KnE Materials Science
SMBIM Conference Proceedings
Shape Memory Biomaterials and Implants in Medicine (2017), Volume 2017

Conference paper

Electrochemical Interaction of TiNi-based Implant with Overlay Denture

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Abstract

Experimental electrochemical studies simulating the contact of a dental implant of titanium nickelide and metal frames of a denture covering an implant were carried out. The contact currents in artificial saliva were measured under stationary conditions and when updating the denture surface. Different amounts of the current depending on the denture frame material were registered.

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Received: 23 March 2017
Accepted: 9 April 2017
Published: 16 July 2017

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the SMBIM Conference Committee.

1 Introduction

The use of titanium nickelide alloy (NiTi) in the dental implantology is extending. It has special properties of superelasticity and a shape recovery effect [1, 2, 3]. This publication presents the results of the experimental study of the electrochemical characteristics of the titanium nickelide implant – denture metal frame contact pairs, including those under conditions of surface renewal of one of the elements. Such study is relevant in relation to the requirements of the long-term functioning of dentures on implants [4, 5].

2 Experimental

The samples of common alloys used in prosthetic dentistry were taken as objects for the study (Tab. 1); as an active medium was used a simulated solution simulating saliva of the following composition: 0.4 g/l KCl 0.4 g/l NaCl 0.795 g/l $CaCl_2$ 0.69 g/l Na_2HPO_4 0.005 g/l Na_2S $9H_2O$ 1 g/l urea H_2O (q. s. to one liter of the solution); pH 8.

An electronic pulse PI-50-1.1 potentiostat was used, with the help of a three-electrode cell with an undivided electrode space; as a reference electrode was used a normal chlorine-silver electrode (c.s.e.). The potential values obtained were converted to a normal hydrogen scale ($E_{changed}$ 0.201V) (n.h.s). V7-35 ampere meter was also used to study the contact electromotive force and corrosion current of the contact pairs.

Table 1 Chemical Composition of Dental Alloys

Alloy	**Chemical composition** (% by weight)
NiTi titanium nickelide	Ti(50), Ni(50)
NiCrMo (Cellit-H) nickel-chromium	Base – Ni(61.4), Cr(22.9), Mo(4–6), Si(0.8–0.12); the rest C, rare-earth elements
Ti (Rematitan) titanium	Ti(100)
CoCrMo (Cellit-K) cobalt-chromium	Base – Co, Cr(22–25), Mo(10), Si(1.0); the rest V, C, rare-earth elements
CoCrMo (Remanium 2000) cobalt-chromium	Co(61), Cr(25), Mo(7), W(5), Si(1.5); the rest Mn, Ce, C, N
CoCrMo (Cellit-K) cobalt-chromium with TiN coating	Base – Co, Cr(22–25), Mo(10), Si(1.0); the rest V, C, rare-earth elements
Zr zirconium	Zr(100)
BT5 titanium	Base – Ti, Al(4.3–6.2), Fe(0.3), Si(0.15), O(0.2), C, N, H (0.1–0.015)
BT14 titanium	Base – Ti, Mo(2.5–3.8), Al(3.5–6.3), V(0.9–1.9), Fe(0.3), Si(0.15), O(0.15), C, N, H(0.1–0.015)
Au-Pt gold-platinum	Au(87), Pt(10.6), Zn(1.5); the rest In, Mn, Ta, Rh
NiCrMo (Remanium 2000) nickel-chromium	Ni(59.3), Cr(24), Mo(15)

A current corrosion index was used to analyze corrosion rate, and to calculate a negative exponent of mass variation and a corrosion depth index.

3 Results and discussion

Table 2 shows the results of measurement of electromotive force of the contact pairs compared to theoretical values obtained from the measurement data of stationary potential and corrosion current densities.

The measured values of electromotive force (EMF) and galvanic currents in the NiTi-metal (alloy) contact systems without surface renewal show that the lowest values of EMF and currents (<0.1 μA/cm^2) are set in the NiTi-NiTi, NiTi-CoCrMO and NiTi-

Table 2 Electrochemical Characteristics of Contact Pairs of NiTi-Metal (Alloy) in the Simulated Biological Solution at 25 C.

Second element of the contact pair	Experimental value of electromotive force, mV	Experimental value of current density of the contact pair, μA/cm²	Theoretical value of electromotive force, mV
CoCrMo (Cellit-K) cobalt-chromium	42	<0.1	118
CoCrMo (Cellit-K) cobalt-chromium with TiN coating	97	0.1	61
CoCrMo (Remanium 2000) cobalt-chromium	12	<0.1	46
NiCrMo (Cellit-H) nickel-chromium	95	0.1	81
NiCrMo (Remanium 2000) nickel-chromium	30	0.1	6
Ti (Rematitan) titanium	34	0.1	79
BT5 titanium	86	0.2	92
BT14 titanium	106	0.4	72
Zr zirconium	65	0.2	180
Au-Pt gold-platinum	196	1.0	169
NiTi titanium nickelide	10	<0.1	25

Cellit-K systems, which can certainly be recognized as electrochemically compatible systems in stationary conditions. The second group of compatible materials can be classified as systems in which the values of galvanic currents are 0.1 μA/cm²: NiTi-Ti, NiTi-NiCrMo, NiTi-Cellit-H (ranked by increase in EMF). The third group on the degree of compatibility includes the systems of NiTi-Zr, NiTi-BT-5, NiTi-BT-14 (ranked by increase in EMF), and the fourth group includes NiTi-AuPt.

When calculating the corrosion rate of the elements of the NiTi-denture metal frame contact pairs it was revealed that, under stationary conditions, the corrosion rate did not exceed 10^{-3}–10^{-2} mm/year, which in the absence of pulse currents caused by mechanical depassivation of the alloy surfaces ensured the lack of damage of the denture structure due to corrosion for several decades. The obtained values of corrosion rates under stationary conditions are very small and, according to a ten-point scale of corrosion resistance of metals, can be attributed to the second group of resistance (very resistant) with the 2 and 3 points of resistance (the maximum score of absolutely resistant materials is 1).

Measuring of the pulse currents at surface renewal of the contact pair elements and the study of kinetics of repassivation of the renewed surface while using titanium nickelide implants showed signifi t changes in the electrochemical parameters (Tab. 3).

Table 3 Maximum Pulse Current Densities of Contact Pairs at Surface Renewal and Repassivation of Newly Formed Surface of the Second Element, when Used as a Base Element of NiTi Alloy

Base (non-renewable) element of the contact pair	Renewable element of the contact pair	Maximum current density on the renewed surface, μA/cm²	Time of complete repassivation of the renewed surface t_p, s
NiTi	Cellit-K	113.3	14
NiTi	CoCrMo (Remanium)	113.3	9
NiTi	Cellit-H	40	4
NiTi	NiCrMo (Remanium)	53.3	9
NiTi	Ti	266.7	4
NiTi	BT5	280	40
NiTi	BT14	240	40
NiTi	Zr	813.3	140
NiTi	AuPt	255.6	9
NiTi	NiTi	40.0	4

Taking into account the total repassivation parameters (maximum current pulse at the time of renewal, time of 90 % of the current pulse droop) in operating conditions of NiTi as a base (unrenewable) element by electrochemical compatibility degree, the contact systems can be ranked as follows:

– first group: NiTi-CoCrMo, NiTi-Cellit-K, NiTi-Cellit-H, NiTi-NiTi;

– second group: NiTi-Ti, NiTi-BT-5, NiTi-BT-14;

– third group: NiTi-NiCrMo, NiTi-Zr, NiTi-AuPt.

The contact pairs of the third group of NiTi-AuPt cannot be recommended for use due to high current pulses at surface renewal and low rate of repassivation. The systems of NiTi-NiCrMo and NiTi-Zr can be conditionally recommended for joint use.

The surface renewal causes smaller or greater, but generally significant changes in the magnitude of corrosion current of the contact pairs. Depending on the nature of the pair elements and the renewed elements, the corrosion current instantaneous values vary from 40 to 800 μA/cm². However, in most cases, the surface repassivation process is substantially (90 %) completed during the first 4–10 seconds, so it can be assumed that the materials are under conditions of abnormally high corrosion rate for 1–2 seconds. In this case, the main problem of the joint use of titanium nickelide implants and metal dentures is a possible effect of galvanism. Under conditions of the surface presence in the long depassivated (renewed) state as a result of long-term mechanical impact, the corrosion loss of metal structures is possible.

4 Summary

The interaction of a titanium nickelide implant with artificial crowns on cast metal frames is connected with the possibility of occurrence of contact electrochemical interaction that cannot cause galvanic reaction under normal conditions, or corrosive phenomena. This also relates to short-term situations of renewal of dentures surface during functioning. To prevent possible electrochemical phenomena, the ceramic veneer of metal frames of dentures on titanium nickelide implants or the use of metal-free prosthetic structures are recommended.

References

[1] V.E. Gunter. Shape Memory Alloys – New Generation of Materials in Dentistry // In the Collection: Biocompatible Materials and New Technologies in Dentistry. Collection of Articles of the International Conference. Sci. editor R.G. Khafizov. 2014.

[2] A.A. Klopotov, V.E. Gunther, E.S. Marchenko, G.A. Baygonakova. Effect of Heat Treatment on Physical and Structural Properties of the Alloy TI 50NI 47.7MO 0.3V 2 with Shape Memory Effects // Bulletin of Higher Educational Institutions. Physics. 58 (2015) 7-2 68–74.

[3] V.N. Khodorenko, M.I. Kaftaranova, V.E. Gunther. Structure and Properties of Functional Alloys Based on TN-10, TN-20, TN-1B Titanium Nickelide // Bulletin of Higher Educational Institutions. Physics. 58 (2015) P. 44–50.

[4] R.U. Bersanov, M.Z. Mirgazizov, A.A. Remizova, D.A. Bronstein, A.I. Tikhonov, F.G. Shumakov, E.P. Yuffa. The Functional Efficiency of Modern Methods of Prosthetic Rehabilitation of Patients with Partial and Complete Edentia // Russia Bulletin of Dental Implantology. 2 (2015) 31–37.

[5] V.N. Olesova, D.A. Bronstein, M.S. Grishkov, P.A. Zakharov, V.S. Pechenikhina. Long-Term Results of the Analysis of the Peri-Implant Tissue State Depending on Dental Implantation Conditions // Russia Bulletin of Dental Implantology. 2 (2016) 36-40.