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THEORETICAL AND PRACTICAL JUSTIFICATION OF MEASURING ORAL CAVITY MUCOSA INDIVIDUAL ELECTROSENSITIVITY THRESHOLD REGARDING LOCATION OF BIOLOGICALLY ACTIVE POINTS

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INTRODUCTION

Measuring alive tissue resistance to constant current, despite its evident simplicity, is characterized by several peculiarities, which should be known and considered when assessing the obtained values. Measuring alive tissue resistance significantly differs from measuring the resistance of any other materials: conductors, dielectrics, solutions.

The above-recalled materials are more or less resistant to the current. The processes, related to attempts of measuring electrical resistance (conductivity) in alive organisms are totally different.

The oral cavity electrical characteristics, mentioned many times by the authors, from classical science view are quite controversial. They cannot serve as reliable arguments during discussion. The paper reveals the rules of correct assessment of the oral cavity resistance to electricity, with least effect of devices on the measured object; as well as describes the methods and criteria to be used to prevent rough mistakes, leading to incorrect conclusions.

Also, the authors would try to reveal possible causes of huge measurement inaccuracy when the measuring electrode (one or two) touches the biologically active point region or the biologically active point itself.

1. Measuring the living tissue resistance to the direct current

There are several peculiarities of measuring the living tissue resistance to the direct current, which a person should know and regard when assessing the obtained results. Measuring the resistance of the functioning tissue significantly differs from measuring resistance of other materials: conductors, dielectrics, solutions, etc. The recalled materials are more or less resistant to the current. As for the homogenous materials of permanent cross section, prolonged length of the current pathway, and/or decreased transverse section of the material lead to increase of the resistance absolute value. The above-mentioned is proven by a simple example (see fig. 1 and 2).

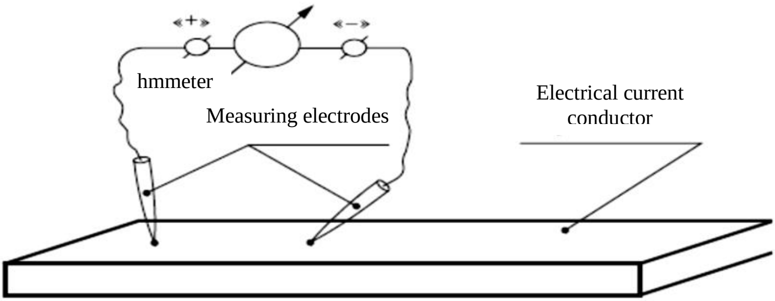

Fig. 1. Scheme of measuring the material electrical resistance between points A and B

The figures illustrate that in the first case (see fig. 1) the voltage is applied between the points (A and B), and the pathway of electrical current from point A to point B is shorter than that in the second case (fig. 2), so, the frames of the areas AB will differ. In these terms, the electrotechnical science operates with definition of the specific resistance. A symbol ρ stands for the specific resistance; measured in Ohm mm^2/m. Let's divide the parameter measured in mm^2 (section of the conductor measured in square millimeters) by the conductor length, measured in m, in order to obtain less evident measurement parameter i – 1×10^{-6} Ohm·m. The reference books most often use the characteristic of ρ measured in Ohm mm^2/m under the conductor temperature +20 °C. Sometimes, to characterize the electrical conductivity properties one should use the specific conductivity, a characteristic, directly opposite to the specific resistance. It is denoted with a symbol γ, being measured in cm m/mm^2. The resistance of conductors under constant temperature stays permanent.

If higher voltage is applied to the points A and B, evidently, greater current will appear between these points. The relation between the current, voltage and resistance of a certain area complies with the Ohm's law:

$$I = U/R,$$

where: I – current, A;
U – voltage, V;
R – resistance, Ohm.

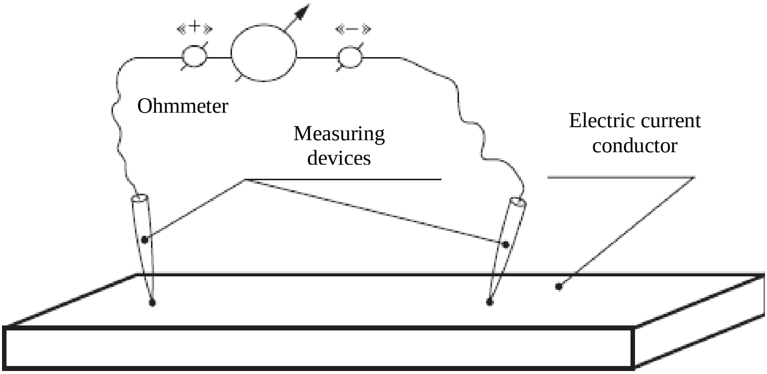

Fig. 2. Measuring electrical resistance of the material between points A and B (the distance between A and B exceeds that in picture 1)

The mentioned dependence is illustrated by the chart in figure 3 (unbroken line), which is called current versus voltage curve (VI characteristic). If the resistance is changed (increased or decreased), the VI characteristic angle changes as well (in figure 3 – lines R1 and R2).

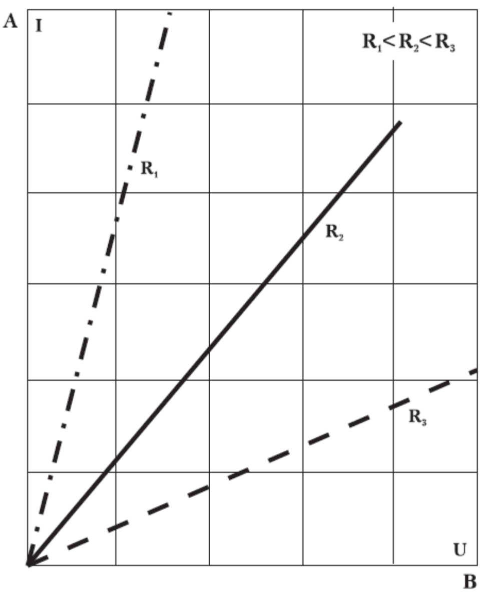

Fig. 3. VI characteristic of electrical conductors under various resistances

Any voltage change by the ΔU parameter will lead to analogous change of the current by ΔI. The relation $\Delta U/\Delta I$ is called differential resistance, and, except for rare cases, it is always positive in non-living objects, i. e., $\Delta U/\Delta I > 0$. If $\Delta U/\Delta I < 0$, it means that the VI characteristic contains an area (one, or several) with negative differential resistance or just with the negative resistance. The electronic industry produces the facilities with negative resistance of the VI characteristic, e. g., negative-resistance diode.

The explained above leads to the conclusion which will be used further in the paper: to measure electrical resistance or electrical conduction of any material or substance this material should be treated with electrical current. The characteristic of the electrical current should not cause changes in the material or substances themselves (physical, chemical, structural).

The processes related to the attempts of measuring the electrical current (conductivity) in living organisms are totally different. The electrical properties of various body tissues differ. The liquid media are characterized by good electrical conductivity, which includes blood, blood plasma, saliva with components, intercellular liquid, etc. The nerves situated along the nerve fibers are good conductors. Some tissues, by the electrotechnical criteria may be referred to isolators, including tendons, dry skin, and bones without periosteum. Though, electrical conductivity of certain body parts and body in the whole is determined not only by absolute characteristics of tissue electrical conductivity, but, mainly, their topography and functional condition. After touching with two electrodes (as in case of measuring resistance of homogenous material on the AB line, fig. 1.) iving tissue, the electrical current is directed from electrode to electrode by the least resistance pathway, by blood vessels, muscles and other tissues with greater content of liquid media, vastly disseminating and deviating from the shortest geometrical intraelectrode space (in this case, AB). Throughout the electrical current pathway, the resistance may change, according to penetration of blood in the tissues. When the blood vessels dilate and their blood volume increases, which occurs under the electrical current action, the resistance will decrease, but the electrical current rise. In the area of electrodes in points A and B the orientation semiconductors (dielectrics) polarizing occurs, as well as accumulation in points of electrode contact of the like-charged particles, which are moved with the electrical current. The described above event is called intratissue polarizing. Such unsteady process does not last long, followed by the energetic balance.

One should emphasize that the energy balance within the system “living tissue resistance measuring device – living tissue” may come in action, though, the electrical energy is still transferred from the device, i. e., living tissue may absorb electrical energy. The electrical energy of the device is transformed into the physical factor in the body, as well as into the biological process: it is used for heating, the receptors, nerves and other tissues are irritated, the relation between the ions and the medium pH changes, biological links may be destroyed or changed with the newly formed ones. So, the issue of absorbing the electrical energy by the living organisms isn't studied sufficiently now, which may be related to the complexity of the tissue structure, continuous dynamic pattern and extreme complexity of the biological processes.

If electrodes are separated onto distance, the device estimates will change as well. The electrical current will flow by the way where its losses will be minimized, and, appropriately, the resistance of the AB line will be minimized as well (fig. 2). As it was mentioned above, the AB resistance for the non-living tissue will change proportionally to the AB distance (with permanent transverse material section). The proportion of measuring the resistance according to the distance between A and B points of the living tissue is quite relative, due to both low homogeneity of the tissues electrical resistance, transformation of external electrical energy of measuring facility into physical factor (a component is represented with the local heating), and the biological process.

Another considerable factor which we would refer to while measuring the living tissue electrical resistance, is represented with possible causes of huge errors when the measuring electrode (one or both) touches the biologically active point region or the biologically active point itself.

2. Biologically active points in oral cavity

What is meant by the biologically active points in oral cavity?

The eastern medical and philosophical concept of the human body interacting with the environment through the skin has existed for several thousands of years, thus developing opportunities for managing such interaction by physical effects exerted on the skin.

The concept makes a fundamental basis for acupuncture, acupressure, electropuncture and other appropriate treatment methods.

In 1935 German physician E. Foll initiated studies of the electropuncture diagnostics and therapy method. The method was approved by the Ministry of Health of the USSR in 1989, being permitted for use in healthcare institutions. The method of application of the diagnostic and treatment has been studied and improved, with described method of measuring 14 basic meridians and Chinese points (biologically active points), inside which energy is circulating [1]. In order to find the biologically active points and

[1] Гуща Д. К. Измерение сопротивления тканей полости рта: особенности, последовательность, незамеченные ошибки. Соврем. стоматология. 2009. № 4. С. 112–116.

measure the effect on them, electronic devices are used, which produce impulses of a certain shape, amplitude and frequency [2]. An electrothermal model of the biologically active points has been offered. An attempt of mathematical description of the biologically active points during their irritation by acupuncturing, burning and electrical current effect has been made, with the static VI characteristics of the human skin biologically active points emphasized.

The charts show (fig. 4, 5) that both in the biologically active point and beyond its borders there is a living tissue region with negative resistance; in the biologically active point itself the electrical resistance, estimated by the Ohm law, is significantly lower than the resistance beyond the biologically active points [2].

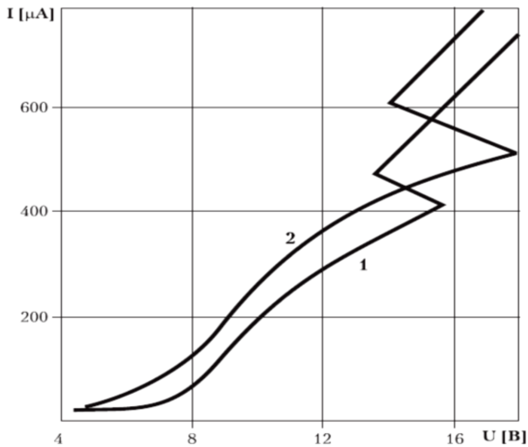

Fig. 4. VI of type S measured in biologically active points of human skin (1 – left; 2 – right)

Besides, the biologically active points and the regions near them generate the "living" electromotive force. These local electromotive forces, being added to or subtracted from the external voltage where electrodes contact with A and B points (in living tissue), respectively increase or decrease the measured current value.

According to the above-mentioned, let's conclude on the rules which one should keep to while measuring the living tissue resistance:

[2] Ромоданов А. П. Первичные механизмы действия иглоукалывания и прижигания / А. П. Ромоданов, Г. Б. Богданов, Д. С. Лященко. К. : Вища шк., 1984. 112 с.

1. The distance between measuring electrodes (geometric centers) should be a constant value, e. g., 10±0.1 mm.

2. The diameter and shape of electrodes touching the living tissue to measure resistance, should be consistent: e. g., a diameter 1±0.05 mm, in region of contact with the alive tissue, a sphere 0.5 mm in radius.

3. Theoretically, maximum contact surface area of each electrode with living tissue is calculated using the formula $\mathbf{2\pi R^2}$ (for semi-spheric electrode), which in this case is 1.57 mm^2.

4. None of the measuring electrodes during the assessment should be in the biologically active point area, which includes the biologically active point itself as well.

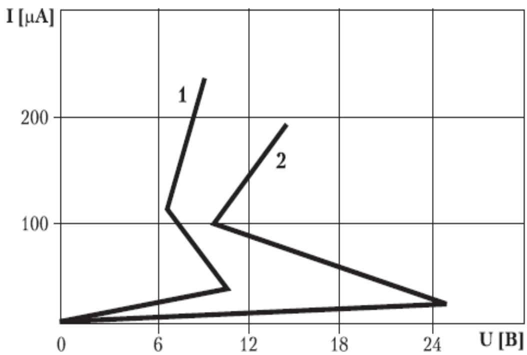

Fig. 5. The VI characteristics of the biologically active point (curve 1) and skin apart from the biologically active point (curve 2)

In order to keep to the last, fourth rule, the researcher should seek the biologically active point directly on the living tissue.

Special and general papers on electro- and acupuncture describe thoroughly biologically active points of human body. Presumably, atlases with active points location, their interrelation and sequence of their use according to the desired treatment effect contain description of the points on the external human body parts and organs (arms, legs, head, etc.) [3, 4]. The search found considerably less sources describing the study of the oral cavity biologically active points. Working over the thesis, the author thoroughly studied researches of the oral cavity tissue biopotentials,

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[3] Гуща Д. К. Измерение сопротивления тканей полости рта: особенности, последовательность, незамеченные ошибки. Соврем. стоматология. 2009. № 4. С. 112–116.

[4] Мачерет Е. Л. Основы электро- и акупунктуры / Е. Л. Мачерет, А. О. Коркушко. К. : Здоров’я, 1993. С. 121–130.

recalled in the sources [5, 6]. According to Hoang Bao Tiau, all biologically active points located in the oral cavity, refer to out-of-meridian, i. e., they refer neither to 12 basic, nor to anterior-medial or posterior-medial meridians. The biologically active points are usually situated beyond the meridians, although those which coincide with meridians, don't belong to them. In order to produce a complete pattern of the oral cavity informative points position in figure 6 we represent a photocopy of the scheme from the source [7].

One could precisely "shoot" the biologically active point only basing on the electrical measurements: due to the electricity potential tissue value or due to the oral cavity superficial potential values. From the point of the electrical measurements rules on the minimum electrical resistance force-generating biological objects, the biologically active points should be determined only by the electrical potential. The losses of the electrical potential from the biologically active points should be minimized. Also, to measure the individual electrical sensitivity threshold of the oral cavity mucous membrane to electricity by the author's method [8], without changing the electrodes polarity, it is necessary to regard that the oral cavity maintains constant electrochemical balance value. The further voltage increase leads not only to increase in the electrical current values, but to thermal and mechanical cell destruction.

Regarding that the main and specific component of the electrical current action is its effect on various ions relation in the tissues, which represents an important chain in regulation of their functional condition, numerous problems in the existing methods of the individual electrical sensitivity threshold measurement arise.

The statement is explained by the following factors. Suppose that in the previous time period the electrode A potential was positive ("+"), and the electrode B – negative "–". Respectively, near electrodes A and B the areas with excessive positively and negatively charged ions were created. Also, action of electrical potential applied between the electrodes, brought upon a certain charge to the living tissue membranes. Then, just after changing the polarity of the applied to electrodes potential, the following occurs: neutralization of previously charged ions located in the electrodes A and B regions, oral liquid polarization, the living tissue cell membranes

[5] Никитина Т. В. Возрастная характеристика биопотенциалов тканей полости рта / Т. В. Никитина, К. Х. Урусов, С. В. Попов // Стоматология. 1979. № 3. С. 1–5.

[6] Хоанг Бао Тяу. Иглоукалывание. М. : Медицина, 1988. 672 с.

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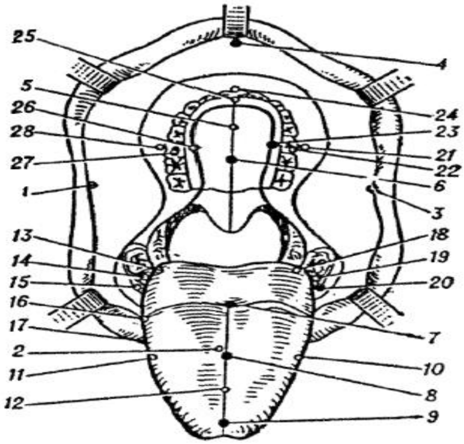
[8] Онищенко В. С. Непереносимость сплавов металлов зубных протезов: дис. ... доктора мед. наук: 14.00.22. К., 1995. 249 с.

deformation (at first the distance between the membranes decreased to the minimum value, the membrane surface potential difference equals null, and then the membranes are pushed apart from each other, with the potential between the membrane surfaces reaching maximum values, without damaging the membrane itself). This explains for the fact that at the moment when the electrode polarity is changed, the electrical current indicator first deviates greatly, then reaching its standard value. At the polarity change moment the patient subjectively feels the shot (under the negative electrode).



Fid. 6. Scheme of location of the points while measuring the oral cavity electrical potentials. The numbers stand for the points where the electrical potential was measured. The most informative among them are:
3 – left mouth corner; 4 – upper lip; 6 – medial palatal third; 7 – tongue root; 8 – medial tongue third; 9 – mouth tip; 20 – in the 6^{th} tooth region on the vestibular side; 23 – in the 6^{th} tooth region on palatal side and skin, far from the biologically active points (curve 2)

In addition, it was proven that the increase in excitation and appearance of excitation near the cathode occurs due to presumable accumulation in this region of univalent ions, characterized by higher mobility compared to bi-valent ions, which, due to their low mobility stay near the anode.

Functional condition of the tissues is also defined by changed relation between the hydrogen and hydroxyl ions, which causes the electric current. Here, an increase in the hydrogen ions concentration near the cathode leads to increased excitement there, while the increase in hydroxyl ions near the anode – to its decrease.

Ionic shifts, changes in the acid-basic balance and colloid dispersion in tissues under the electricity applied, as well as formation of the biologically active substances (BAS) exert exciting effect onto external and internal receptors, creating the stream of afferent impulses migrating to the segmental nerve apparatus and central nerve system. Resulting from these impulses spread, including the segmental level impulses, the efferent impulses are formed, then affecting and initializing function of various organs and systems, which eliminate or decrease the changes caused by the electrical current. According to expression of these changes and, mainly, to the tissues volume, the responses may be local, regional or general. The responses are vividly manifested not only as feelings, but the blood flow intensification. I. e., hyperemia caused by the vascular dilation and intensified blood flow in them may develop under the electrodes (the cathode). Hence, hyperemia develops not only resulting from the electrical current reflector manifestations, which are short-lived, but due to the direct effect on the vessel walls of the BAP produced in the tissues, e. g., acetylcholine and adrenaline, etc [9].

On the pathway of electrical current in semi-permeable membranes, including cell membranes, on both sides of them, accumulation of the like ions is observed. Between accumulation of the opposite polarity ions there appears intratissue polarization current of reverse direction. On one side, it creates reverse resistance to the acting electrical current, on another – such areas inside the tissue are the points of stronger electrical current action. The electrical current action is explained from the ionic excitement theory, presented by A. N. Obrosov (1958) and J. Loeb (1915), which, in its turn, is based on the electrolyte dissociation theory by S. Arrenius (1887). According to this theory, in electrolyte solutions there is continuous breakdown of neutral molecules onto the positive and negative-charged particles: ions, and, simultaneously, their recombination in neutral molecules. J. Loeb [10] established that for normal condition of various tissues as well as for their excitement, crucial importance attains not concentration, but the quantity relation between the uni- and bivalent Sodium and Potassium ions on one side, and the Calcium and Magnesium ions, on another.

During increase of such relation, due to increase in potassium and sodium ions, there appears excitement. When this relation decreases due to calcium ion content increase, tissue vital processes intensity falls.

If the electrical current direction (polarity of charges which make it) occasionally changes, it is termed as a temporary electrical field. The liquid body media contain predominantly electrolytes, salts mostly. The effect of

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9 Ясногородский В. Г. Электротерапия. М. : Медицина, 1987. 240 с.

10 Spiechowicz E., Glantz P. O., Axell T., Grochowski P. A long-term follow-up of allergy to nickel among fixed prostheses wearers. Eur. J. Prosthodont. Restor. Dent. 1999. Vol. 7, N 2. P. 41–44.

applied potential difference leads to the opposite motion of oppositely charged ions. The speed of such motion in water solutions is represented with one-millionth of the meter per second, with the voltage IV per 1 cm.

Along with electrolytes, tissue media always contain huge amount of dielectrics, as molecules which don't dissociate in ions. These are molecules of aminoacids and proteins. In such, generally neutral molecules, as a rule, according to their structure peculiarities, the equal by the absolute value opposite charges are located at a certain distance from each other, thus forming the so-called dipole. With absent external electrical field, the dipoles don't have definite orientation. Under the permanent electrical field condition, the dipoles are located so that the molecule side with positively charged ion is situated near negative electrode, and the negatively charged molecular side – near positive electrode, i. e., the dipoles obtain orientation. The dielectrics without structural dipole, under the effect of electrical field obtain it, being polarized. The property of the substance to polarize is characterized by dielectrical constant. Under the effect of external variable electrical field, each change of its direction leads to the dipoles direction change(relaxation fluctuations) and the recurrent polarized charge fluctuations in dielectrics without dipoles. The heat is produced under the action of recurrent dipole charge change and polarization fluctuations of dielectric charges in the tissues. Its quantity increases as the frequency and dielectrical constant substance amount rise.

So, the electrical resistance of the living tissue depends on the character and shape of the external electrical fields, liquids and various ions constituting the tissues.

The most appropriate task solution was probably offered by the inventor of the diagnostic-curative acupuncture apparatus V. Ketners [11, 12]. Without detailed schemes of the apparatus, we would like to reveal its principle. Fig. 7 simplifies the functional scheme of measuring the active points biopotentials.

The passive electrode represents as a metal tube, 30 mm in diameter, 80–120 mm in length; the active electrode is a metal pin, 1 mm in diameter. The end tip of the pin is rounded as a sphere, 0.5 mm in radius. The electrode itself is covered with electroisolating material, and its protruding (indicator) part is 0.5 mm. The patient clasps in his hand the passive electrode, in this way equalizing the biologically active points' potentials of

[11] Гуща Д. К. Измерение сопротивления тканей полости рта: особенности, последовательность, незамеченные ошибки. Соврем. стоматология. 2009. № 4. С. 112–116.

[12] Гуща Д. К. Діагностика електрохімічних та електроенергетичних змін в порожнині рота пацієнтів з несприйняттям до металевих зубних протезів: Дис. … канд. мед. наук: 14.00.22. Київ, 2011.

the palm. In this case, the passive electrode potential is considered as null V. Touching with the active electrode to the patient's various body points, the electromotive resistance force is determined. In the above-mentioned considerations we didn't emphasize the fact that if an active electrode treats the electrolyte (here the saliva represents as an electrolyte, with all chemical components), the electrode itself instantly turns into the active semi-element, with its own electromotive resistance force. To neutralize it, the intensifier "null value" compensator is used in the apparatus (position 5, fig. 7).

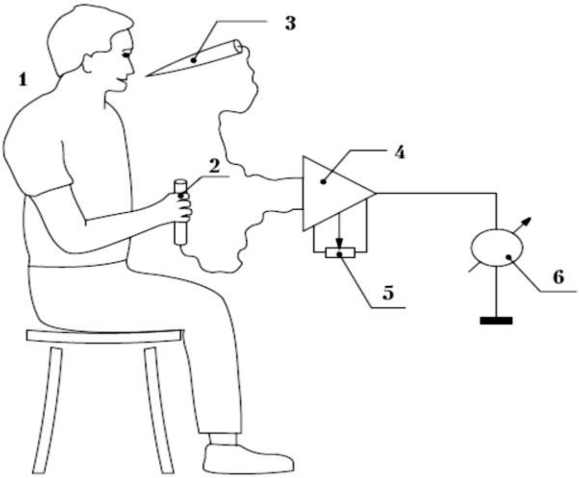

Fig. 7. Functional scheme applied during measurement of the active points potentials:
1 – patient; 2 – passive electrode; 3 – active electrode;
4 – highly-sensitive intensifier of constant current with huge input opening;
5 – "Null" compensator; 6 – microvoltmeter

When changing the voltage polarity, which we suggest, the established by the previous electrical current direction process is disrupted, the process being related to the oral liquid electrolysis and changes of poles on certain living tissue cell surfaces. So, we suppose that the current of 8 мсA, the value accepted as a standard for the individual electrosensitivity threshold, is the threshold value of the electrical current, which is associated with the living cells destruction. Also, defining the electrosensitivity threshold is the last procedure which is performed, as the measurement itself leads to changes of the oral cavity electrical energy and electrochemical balance changes.

CONCLUSIONS

So, the results of the alive tissue resistance testing, conducted in different clinics, can be compared and analyzed only when: during the testing distance between electrodes (the AB distance) is a permanent value, area of each electrode contact is constant, the current value is constant and standardized, none of the electrodes is located in the biologically active point region or on the biologically active points.

The applied original electrodes made from noble metals, usually used for measuring the oral cavity pH, potentials and currents of mechanical removable prosthesis don't produce any errors, regarding the electrochemical oral cavity equilibrium and general structure of the tests.

Being electropositive by several voltage values, the electrodes don't affect the oral cavity chemical composition. Very high input resistance values of the apparatus, reaching $1 \cdot 10^{15}$ Ohms, almost don't absorb electrical energy from the metal removable prosthesis, i. e., "pure" prosthesis potential is measured. The electrical current on the metal prosthesis is measured by compensating the prosthesis potential by external resistor with huge potential. The resistance value of the external resistor exceeds by thousand times possible value of the alive tissue resistance and electrolyte (oral liquid) resistance.

So, the electrical energy, generated by the metal removable prosthesis during testing the electrical current, is completely restored.

SUMMARY

The article reveals physical, electrochemical and biological processes which occur during measurement of the living tissue electrical resistance. The paper contains practical recommendations on detecting the resistance, describing certain conditions of conducting measurements, regarding the limiting factors.

Key words: Measurement of the oral cavity electrical resistance, effect of various factors on the results.

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