Research Article

Experimental comparison of osseointegration of titanium Grade 4 and hyperelastic titanium alloy Ti-22Nb-6Zr

Aleksandr V. Tsimbalistov[1]*, Egor E. Olesov[2], Valentina N. Olesova[3], Sergey Y. Ivanov[1,4], Irina P. Ryjova[1]

ABSTRACT

According to biomechanical studies, a superelastic titanium-nickel alloy of titanium is more favorable as dental implants in comparison with titanium because of its physical and mechanical properties closer to bone tissue. However, the presence of nickel in titanium-nickel inhibits its use as a material for dental implants. NUST MISIS has developed a superelastic nickel-free titanium-niobium-zirconium alloy. Morphological studies on animals of osseointegration of this alloy in comparison with Grade 5 titanium were carried out. Control of interaction with bone tissue samples of titanium alloys was 30 and 90 days; the method of study – scanning electron microscopy and microprobe elemental analysis of tissue on the border with titanium alloys. The proximity of the morphological picture and the elemental composition of bone tissue along the border with titanium and titanium-niobium-zirconium both at the control period of 30 days (in contact with the alloys, a low-mineralized connective tissue was found) and at the control of 90 days (the border with titanium alloys is covered with mineralized bone tissue similar in composition to the surrounding bone tissue).

KEY WORDS: Bone tissue, Elemental composition, Implant, Morphology, Titan ium, Titanium-niobium-zirconium

INTRODUCTION

Despite the excellent biocompatibility of titanium alloys, especially Grade 4 alloy, the search for new structural materials of dental implants does not stop.[1-5] This is due to a significant difference in the physical and mechanical properties of implants and bone perceiving tissue, which can lead to its overload, especially with an insufficient number of implants in complex clinical conditions. The titanium-niobium-zirconium (Ti-22Nb-6Zr) alloy obtained in NUST MISIS has superelasticity properties characteristic of bone tissue and is more suitable for the manufacture of dental implants in comparison with the superelastic alloy of titanium-nickel due to the lack of nickel in its composition.[6-11] Along with the superelasticity properties inherent in titanium nickelide (Ti-50Ni), the new titanium alloys do not have nickel in their composition.

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OBJECTIVE

This study aimed to analyze the experimental morphological study of osseointegration of nickel-free superelastic titanium alloy (Ti-22Nb-6Zr) in comparison with Grade 4 titanium.

RESEARCH METHODS

Rabbits breed Gray Giant number 12 with an average weight of under 2,500 g intramuscularly 2% by ramatroban. Anesthesia produced by the incision length of 4 cm in the submandibular region, skeletonema surface of the jaw and formed hole with a diameter of 4 mm and a depth of 2 mm. With the subsequent introduction of a bone bed with the force of samples of alloys after treatment of the wound with 3% solution of hydrogen peroxide it was sutured in layers. The animals were removed from the experiment within 30 and 90 days by intramuscular administration of 6 ml of calipsol; bone blocks were taken, which were placed in a solution of 10% neutral formalin; X-ray control

[1]Department of Pediatric and Prosthetic Dentistry, Belgorod State University, 308000, Belgorod, Pobeda Street, 85, Russia, [2]Department of Clinical Dentistry and Implantology, Institute of Advanced Training of the Federal Medical and Biological Agency, 123098, Moscow, Gamalei Street, 15, Russia, [3]Department of Dentistry, Institute of Postgraduate Professional Education A. I. Burnazyan 123098, Moscow, Marshal Novikova Street, 23 Russia, [4]Department of Oral and Maxillofacial Surgery and Implantology, First Moscow State Medical University named after I.M. Sechenov, 119991, Moscow, St. Trubetskaya, 8, p. 2, Russia

***Corresponding author:** Aleksandr V. Tsimbalistov, Department of Pediatric and Prosthetic Dentistry, Belgorod State National Research University 85, Pobedy St., Belgorod, 308015, Russia. E-mail: tsimbalistov@bsu.edu.ru

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was performed on Pan Exam+ (KaVo) apparatus. The morphological study was conducted at the Kazan Federal University (laboratory of laser confocal microscopy of the interdisciplinary center for analytical microscopy). The bone blocks were previewed by means of an optical microscope at the magnification of ×50, ×100, and ×200. The contact area of the bone tissue samples of titanium alloy was analyzed on high-resolution field emission scanning electron microscope Merlin (Carl Zeiss) after treatment of blocks in the vacuum system Q150T ES (Quorum Technologies) for applying a conductive alloy layer of Au/Pd (Gold-Palladium) in a ratio of 80/20 with a thickness of 15 nm by means of cathode sputtering. The microscope is equipped with an energy dispersion spectrometer AZtec X-Max (Oxford Instruments) with a resolution of 127ev spectrometer; measurement accuracy of 0.01-1%. Element X-ray microprobe analysis accompanied by a spectrogram was carried out on an electronic microanalyzer EVO GM (Carl Zeiss) at an accelerating voltage of 20 keV and a working interval of 10 mm using a set of standards for quantitative microanalysis, sounding depth of about 1 μm, and detection limit of 1500–2000 ppm elements.

RESULTS AND DISCUSSION

Experimental studies have demonstrated the osseointegrative properties of Ti-22Nb -6Zr,comparable to Grade 4 titanium. After 30 days after the integration of titanium-niobium-zirconium samples between them and bone tissue in some places along the contact line with an increase in the scanning electron microscope by 50, 100, and 500 times, a gap of up to 20 microns is revealed. Over a longer period of contact with the implant, large areas of tissue covering the edges of titanium-niobium-zirconium samples were revealed [Figure 1a and b]. In the zones of "growth" of tissue on samples of titanium-niobium-zirconium, the main elements are carbon (72.45 wt.%) and oxygen (13.45 wt.%), which is regarded as connective tissue [Table 1].

After 90 days, the surface of titanium-niobium-zirconium samples is completely covered with mineralized bone tissue, as evidenced by microelement analysis showing the following composition: Ca: 27.27, P: 13.77, C: 29.68, and O: 25.84 weight. % [Figure 1c].

The presence of titanium Grade 4 in the bone tissue during the period of 30 days is also accompanied by the presence of crevices between the metallic specimen of the implant and the bone tissue to 10 microns. With a large increase, numerous accumulations on the metal tissue of the bone bed are detected. This fabric is by elemental composition mainly with C: 61.12 weight. % and O: 21.67 weight. % [Table 1]. At 90 days of control, titanium samples are completely covered with

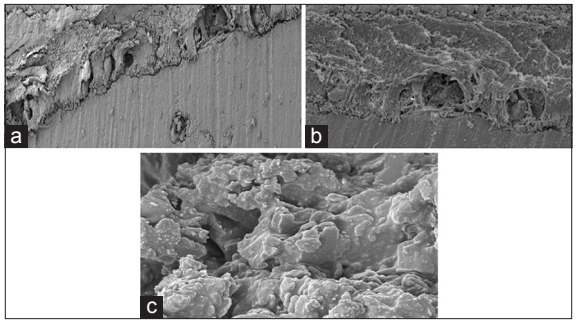

Figure 1: Border of bone tissue contact with titanium-niobium-zirconium samples: (a) Duration of the experiment 30 days, an increase ×50. (b) Duration of experiment 30 days, increase ×100. (c) Duration of the experiment 90 days, an increase in ×5000

Table 1: Data of elemental microprobe tissue analysis on the boundary of titanium-niobium-zirconium and titanium samples (weight.%)

Element	Ti-22Nb-6Zr		Ti Grade 4	
	30 days	90 days	30 days	90 days
C	72.45	29.68	61.12	27.83
N	9.49	2.56	3.01	0.00
O	13.45	25.84	21.67	29.60
Na	0	0.26	0.10	0.34
Mg	0.11	0.51	0.20	0.69
P	0.81	13.77	3.76	13.76
S	1.66	0	1.69	1.14
K	0.10	0.11	0.08	0.15
Ca	1.94	27.27	8.37	26.49
Amount	100.00	100.0	100.00	100.00

mineralized bone tissue composition: Ca: 26.49, P: 13.76, C: 27.83, and O: 29.60 weight % [Table 1].

CONCLUSION

1. Ti-22Nb-6Zr alloy implant samples are integrated by bone tissue in the animal experiment, as well as titanium Grade 4 implant samples.
2. Osseointegration of the superelastic Ti-22Nb-6Zr alloy is completed after 90 days of stay in bone tissue, accompanied by mineralization of connective tissue at the interface with the alloy formed in the initial period after the introduction of samples into bone tissue.
3. The study determines the possibility of pre-clinical trials of dental implants made of Ti-22Nb-6Zr alloy.

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