laser-induced fluorescence spectra this fact appears in the "red" region of a fluorescence band of 650–716 nm. The fundamental differences that were found in the spectra are markers of pathologies in dentin tissues of human teeth during the development of caries and they can be employed for methods of in the early diagnostics.

Introduction

Precise diagnostics of pathologies of the oral cavity organs at different levels of pathologies using non-invasive optical methods are essential for high-quality therapeutic dentistry [1]. Advances in the optical analysis methods, i.e. laser-induced fluorescence and Raman spectroscopy, IR-spectroscopy and optical tomography, allow (provide) information about the character of a disease to be identified and visualized at the early stages [2,3]. However, for deep caries damage that affect dentin, interpreting the results might be quite challenging [3]. Obtaining information on disorganization of a native dentin matrix is a focus of the ongoing studies that seek to improve the quality of early diagnostics and prevention of secondary caries.

Methods

In this work the spectra of laser-induced fluorescence and Raman spectra from different parts of the tooth including healthy and dentin caries damaged areas were obtained at the room temperature by means of the standard method with the use of the unit supplied with TRIAX 550 monochromator and CCD detector [4]. The laser output power was of 30 mW. The wavelength of an exciting laser radiation was 514,5 nm and due to recording of both luminescence and Raman signal spectra in the same microarea. The resultant spectra were registered through the 515 nm rejection filter that allows observation of the intensive response from the dental tissues microareas.

Results

Our results show that the data obtained near the boundary of intact and infected dentin by these two methods at simultaneous scanning from micro-regions confirm and complement each other. It was shown that for different areas of infected dentin in Raman spectroscopy there is a set of the same modes in the range of 760, 786, 960 1320, 1335 cm^{-1} (Fig. 1a, line 2,3), unlike of the intact dentin (Fig. 1a, line 1). These vibration modes can be attributed to the amino acid component of carious bacteria and their products – porphyrins as it was shown in [5,6]. At the same time, in the fluorescence spectra of infected dentin there are also emission bands of about 570, 628, 690, 716 nm (Fig. 1b, line 2,3) which are associated with the porphyrins [7]. The Redistribution of the intensity of the main maxima in the luminescence spectra that are observed in the range of 570 and 628, 690, 716 nm as well as changes in the shape of the edge of the luminescence band in the range of 520–550 nm indicate that there is not only a growth in the proportion of microorganisms in the caries damaged area occurs as it is shown in [7] but that there is also disorganization of the dentin structure, i.e. changes in the phase composition of the organic and mineral component [4]. It should be noted that the luminescence

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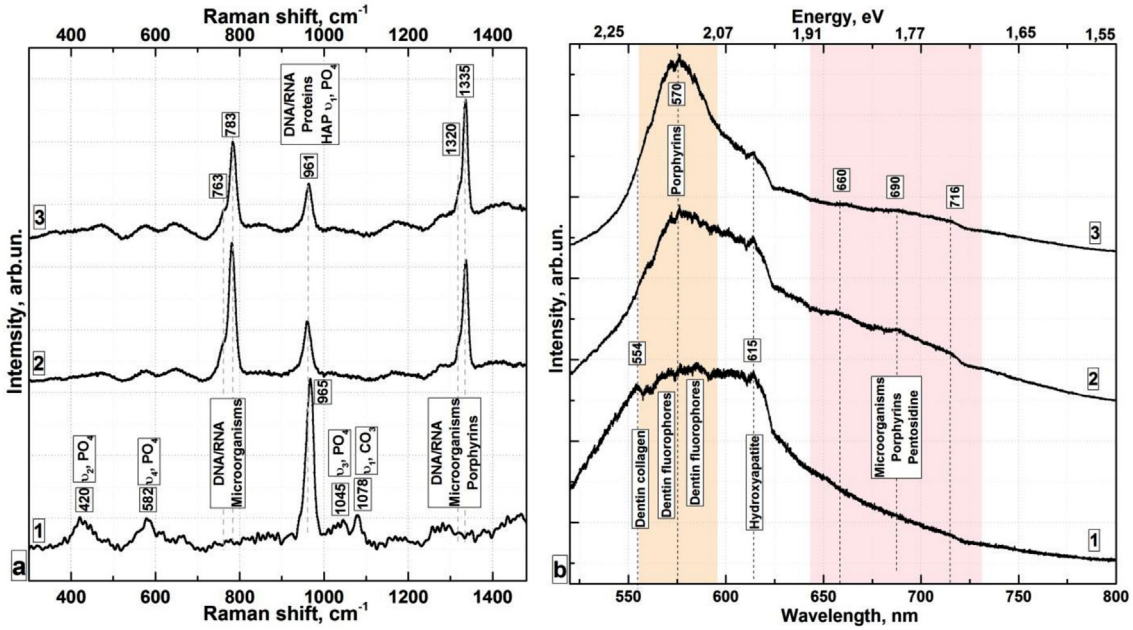

Fig. 1. The (a) LIF and (b) Raman spectra of: 1 – sound dentine, 2 – first point of infected dentine 3 – second point of infected dentine (excitation wavelength was of 514.5 nm).

spectrum of the intact dentine (Fig. 1b, line 1) is characterized by a number of the features associated as with carbonate-substituted hydroxyapatite [8] as with those ones determined by the contribution of organic component in the composition of the natural hard dental tissue [4].

Conclusions

Using laser-induced fluorescence and Raman microspectroscopy techniques analysis of microareas of the human hard dental tissues with caries lesions was performed within the frameworks of the integrated measuring system. Employing of the laser emission with the wavelength of 514,5 nm and inclusion of the 515 nm rejection filter allows observation of the intensive response from microareas of the dental tissues affected with caries as within the range of Raman scattering as in the range of the excited luminescence. Comparing of the results obtained in our work with those ones known from scientific information demonstrated that high-intensive modes of vibrations appearing in the Raman spectra refer to the amino acids of DNA/RNA of microorganisms. This fact is corroborated by the presence of porphyrins bands in the spectra of laser-induced luminescence that represent being the products of their biological activity. These data can be employed for developing of the early screening methods in the dentin caries diagnostics.

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