Application of nanophotosensitizers (aluminum phthalocyanine nanoparticles) for early diagnosis and prevention of inflammatory diseases

J O Kuznetsova[1], V I Makarov[2]

[1]National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), 31Kashirskoe shosse, 115409 Moscow, Russia
[2]Prokhorov General Physics Institute, Russian Academy of Science, Vavilov str.38, 119991 Moscow, Russia

E-mail: YOKuznetsova@mephi.ru

Abstract. This paper deals with a possibility of new types of photosensitizers application – Aluminum Phthalocyanine nanoparticles (nAlPc) in clinical practice for diagnosis, prevention and therapy of inflammatory diseases in dentistry and traumatology. It was detected that the aluminum phthalocyanine (AlPc) fluoresces in the nanoparticle form in the presence of pathologic microflora or inflammation process. It will make possible to detect the local accumulation of pathological microflora on the enamel surface and also for diagnostics and treatment of inflammatory diseases. Experimental studies of interaction of NP-AlPc with tooth enamel and with biological joint tissue at arthrosis are presented.

1. Introduction

Nanophotosensitizers application opens new perspectives in the drug delivery system. They can be used for fluorescence diagnostics and treatment by photodynamic therapy (PDT). Aluminum phthalocyanine nanoparticles (nAlPc) are suitable for clinical use because they have a good transportation in aqueous media and penetration into the tissue. Also they are convenient tool for fluorescence diagnostics because nAlPc does not fluoresce in the nanoparticle form but in the monomeric form it does. The fluorescence occurring when AlPc molecules arranged vertically are attached to the surface of the nanoparticles during the dissolution process or the interaction with pathological tissue, pathologic microflora and macrophages [1], [2].

The application possibility of nAlPc in clinic practice are the following: in dentistry for detection of a local accumulation of pathological microflora on the enamel surface and in microcracks, in traumatology for fluorescence diagnostics and the photodynamic therapy of osteoarthrities. These applications are presented in this work.

Early diagnosis of tooth-enamel microcracks is of great importance in modern dentistry for caries prevention. Diagnostic methods being used in clinical dentistry (visual inspection, probing, vital enamel staining) can detect enamel damages of a rather large size. For diagnostics it is possible to use porphyrins autofluorescence when microflora is abundant in the microcracks. Otherwise the microflora autofluorescence is relatively weak. The problem can be solved by using nAlPc as exogenous fluorophore.

For clinical application nAlPc in orthopedics area the model of photoactivity appearance in the affected joint tissue is proposed. Photoactivity occurs in the body after the application of nAlPc only in diseased biological tissues whose microflora and immune system response differ from healthy biological tissue.

2. Materials and methods

The water colloids of AlPc nanoparticles in a concentration 50 μg/ml was received by ultrasonic dispergation large-dispersed AlPc crystals for 50 min using a Bandelin SONOPLUS HD2070 ultrasonic homogenizer with a KE76 attachment (20 kHz, 165 μm amplitude). The hydrodynamic radius of the obtained nanoparticles measured with the use of a dynamic light-scattering spectrometer, Photocor Complex (Photocor Instruments Inc., USA) was 25–100 nm. For fluorescent measurements a fiber-optic spectrometer LESA-01-BIOSPEC was used. He–Ne laser with the wavelength of 632.8 nm and the output power of 5 mW at the fiber end was used as an irradiation source for fluorescence excitation. A fiber-optic probe with one illuminating and six receiving fibers (each of 200 μm diameter) was attached to the spectrometer. Reference [3] contains a detail information about experimental setup.

The sample containing enamel powder and colloidal solution of AlPc nanoparticle was prepared to determine the nature of the interaction. Animal model of osteoarthritis was using for observing AlPc fluorescence enhancement in affected tissue. During experiment 1 ml of AlPc nanoparticles colloid in concentration 50 μg/ml was injected into joint capsule of affected and healthy joint. Before nanoparticles injection the autofluorescence of healthy and pathological joints was detected. The fluorescence spectra of nAlPc from both joints were measured 48 hours after nAlPc injection.

3. Results and discussion

3.1. The nAlPc fluorescence in the presence of enamel powder

Figure 1 presents the fluorescence of colloidal solution of AlPc nanoparticle mixed with enamel powder. As seen the AlPc fluorescence enhancement is present in the enamel powder. This fact confirms the theory of «nAlP activation» when on the enamel surface and in the microcracks there are pathological microflora.

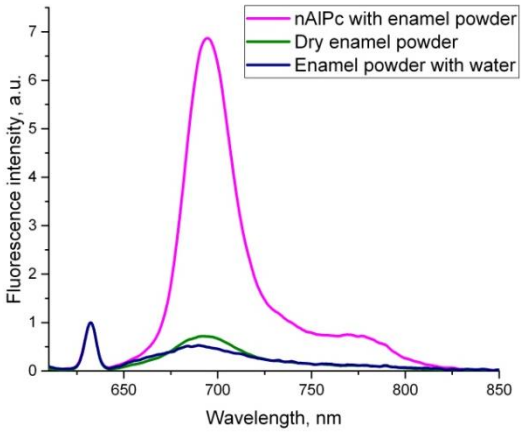

Figure 1. The nAlPc fluorescence in the presence of enamel powder

3.2. The nAlPc fluorescence in pathological joint

Figure 2 demonstrates that 48 hours after nAlPc injection the fluorescent intensity is 5-7 times higher in pathological joint than in healthy joint. It indicates that the nAlPc fluorescence enhancement occurs only in tissue with inflammatory processes.

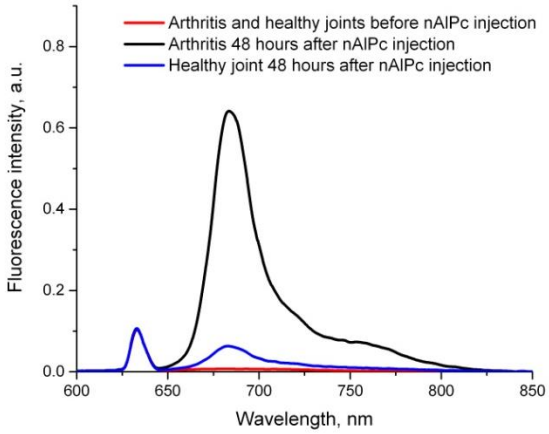

Figure 2. The nAlPc fluorescence in healthy and pathological joint

4. Conclusions

During the experiment it was revealed that nAlPc fluorescence enhancement occurs in the presence of enamel powder with pathological microflora. The nAlPc can be used as exogenous fluorophore for detection of a local accumulation of pathological microflora on the enamel surface and in microcracks in dentistry in the future .

In diseased biological tissue of joint the increasing of nAlPhc fluorescence intensity was obtained. In traumatology nAlPc fluorescence enhancement in pathological tissue can be used for fluorescence diagnostics and the photodynamic therapy of arthrosis.

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References

[1] Breymayer J, Ruck A, Ryabova A V, Loschenov V B and Steiner R W 2014 *Photodiagnosis Photodyn. Ther.* **11 (3)** pp 380–390
[2] Vasilchenko S Y, Volkova A I, Ryabova A V, Loschenov V B, Konov V I, Mamedov A, Kuzmin S G and Lukyanets E A 2010 *J. Biophotonics* **3 (5–6)** pp 336–46
[3] Loschenov V, Konov V and Prokhorov A. 2000 *Laser Physics* **10 (6)** pp 1188–1207