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Selecting clinical and laboratory methods of manufacture of orthopaedic titanium alloy structures using a biopotentiometer

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The present communication aims at determining an optimum method of manufacture of orthopaedic arch titanium alloy dentures that would not cause galvanosis in patients using such dentures. A clinical randomized controlled retrospective study was conducted. Sixty patients who used arch titanium alloy dentures were examined. Three measurements of electrochemical potentials in various areas of the oral cavity were done in all patients, using a biopotentiometer. Linear prediction of differences in potentials in measurement areas 1–3 for the control group (CG) of patients exhibited minor growth dynamics, which can be indicative of the risk of galvanosis in CG patients in the future.

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ONE of the problems in patients using metal dentures is the emergence of galvanic currents leading to galvanosis. This depends greatly on the correct choice of clinical and laboratory methods of denture manufacture. Despite the fact that removable dentures are still available in dental practice, fixed dentures have lately been in demand among patients[1,2].

Intolerance to dentures made of metal alloys in the oral cavity is a pressing problem in dentistry. It was reported that the use of fixed metal dentures may cause various dental pathologies[3–6]. However, there is no alternative to metal dentures for now, because of low physical and chemical properties of other materials, which includes high-breaking frequency[7,8]. Combination of metals and other materials, for example, ceramics, zirconium dioxide and others, is considered the most acceptable alternative option[9–13]. Nevertheless, the use of additional materials, in combination with metals, does not solve the problem of such metal structures in the mouth which affect biomedical parameters of patients[14–17].

Another important requirement to fixed structures in oral cavity is high wear resistance and minimum adverse effects[17]. Titanium and titanium alloys are among materials that are widely used in dentistry for making metal dentures. Titanium alloys are usually manufactured by milling and casting[18]. Sophisticated dental treatment methods are becoming increasingly common place, including those that use titanium alloys. Such alloys are cast in a furnace at high temperatures and milled via CAD/CAM technology[19]. The alloys differ drastically by the type of their surface, which is well seen on micrographs (Figure 1).

At the moment, titanium alloys of all types from different manufacturing techniques are used equally. At the same time, the question of preference still remains. The fact that no preference has been given to any manufacturing technique of titanium alloy is explained by the fact that titanium itself is one of the most bio-friendly materials that satisfies the physical and chemical requirements of dentures[20,21].

In the case of using a titanium alloy, the impossibility of using recoverable materials is also the undoubted advantage of its processing, as this feedback differs significantly from the original materials in composition and properties, thus leading to a decrease in the quality of orthopaedic structures: cast surface defects, intensive corrosion, and eventually, development of intolerance to dental materials[22].

Nevertheless, titanium dentures still have flaws that are typical of other metal dentures as well[23–26]. Increased galvanic currents in the mouth are another disadvantage of titanium and other metal dentures[27,28]. On one hand, galvanic currents which are induced by metal dentures in a patient's mouth, affect material strength and corrosion resistance and lead to faster destruction of dentures, thus reducing their service life[29].

On the other hand, metal denture-induced galvanic currents may cause adverse health-related effects, including development of galvanosis in the patient. Galvanosis involves abnormal phenomena such as metallic or acid taste in the mouth, dry mouth due to reduced salivation, taste perversion, and a burning mouth. General physical complaints include irritability, general weakness and headaches. According to various data sources, the prevalence of symptoms typical of galvanosis among patients using metal dentures varies from 15% to 35%. The above symptoms usually occur 1–2 months after the metal dentures have been installed[30–32].

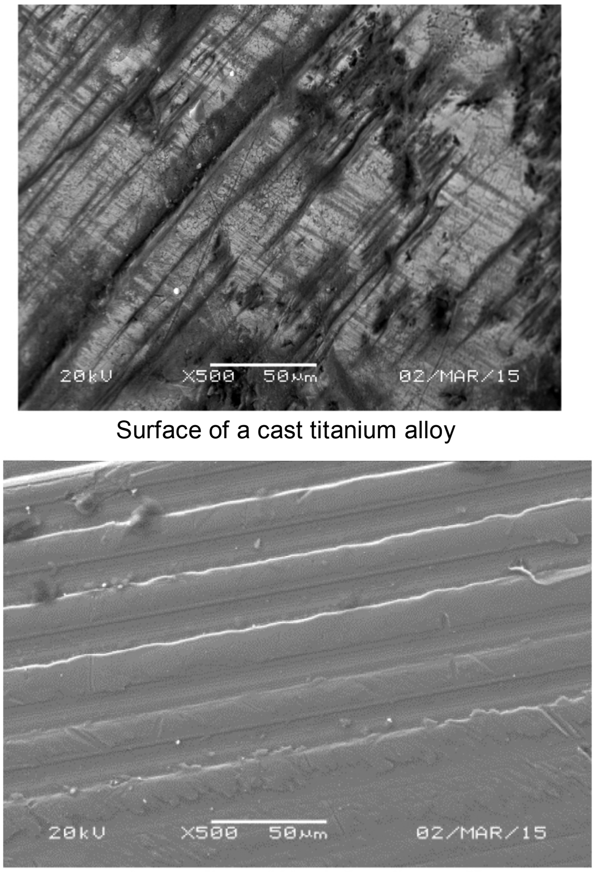
According to latest studies, patients with abnormal galvanic currents exhibit elevated metal levels in their saliva, including mercury, stanum, silver, copper and gold. It was also stated that high galvanic currents in the mouth lead to a decrease in immune defence reaction in the patient's oral cavity[33]. Thus, increased galvanic currents in the mouth is one of the reasons for oral discomfort in patients using metal dentures[34]. Abnormal galvanic currents in the mouth are identified by measuring the bioelectrical potential. A difference in potentials between dentures may be as high as 600 mV (ref. 35).

The difference in potentials favours dissociation of crystal lattices of metals, ingress of ions into the saliva and accumulation in the body. Furthermore, the difference in potentials that occurs in a number of heterogeneous areas of a single denture and between dentures has a complex reflective action on the receptor complex of the oral cavity[36].

The difference in potentials depends on the degree of corrosion of denture metal, rheological, acidic-basic and other properties of the saliva, available micro-damage and inflammation processes in the oral cavity. It is possible that colonies of dental plaque play a certain role in the increased difference in potentials, when there are metal inclusions[37].

It has been stated that a test for galvanic currents in the oral cavity should be done in patients with clinical manifestations of intolerance to denture metals – when two or more metals are present in the oral cavity[38]. It is believed that if the measured difference in potentials is higher than 150 mV, the causative metal insertions should be removed and new dentures should be provided. Currently, we do not possess the knowledge to overcome emergence of abnormal galvanic currents, when dentures are installed. Studies primarily focus on preventing corrosion of titanium implants, which has an indirect impact on galvanic current intensity in the mouth[19]. There are only a few targeted studies to reduce abnormal galvanic currents induced by dentures in the mouth. The use of a single metal or, minimum number of metals, for denture treatment is offered to prevent galvanosis development[39,40]. Proper replacement of metal dentures with signs of corrosion is another way to prevent galvanosis[34,35]. However, less data is available on the effect of manufacturing methods of Ti dentures on the growth of galvanic currents in the mouth.

We have hypothesized that the method of manufacture of titanium dentures – casting or milling – may increase galvanic currents in the mouth and pose a risk of galvanosis. Accordingly, to prevent development of galvanosis in patients, preference must be given to dentures manufactured in a certain way. Installation of the most inert denture may be another way to prevent galvanosis in dental patients. Special literature states that measurement of galvanic currents may be a useful diagnostic technique to predict presence of metal elements in the saliva and oral discomfort[35,41]. In line with the above, we have a second hypothesis that, galvanosis development in the



Surface of a cast titanium alloy

Surface of a milled titanium alloy

Figure 1. Titanium alloy surface with different treatment techniques.

future, in patients with titanium dentures may be predicted by measuring and analysing electrochemical potentials in different areas in the mouth. This will allow for early prevention of galvanosis in risk patients.

Provided that our hypotheses are validated this knowledge will help improve therapeutic approaches to dental patients by choosing correct dentures that are manufactured in a certain way. This will also help in taking early measures to prevent galvanosis in risk patients.

The objective of this randomized controlled retrospective clinical study was to determine the optimum method of manufacture of orthopaedic arch titanium alloy dentures that would not cause galvanosis in patients using such dentures. Optimum type of arch denture was selected by examining for galvanosis in patients with titanium alloy dentures that were manufactured using different methods. Biopotentiometry was used to optimize the selection by measuring the electrochemical potentials.

A clinical randomized controlled retrospective study was conducted at the Department of Orthopaedic Dentistry of the I. M. Sechenov First Moscow State Medical University. As a part of this study, we examined 60 patients who used arch titanium alloy dentures. Our examination was conducted for three years, relying on principles of bioethics and deontology.

Using a biopotentiometer, three measurements of electrochemical potentials in various areas of the oral cavity were done in all patients. To reach the study objectives, the patient population was divided into two study groups.

The experimental group (EG) comprised 30 patients with orthopaedic structures made of titanium alloy and milled with the help of CAD/CAM technology. Mean age across the group was (56 ± 1.02) years. The control group (CG) comprised 30 patients with cast titanium alloy dentures. Mean age across the group was (57 ± 1.08) years. Inclusion criteria: milled or cast arch titanium alloy dentures; dentures installed less than a month before the study. Exclusion criteria: use of non-titanium alloy dentures; simultaneous use of cast and milled titanium alloy dentures; dentures installed over a month before the study; concurrent lesion of the oral cavity of bacterial, fungal, neoplastic, or autoimmune genesis; acute somatic abnormality. Three measurements of electrochemical potentials in various areas of the oral cavity were done for each patient, using a biopotentiometer. Biopotentials were measured in the following areas of patient's mouth in all study groups: area 1: between metal inclusions (metal–metal pair); area 2: between metal inclusions and the mucosa of the mandibular and maxillary alveolar processes, accordingly (metal–mucosa pair); and area 3: between the mucosa of the mandibular and maxillary alveolar processes (two mucosa area pair).

Study methods: clinical anamnestic, social demographic, clinical, physical, instrumental and statistical methods. A biopotentiometer that was developed at the Department of Orthopaedic Dentistry of the I. M. Sechenov First Moscow State Medical University (Patent for invention of the Russian Federation number 173379, dated 20 February 2017) was used for biopotentiometry (Figure 2). This device measures biopotentials in the oral mucosa and is designed for oral mucosa diagnosis, including abnormal dental pockets. The device also monitors treatment dynamics, diagnosis, and predicts development of galvanosis.

The operation principle of this device involves measurement of bioelectrical potentials between intact and affected areas of the oral mucosa and determination of the electrochemical potential of metal inclusions. The technical result achieved is the ability to measure biopotentials of the mouth, including cases where orthopaedic structures are installed, and the capability of sterilization of measuring electrodes for repeated use.

Mathematical and descriptive statistical methods were used for statistical manipulations (including determination of arithmetic means and deviations, $M \pm s$; standard error of mean, $M \pm m$; Fisher's angle-transformation, φ^*; Pearson's test, χ^2; Student's t-test, t; universal statistical probability, p). Both study groups consisted of patients, 51–70 years of age (Table 1).

Patients over 50 years of age in the study cohort were natural, considering the type of dentures. Also, patients in these age groups were at risk of developing galvanosis. Gender distribution of patients in the study groups is given in Table 2.

According to Table 2, the ratio of males and females was practically equal in all study groups. This study showed significant differences in the electrochemical potentials in the EG and CG groups in all three measurement areas (Table 3).

The EG values of the electrochemical potential were significantly lower than CG, i.e. by 5.77 mV in

Figure 2. Biopotentiometer.

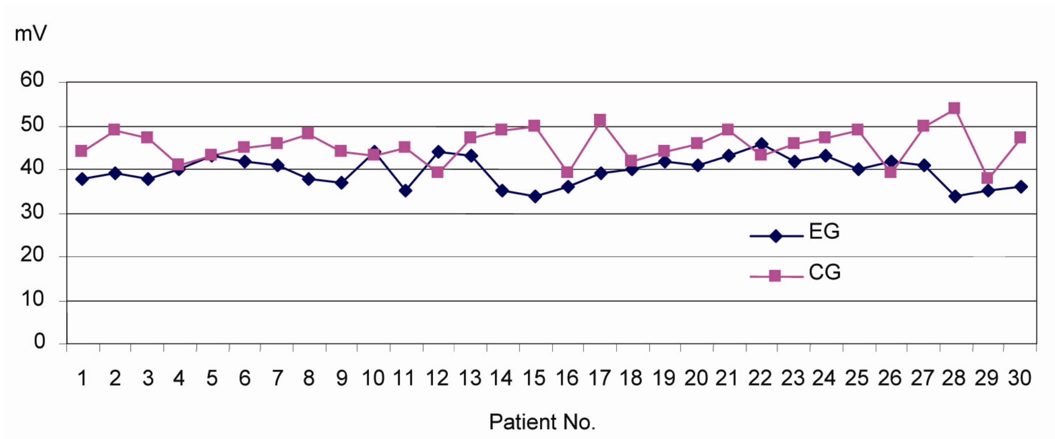


Figure 3. Graph 1 comparing parameters in the experimental group (EG) and control group (CG) in the measurement area 1.

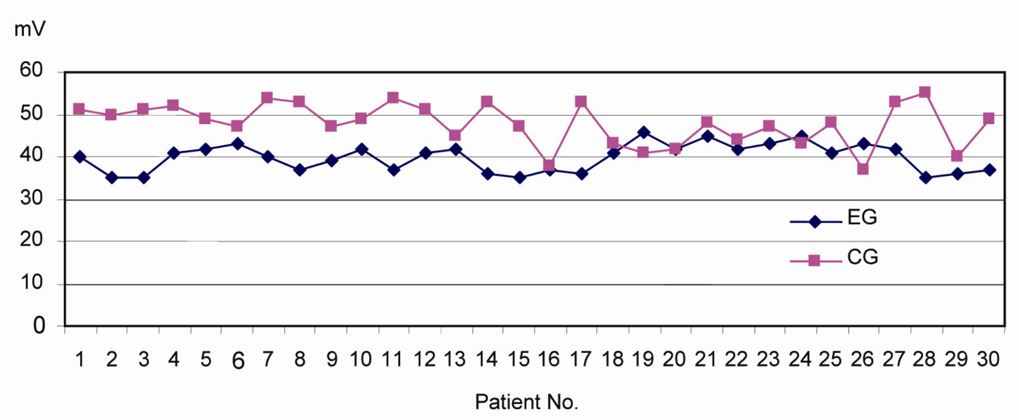


Figure 4. Graph 2 comparing parameters in EG and CG in the measurement area 2.

Table 1. Age distribution of patients in the study groups

	Age					
Group	41 to 50 years abs. (%)	51 to 60 years abs. (%)	61 to 70 years abs. (%)	Over 70 years abs. (%)	χ^2	P
EG (n = 30)	4 (13.33)	12 (40.00)	10 (33.33)	4 (13.33)	9.07	<0.05
CG (n = 30)	3 (10.00)	12 (40.00)	10 (33.33)	5 (16.67)	3.66	<0.05

EG, Experimental group; CG, control group.

Table 2. Gender distribution of patients in the study groups

	Gender		
Group	Males abs. (%)	Females abs. (%)	Total abs. (%)
EG (n = 30)	13 (43.33)	17 (56.67)	30 (100.00)
CG (n = 30)	15 (50.00)	15 (50.00)	30 (100.00)
φ^*_{emp}	0.523		
P	>0.05		

measurement area 1, by 7.93 mV in measurement area 2, and by 7.53 mV in measurement area 3.

A comparison of biopotential readings in the oral cavity of patients in both groups showed that EG patients did not exhibit any signs of galvanism. The difference in potentials in the EG group differed from that in the CG group by 7.09 ± 0.67 mV.

Having traced the change in difference in biopotential values in the study groups and relying on the accurate age of arch dentures in the study patients, we predicted oral mucosa lesions in one year following the study. Linear approximation was used for the prediction, which allowed tracing linear change of the studied parameter, based on mean values. For higher accuracy, the prediction lines were placed over the graph that represents differences in potentials at all measurement points for both study groups (Figures 3–5).

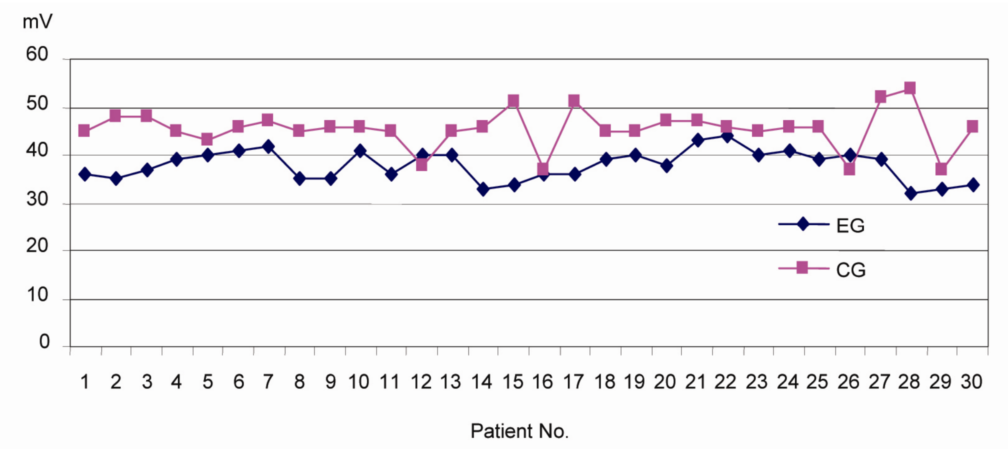


Figure 5. Graph 3 comparing parameters in EG and CG in the measurement area 3.

Table 3. Electrochemical potentials in EG and CG in the measurement areas (mV)

Measurement area	Study groups: EG (n = 30) $M \pm m$	Study groups: CG (n = 30) $M \pm m$	t_{emp}	P
1	39.70 ± 0.61	45.47 ± 0.72	6.1	<0.01
2	39.87 ± 0.61	47.80 ± 0.91	7.3	<0.01
3	37.93 ± 0.58	45.50 ± 0.74	8.1	<0.01

Visual estimation showed that linear prediction of differences in the electrochemical potentials in measurement area 1–3 for CG patients (the ones using cast arch dentures) exhibited growth dynamics, then as the indicators in EG was less than the mean values. This fact can be used as a marker for the risk of galvanosis development in CG patients in future.

Study findings coincide with modern beliefs that it is not exclusively the type of alloy, but treatment quality as well that favours increased galvanic currents in the mouth[34,42]. The problem of method of manufacture of titanium dentures affecting galvanic current intensities in patient's mouth requires further study by involving patients who have been using dentures for a longer period of time.

It has been determined that patients 51–70 years of age are in the galvanosis risk group. The risk of developing galvanosis in the future after dentures are installed is higher in the CG group when compared to the EG group.

Electrochemical potentials were minimum in the EG group, when compared to the CG group. This indicates that the preferred methods of manufacture of arch dentures is milling using CAD/CAM technology. This method prevents galvanosis, and thus improves the quality of life of patients.

It has been determined that a change in the difference in biopotentials and age of arch dentures in patients may be used as prognostic markers for galvanosis development. High potentials of bioelectric activity have been proven as factors that cause galvanosis.

Scientific value: Use of milled arch titanium dentures manufactured using CAD/CAM technology results in lower galvanic currents in the oral cavity when compared to cast titanium dentures.

Practical value: recommendations have been made on the selection of titanium dentures to prevent galvanosis in patients.

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