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A Study of the Relationship of Joule-metric Settings with the Inflammatory Changes in Periodontal Tissues

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Abstract

One of the areas of research, allowing us to get close to the possibility of adequate monitoring of therapy of periodontal disease, is the study of biological and electrochemical processes in healthy tissues and in inflammation. For this purpose, there was conducted a survey of 119 patients with inflammatory diseases of periodontal tissues (49 men and 70 women). The interrelation of joulemetric parameters with inflammatory changes of the periodontium was revealed. The results of the study showed that there is a relationship between joulemetric parameters and the depth of the periodontal pocket. Higher the inflammatory changes in periodontal tissues, higher the value of the electrical current at work. Thus, measurements of joulemetric parameters (of current) in patients with different forms of periodontitis can be used in clinical practice for the diagnosis of inflammatory periodontal diseases as well as monitoring the effectiveness of the therapy of this pathology.

Keywords

Periodontitis; Diagnosis of periodontitis; The dynamics of the inflammatory process; Electrochemical and morphological changes

Introduction

The urgency of diagnostics and treatment of periodontal disease is due to the high prevalence of this disease, which is one of the main causes for a complete loss of teeth, and the negative influence of lesions of periodontal infection on the condition of the internal organs [1].

Despite significant advances in modern dentistry in the diagnosis and treatment of inflammatory periodontal diseases, there is a high frequency of relapses, short periods of remission, and the transition to more severe forms of the disease. This usually indicates the lack of effectiveness of frequently applied methods for the diagnosis and complex therapy of inflammatory periodontal diseases [1].

It is known that the clinical criteria of severity of periodontal damage use such characteristics as the degree of resorption of the alveolar bone and the periodontal pocket depth. But these options do not take into account the current activity of inflammation in gingival tissues, although it is closely associated with local pathological reactions in the periodontal tissues [2].

In modern periodontology, there remains the question of the establishment of new methods of diagnosis of inflammatory periodontal diseases, as well as the question of monitoring the effectiveness of the therapy of this pathology.

One of the areas of research, allowing us to get close to the possibility of adequate monitoring of the therapy of periodontal disease, is the study of biological and electrochemical processes in healthy tissues and in inflammation [3]. The electrical properties of any biological objects change due to the action of various physical and chemical factors of the external and internal environment of the organism: temperature, volume, concentration of electrolytes, maintenance of blood cells, the changes of structural parameters of tissues, and so on [4].

The advantages of electrochemical methods are the efficiency of use, ease of implementation, security for health, low cost of research, and the high information content [5,6].

One of the common methods is the electrochemical impedance method. The study of the impedance of tissue was held by Khachatrian [7]. The results showed that the impedance analysis carries some useful information about the processes occurring in biological objects. A comparative study of the impedance of the tissue in the area of inflammation and the impedance of the discharge from the wound fluids showed higher informativity assessment of the dynamics of the inflammatory process in the impedance parameters in the biological fluids.

In the impedansometry, the studied system "electrode-environment-electrode" is outraged by the sinusoidal signal, and the resulting response to the electrodes is measured. By measuring the values of the input and output signal at different frequencies, the transfer function of the system is determined. The representation of the transfer function in the form of Cowher allows producing the parametric identification of accepted working models.

Biological tissue, in most cases, is characterized by the heterogeneity of the properties of the filled working volume of the sensor. The construction of the equivalent schemes of such objects is based on the assumption that it consists of a separate, internally homogeneous layer with constant parameters. The scheme is built from individual links describing local processes in a separate layer with a finite conductivity and time constant. Therefore, each elementary unit consists of a resistor representing the finite conductivity of the bulk layer and capacitance, with resistance forming the time constant of this layer. This scheme allows modeling the structure, the characteristics of which correspond to the static properties of the object.

While controlling the biological objects by methods of impedance, the disadvantages of a long time of research associated with the need to conduct experiments in a wide range of frequencies and multiple submissions of test signals should be considered. The disadvantage is also the limited number of features that characterize the object under study. Their number is determined by the order adopted a priori or on the basis of preliminary data of an equivalent model of the object. The increase in the number of elements included in the circuit leads to the appearance of instabilities in the working models during the transition to different types of objects and changing modes of system operation. The limitation of the method is also the lack of information about the Faraday processes.

The complexity of the study of electrochemical cells is that it is almost impossible to identify the value of the overvoltage at the electrodes and the voltage drop in the electrolyte by direct methods.

It should also be taken into account that biological objects are a rather complex system. Unlike the isolated and close to equilibrium experimental processes, the possibility of using the considered above electrochemical methods are very limited. The ability of biological systems to generate a response and to recover in a short period of time makes a significant error in the basic equations of kinetics and conversion of the parameters of electrochemical processes in electrical quantities [4].

In practical use, the impedance methods require a long period of time for the removal of the impedance curve in a given range of frequencies [8].

In this regard, in order to solve the assessment problems of the state of biological objects the method of joulemetry was proposed, which possesses high sensitivity and allows us to increase the number of informative features in a small period of time.

In joulemetry, the value of work expended by an external source of electrical energy for transferring the investigated object from one state to another is assessed. To estimate and predict the dynamics of the inflammatory process in periodontal tissues at the Department of Medical Cybernetics and Informatics of the Penza State University was developed a method of direct joulemetry and a device for its implementation [9,10].

A work is a form of energy that transfers from the system, committing it to the system on which it is running. The internal energy of the system that performs work is reduced, and the energy of the influenced system exposed to it increases by an amount corresponding to the work produced.

Considering the processes occurring in electrochemical objects, as processes, which require for a certain period of time, the expenditure of external energy in an amount proportional to the change produced, we can say that the work serves as an integral parameter characterizing the entropy change. It depends on the reaction of all kinds of particles contained in the system that is under the study, the dynamics of their transformation as a result of electrochemical reactions, and the response of a biological object.

The basis of the joulemetric method is the correspondence between the work done by the external electrical energy source in the studied object and a change in a state of the object.

If we use current $I(t)$ as an external influence, and the change in the voltage between electrodes $U(t)$ in time as a parameter characterizing the state of the object, in this way the values of the work $A(t)$ in the time interval from t_1 to t_2 can be determined on the basis of the following relationship:

$$A(t) = \int_{t_1}^{t_2} I(t)U(t)dt. \qquad (1)$$

The value produced by the current work $A(t)$ is based on the processing dependencies of current $I(t)$ and voltage $U(t)$ in time. Measuring the change in parameters of current work in time, it is possible to judge the dynamics of proinflammatory process.

Its distinguishing feature is in the evaluation, in dynamics of changes of values of the work taking place in the biological object. The work spent on the transformation of the investigated object from one state to another characterizes the electrochemical properties of the object. This parameter is sensitive enough, because it takes into account the changes of properties at the level of the ionic composition of the object.

The joulemetric method of monitoring the state of biological objects has been used successfully in the study of biofluids in abscesses of the abdomen, in the ENT practice in inflammatory diseases of the paranasal sinuses, in evaluating the condition of bone tissue in fractures and in the lengthening of the limb, and in determining the boundaries of the resection of the body for the removal of neoplasms; however, in dentistry such studies to date have not been conducted [4].

Materials and Methods

At the preliminary stage, the scheme of the study was developed. To explore the joulemetric values of intact periodontium, student volunteers of the Penza State University were examined. Inclusion criteria for patients of the control group: intact periodontal, orthognathic bite, the integrity of the dentition and indicators of the CSE index (carious teeth, sealed teeth, the extracted teeth), not exceeding 6-9 units.

The study did not include patients with systemic collagen diseases, respiratory or cardiovascular diseases, endocrinopathy, kidney disease and liver disease, inflammatory diseases of the gastrointestinal tract (stomach ulcer and 12-duodenal ulcer, chronic gastritis).

The study of joulemetric values in periodontitis of varying severity was performed at the clinical sites of the Department of Dentistry of the Penza State University. Clinical studies were conducted in accordance with the ethical standards outlined in the Helsinki Declaration of 1964, modified by the forty-first World Assembly, Hong Kong, 1989. Each patient was provided with an information sheet containing detailed information about the purpose and stages of the future research. The patient was included in the study only in case of receiving a written informed consent about participation in the study.

The main criterion of clinical evaluation of status of periodontal condition was the depth of the periodontal pocket.

To get the volt-ampere characteristics of periodontal tissues there was developed a noninvasive two-electrode sensor (Figure 1), an indicator electrode that was made on the basis of parodontometer, and as a passive electrode for use on the lip.

Using of two-electrode sensors on the basis of the indicator electrode was due to the fact that reducing the area of one electrode (the indicator) compared with the other (passive) resulted in the potential on the indicator electrode being increased, which gave greater reproducibility of results.

During these studies, the joulemetry of the intact periodontal tissue was carried out on 12 sites in the field of the second teeth on the upper
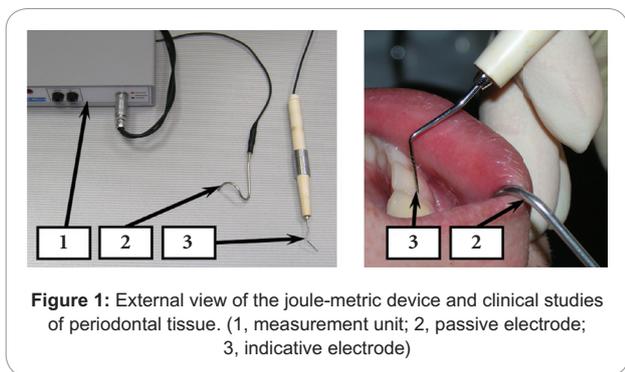
Figure 1: External view of the joule-metric device and clinical studies of periodontal tissue. (1, measurement unit; 2, passive electrode; 3, indicative electrode)

Sex	Control group	Periodontitis of the easy degree	Periodontitis of the average degree	Periodontitis of the severe degree	Total
Men	9	13	12	15	49
Women	11	18	15	26	70
Total	20	31	27	41	119

Table 1: Patient distribution by age and sex

	The depth of the periodontal pocket (mm)	The mean value $A(t)$, μJ	Standard deviation $A(t)$, μJ
Control group	–	262	20
Periodontitis of the easy degree	3.27 ± 0.05	273	22
Periodontitis of the average degree	4.27 ± 0.08	285	25
Periodontitis of the severe degree	6.02 ± 0.12	320	32

Table 2: The relationship of the joulemetric characteristics and the depth of the periodontal pocket

and lower jaws of the left and right frontal area of the alveolar processes of the upper and lower jaw, the first premolars, and in the area of sixth teeth of upper and lower jaws on the left and right areas of the alveolar ridge in the posterior region. In every patient the 12 indicators of the current-voltage characteristics of the periodontium were measured, which allowed us to obtain a picture of the topographical distribution of Joule etric indicators in the gingival tissues.

Results and Discussion

On the basis of preliminary studies of the periodontal tissues, the results were found to be optimal from the point of view of reproducibility of data and of reducing the influence of noise of the parameters of impact; the magnitude of the current: 10 μA and the exposure time of current: 16 s.

A survey of periodontal tissues of 119 patients was made. Among them there were 49 men and 70 women (Table 1).

In patients of the control group, the periodontal pocket was missing; the average value of the performance of the current was obtained as 262 micro Joules (μJ) (Table 2).

In patients with mild periodontitis the destruction of bone tissue of interdental septa down to 1/3 of root length was determined; the expanding periodontal gap in the area of the neck of the teeth and osteoporosis of the interdental septa was observed; the average performance of the current amounted to 273 μJ (Table 2).

Patients with periodontitis of average degree of destruction have the destruction of bone tissue of alveolar process (often uniform) down to 1/2 of the roots of the teeth, the periodontal expansion cracks, and osteoporosis. The average current work in this group of patients was 285 μJ (Table 2).

In patients with severe periodontitis uneven bone tissue destruction of more than 1/2 of the roots of the teeth, periodontal expansion cracks, and osteoporosis were observed; the average performance of the current: 320 μJ (Table 2).

Thus, analyzing the results of the study, it was revealed that there is a relationship between joulemetric parameters and clinical changes in periodontal tissues. Higher the inflammatory changes in periodontal tissues, higher the value of the current work.

Conclusion

Measurement of joulemetric parameters (current) in patients with different forms of periodontitis can be used in clinical practice for the diagnosis of inflammatory periodontal diseases as well as the monitoring of the effectiveness of the therapy of this pathology.

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