The study of laser induced fluorescence of tooth hard tissues with aluminum phthalocyanine nanoparticles

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Abstract. This work is about the possibility of fluorescence diagnosis application with the use of aluminum phthalocyanine nanoparticles (nAlPc) in order to detect enamel microdamage. For the investigation, five human teeth samples of various age groups were removed for various reasons. The autofluorescence spectrums of these samples hard tissues and fluorescence spectrums of nAlPc mixed with enamel powder were obtained during the experiment. The research shows that sample pathogenic microflora causes nAlPc fluorescence. This fact will allow detecting enamel microdamage in future studies.

1. Introduction
The development of laser diagnostic and treatment technologies for different diseases discover new perspectives for doctors and gives hopes for recovery of many patients. Year after year, the number of procedures using the laser techniques in medicine, including dentistry, increases. Laser radiation allows for faster healing process and decreases the risks of infections. It is a painless, non-invasive procedure that only influences the affected tooth areas [1]. Another advantage of using laser in medicine is that such kind of treatment does not cause any allergic reaction. In dentistry the laser is used for enamel whitening, normal and carious tooth tissues removing, diagnosing and treating of enamel, dentine and root canals, treating and preventing abnormal germination of tooth and curing mucous membrane of oral cavity [1,2,3]. Up to now the diagnostics of early caries and other oral cavity diseases, which appear due to genetic predisposition and infection processes, continue to be a relevant problem [2,3]. Laser methods provide lesser detection and treatment times for an early carries stage unlike the traditional tooth filling methods.

One of the most important goals of dentistry is the detection of enamel hidden demineralization areas, teeth deposit, calcified debris, stages of early carious lesion and quantification of lesion size, depth and tooth mineralization stages [3]. Carious is a complicated pathological process, which causes serious destruction of hard tooth tissue structure. Untimely detection and treatment of carious lesion result in significant enamel and dentine destruction and subsequent teeth removal. Assembly of pathogenic microflora in microdamaged areas causes mechanics influence and demineralization of tooth that later turns into carious lesions. Traditional diagnosis methods, such as visible inspection and X-ray examination, cannot detect early stage microdamage. In studies [4] and [5] the authors have carried out investigations of normal tooth enamel fluorescence intensity in comparison to microdamaged
enamel fluorescence intensity. Fluorescence intensity of the microdamaged enamel was almost the same as normal enamel fluorescence intensity.

nAlPc are used for enamel microdamage localization detection. They have a good chemical homogeneity, light absorption in 675-680 nm spectral range, moreover, nAlPc are harmless and may show a repair effect [6]. Pathogenic microflora accumulates in microdamaged enamel. nAlPc interact with pathogenic microflora and acquire fluorescence properties. Among other things, the nAlPc colloid solution does not have fluorescence properties. The investigations of nAlPc interaction with enamel powder are necessary for further enamel microdamage detection studies with the use of nAlPc.

2. Materials and methods
For this investigation, five samples of human teeth of various age groups were removed for various reasons.

The measurement of tooth hard tissues autofluorescence spectrums were taken at 405 nm wavelength laser excitation. One of these teeth was dissected longitudinally on two parts for enamel, dentine and cement autofluorescence spectrums measurement.

Also the fluorescence spectrum of nAlPc (FSUE «SRC NIOPIK», Russia), with enamel powder, was obtained. Water and saliva were added to the enamel powder with AlPc nanoparticles to simulate oral cavity.

The Spectroscopy system LESA-01-BIOSPEC was assembled and adjusted for this investigation (Figure 1). Fluorescence spectrums were taken at excitation by 405 nm semiconductor and 632.8 nm He-Ne lasers. Laser radiation was delivered to biological tissues using optical fiber.

![Figure 1. Measurement setup.](image)

During the biological tissues irradiation, a part of it is absorbed by the tissues and the other part is reflected into the receiving fiber. The signal was detected by the spectroscopy system, which was made for fluorescence signal recording and analysis. Than the information goes to computer, which shows it on the display in spectral form by «Uno Momento» software.

3. Discussion
Using the spectroscopy system, fluorescence spectra of normal and carious lesion were investigated.

Hard tooth tissues autofluorescence spectrums are presented in figure 2(a). It can be seen that the cement fluorescence intensity is higher than the enamel and dentine fluorescence intensity because of different optical properties and hard tissues structure.

Enamel autofluorescence spectra of five different samples were obtained at the same excitation wavelength (Figure 2(b)). Enamel autofluorescence peaks were registered at same wavelength 565
nm. As it is known from earlier studies, enamel fluorescence intensity depends on the stage of mineralization and on the patient’s age [1]. The higher the level of tryptophan in enamel, the higher the fluorescence intensity signal [3].

The fluorescence spectra of nAlPc with enamel powder, water and saliva are presented on figure 2(c).

![Fluorescence spectra](image)

**Figure 2.** a) The autofluorescence spectra of five enamel samples, b) the autofluorescence spectra of enamel, dentine and cement, c) the fluorescence spectra of AlPc nanoparticles mixed with enamel powder, water and saliva.

Thus, microdamaged enamel contains pathogenic microflora. When nAlPc interact with pathogenic microflora, they start to acquire fluorescent properties. It is interesting to note that the nAlPc colloid solution does not fluorescence at 632.8 nm excitation wavelength.
The emergence of fluorescent properties can be explained by external influence. AlPc molecules separate from the nanoparticle and become free, surface molecules transform from para to ortho-position, displaying fluorescence [4,7].

4. Conclusion
During the investigation, the spectroscopy research of hard tooth tissues autofluorescence and fluorescence of nAlPc mixed with enamel powder, were conducted. Normal enamel autofluorescence spectra of various patients varied due to difference of calcium, magnesium, phosphorus content in tooth enamel. Different enamel, dentine and cement fluorescence intensity was caused because of various mineralization stages and different optical properties. Also, the interaction of nAlPc with enamel powder was studied. This results allows detecting and identifying the location of microdamage on the enamel surface using nAlPc as a marker in the future.

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