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PHOTOPLETHYSMOGRAPHY METHOD FOR INVESTIGATION OF TISSUE MICROCIRCULATION DISORDERS AFTER TOOTH EXTRACTION

Abstract. The use of photoplethysmographic method allows to accurately assess the level of blood supply in inflammatory manifestations in patients with diabetes after tooth extraction, this method has positive properties: non-invasive, high sensitivity and probability ease of study. It is shown that photon radiation increases the elasticity of blood vessel walls, elasticity of erythrocytes, oxygen transport function of blood, activity of cell membranes, acceleration of tissue regeneration, reduction of lipid oxidation, normalization of blood rheology. It is shown that the photon radiation of the multispectral photon device for physiotherapy "MultiSpectr-001" leads to anti-inflammatory, desensitizing, analgesic, antispasmodic, anti-edematous effects, which is confirmed in this study in the treatment of patients with diabetes mellitus.

Key words: Photoplethysmographic method, propagation of laser radiation, optic-electronic system, photonic therapy, microcirculation.

Introduction

In clinical dentistry, examination of the microcirculatory system of all tissues and organs of the oral cavity is of considerable interest as one of the methods of studying the blood supply to tissues [1, 2, 3].

Nowadays, the use of traditional methods of examination and diagnosis is insufficient: examination, percussion, electroodontodiagnostics, rheography, radiography, and others. New, more effective methods of differential diagnosis, using laser and optoelectronic computerized systems and complexes are being developed for in-depth study of the condition of tissues and organs of the maxillofacial area. Today, laser treatment and diagnostic technologies are used in dental institutions around the world [4, 5, 6].

Photoplethysmographic method (FPM) diagnostics refers the methods, based on the use of laser and optoelectronic devices and allows measuring blood supply and blood flow in veins, arteries, peripheral vessels and capillaries and is based on the registration of blood flow applying an optical source in the infrared ranges. The greater the blood flow, the less light is absorbed in the tissues of the body; therefore, more light comes to the optical sensor. Photoplethysmogram allows to measure the volumetric pulse of the blood caused by periodic changes in blood volume with each heartbeat, heart rate, heart rate variability [7, 8, 9].

The volume of any organ includes the volume of tissue and the volume of blood that fills it. Thus, the volume of tissues is constant, and the volume of blood varies depending on the phase of the cardiac cycle. These changes, which also depend on respiration, thermoregulation, and activity of the sympathetic nervous system, can be recorded by the devices.

The physiological basis of the photoplethysmographic method is that this method allows to determine the level of perfusion of tissue microcirculation. An integral part of FPM is the analysis of blood flow fluctuations recorded by photoplethysmogram. Rhythms of oscillations (fluctuations) and their ratios play an important diagnostic role. Spontaneous fluctuations in blood flow are largely due to vasomotor – rhythmic changes in the diameter of precapillary resistive vessels, which cause rhythmic fluctuations in the speed of erythrocytes in the microcirculatory tract [10, 11, 12].

At the heart of the pathogenesis of many diseases is a violation of microcirculation. Therefore, the assessment of the condition of the vascular bed, including capillaries, allows to detect at the early stages various diseases, as well as to monitor the treatment of the patient [13, 14, 15].

Methodology. Model of interaction of laser radiation with biological tissues of different types

Many mathematical models are used to describe the interaction of laser radiation with biological tissues, and the theory of radiation transfer is most often used. The equation describing the propagation of laser radiation in biotissue, taking into account the absorption and scattering has the form

$$\frac{dL_c(r,z)}{dz} = -gL_c(r,z),$$

where $L_c(r, z)$ radiation power density [W/m^2] of the beam in place p (place vector) in the z direction, g – attenuation coefficient (sum of scattering coefficients [m^{-1}] and absorption [m^{-1}]) [16, 17, 18].

The response of biological tissue to laser radiation is due to the interaction of photons and molecules or compounds of biotissue molecules. Atomic and molecular processes and subsequent biological reactions are not yet fully understood.

The degree of this or that influence depends on:

– the properties of laser radiation (wavelength, energy density, duration of irradiation and repetition rate);

– the properties of biological tissue (absorption coefficient, scattering coefficient, density, etc.).

Depending on the wavelength, energy density and exposure time of laser radiation, the effect is determined mainly by two internal parameters of biological tissue: on the one hand, the optical properties of irradiated biotissue and, on the other hand, its thermal properties [19, 20. 21].

When laser radiation hits the biotissue, three processes can be observed: reflection, absorption and/or transmission, only a small percentage of radiation is reflected directly from the surface of biological tissue (Fig. 1). Laser radiation that has penetrated the biotissue is partially absorbed, partially scattered and partially transmitted (Fig. 1).

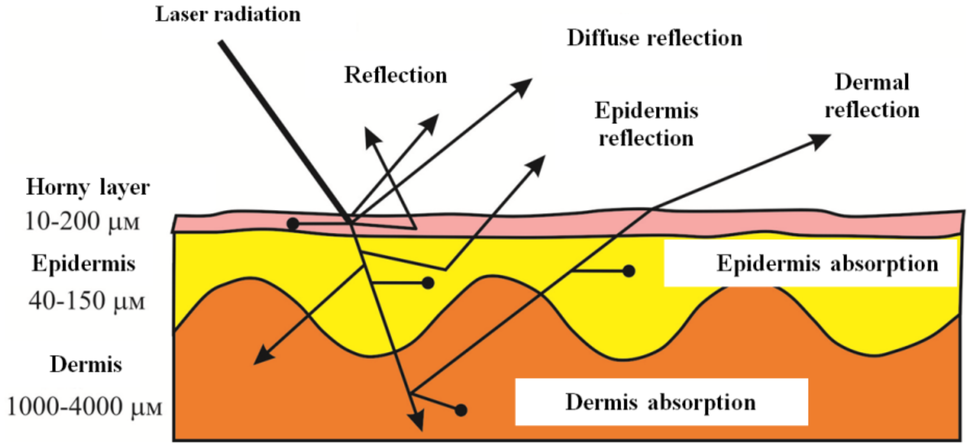

Fig. 1. Optical properties of a layer of biological tissue dermal absorption

Practical realization of optical-electronic system

Today, more and more methods based on the use of optoelectronic devices are being introduced into medical diagnostics. These include the photoplethysmographic method (PPM), which measures blood flow in veins and arteries, as well as in peripheral vessels and capillaries [22, 23, 24].

FPM, in comparison with other means of diagnostics of a biological object (BO) on optical indicators, for example, with a photoacoustic method, distinguishes by the simplicity of devices for its realization, and also that introduction in photoplethysmographic (PPG) devices of elements of light fiber techniques and sources with different wavelengths of probing radiation, it is possible to easily solve the problems of photodynamic research, remote measurement of certain parameters of the desired BO, etc [25, 26, 27].

The usage of optoelectronic and laser sensors in biology and medicine can be carried out in several areas, one of which can be considered the development of new optoelectronic and laser technologies for the detection, identification, study of biological objects, as well as to study the nature of processes occurring in them [28, 29, 30].

The study of photoplethysmographic signals can be carried out according to the developed scheme (Fig. 2) (OB – optical emitter (LED) FD – photodetector (photodiode), P – amplifier, ADC – analog-to-digital converter, MC – microcontroller, PC – personal computer, GIU – galvanic isolation unit, SI – serial interface, PC – personal computer). The device allows to study the tissue microcirculation of the biological object (BO) by illuminating it with a beam of infrared (IR) radiation using an LED, which is partially passing through the tissue or partially reflected from its inner layers, received by a photodetector (photodiode). Pulsations of peripheral vessels caused by the passage of a pulse wave cause fluctuations in the optical density of living tissue, so the infrared radiation flux passed or reflected from the tissues is modulated in amplitude and gives an electrical signal in the photodetector proportional to this flow.

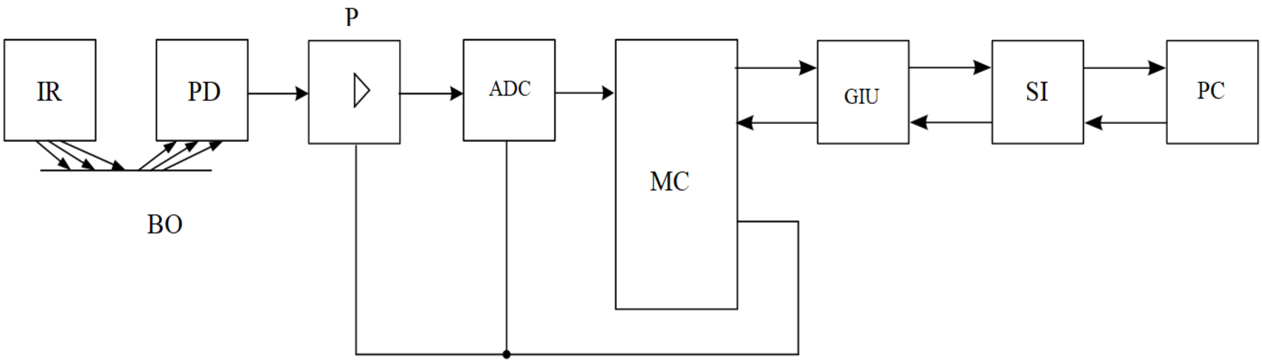

Fig 2. Scheme of realization of optoelectronic system for diagnosing peripheral blood circulation

Results of experimental studies

Clinical examination of patients was conducted on the basis of the Department of Surgical Dentistry and Maxillofacial Surgery of Vinnytsia M.Pirogov National Medical University. The research was carried out in compliance with the basic provisions of the “Rules of ethical principles of scientific medical research with human participation”, approved by the Declaration of Helsinki (1964-2013), ICH GCP (1996), EEC Directive № 609 (dated 24.11.1986), Orders of the Ministry of Health of Ukraine № 690 dated 23.09.2009, № 944 dated 14.12.2009, № 616 dated 03.08.2012.

The research was conducted in the period from 2016 to 2021. Three groups of patients were selected for the study: comparison group (30 patients) – non-diabetic patients who underwent tooth extraction and standardized treatment (see treatment description), main group 1 (30 patients) – patients with diabetes who underwent tooth extraction without additional local treatment, main group 2 (30 patients) – patients with diabetes who underwent tooth extraction, photon therapy and PRF removal of the tooth removed.

Photon therapy was performed using the optoelectronic multispectral system MultiSpektr-001 (Fig. 3) developed on the basis of the Department of Biomedical Engineering and Optoelectronic Systems of Vinnytsia National Technical University and PE “Photonika Plus” (Cherkassy, Ukraine)

Fig. 3. Optoelectronic multispectral system MultiSpektr-001

Irradiation was performed by red light with a luminous flux of 50 mW, duration of 5 minutes; the course was 3 procedures (once a day). Photoplethysmographic diagnostic was performed in patients of all three groups on days 1, 3, 7, 14 of the study.

The examination was performed on the optoelectronic diagnostic complex for the analysis of microcirculatory disorders. Optical radiation was projected on the gums, at a distance of 5 mm from the gingival margin from the vestibular and also from the palatal side in the area of the removed tooth.

On the third day, the mean baseline value of the microcirculation level (H) increased by 69.1 % (p<0.05) (day 3) relative to the value of the microcirculation (H) on the first day. On the seventh day the average initial value of the microcirculation level (H) compared to the third day decreased by 27.9 % (p<0.05) on the third day (7 days), on the 14th day the average initial value of the microcirculation level (H) almost correlates with respect to the value of microcirculation (H) on the first day by 94.3 % (p<0.05), which allows us to conclude that the rapid recovery of the level of microcirculation, which almost correlates with this indicator of the first group.

The average initial value of the microcirculation level (H) in relation to the value of the microcirculation (H) before the photon procedure (increase in blood microcirculation by 26.7 %) (p<0.05) (1 day) The average initial value of the microcirculation level (H) in relation to the value of microcirculation (H) before the photon procedure (increase in blood microcirculation by 41.6 % (p<0.05)) (3 days). Photon procedure (increase in blood microcirculation by 53.5 %) (p<0.05) (7 days) The average initial value of the microcirculation level (H) relative to the value of microcirculation (H) before the photon procedure (increase in blood microcirculation by 47.7 %) (p<0.05) (14 days), this indicates the effectiveness of photon radiation on the restoration of tissue microcirculation (fig. 4).

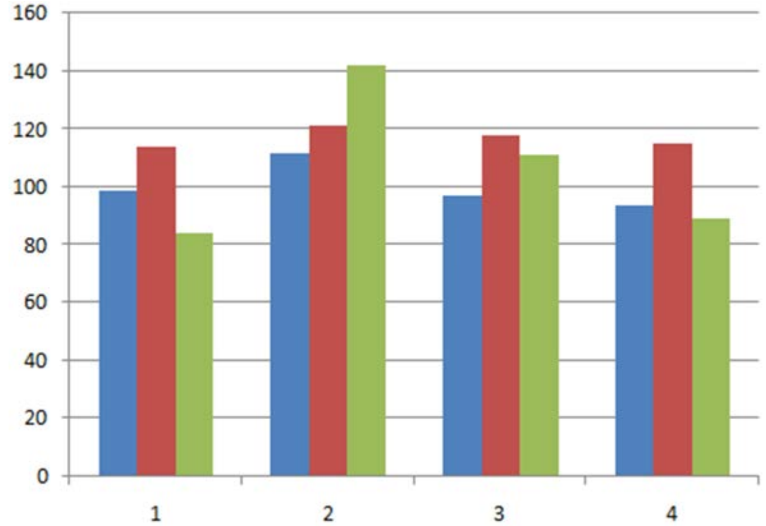

Fig. 4. Comparative evaluation of three groups (Group I (■)– without diabetes and without treatment, Group II (■)– diabetes and without treatment, Group III (■) – diabetes and treatment)

Conclusions

1. The prospects of using photoplethysmographic method to assess microcirculatory changes in peripheral circulation to study the processes that occur during photonic physiotherapy for the complex treatment of chronic complications of diabetes are considered. The use of photoplethysmographic method allows to accurately assessing the level of blood supply in inflammatory manifestations in patients with diabetes after tooth extraction, this method has positive properties: non-invasive, high sensitivity and probability ease of study. The use of this method in maxillofacial surgery allows: to accurately determine the effectiveness of treatment; specify the duration of the rehabilitation period; to detect various vascular disorders in patients with diabetes mellitus; evaluate the effectiveness of local anesthesia (because anesthesia causes vasospasm, the decrease in amplitude can be judged on the effectiveness of anesthesia); apply this method in plastic surgery and transplantation.

2. Thus, the use of complex treatment in patients of the third group allows to obtain the average initial value of the microcirculation level in relation to the first group with a correlation coefficient of 94.6 % (p<0.05) on the 14th day of treatment. At the same time, for the second group the average initial value of the microcirculation level increased by 14.3 % by more than 14 days (p<0.05), respectively, of the first group and 29.2 % (p<0.05) – the third, indicating slow healing and restoration of the level of tissue microcirculation.

3. It is shown that photon radiation increases the elasticity of blood vessel walls, elasticity of erythrocytes, oxygen transport function of blood, activity of cell membranes, acceleration of tissue regeneration, reduction of lipid oxidation, normalization of blood rheology.

4. It is shown that the photon radiation of the multispectral photon device for physiotherapy "MultiSpectr-001" leads to anti-inflammatory, desensitizing, analgesic, antispasmodic, anti-edematous effects, which is confirmed in this study of the treatment of patients with diabetes mellitus.

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