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Corrosion resistance of intramedullary nails used in elastic osteosynthesis of children

A. Krauze, A. Ziębowicz, J. Marciniak

Institute of Engineering Materials and Biomaterials, Silesian University of Technology, 44-100 Gliwice, Poland

Abstract: The paper presents results of research on the pitting corrosion resistance of intramedullary nails made of the 316L stainless steel. The surface of the steel was electrochemically polished and passivated. In particular the corrosion resistance tests were performed for three groups of implants with different time of implantation and surface damage. The corrosion resistance tests of implants in the initial state were performed as the comparison.

Keywords: Intramedullary nails, Corrosion test, Austenitic steel

1. INTRODUCTION

Long term research on the selection of the rigid or elastic intramedullary nails proved that because of the presence of a temporary cartilage in long bones the rigid nails osteosynthesis can not be applied. Therefore to stabilize long bone fractures in children the elastic nails are applied – fig. 1. Geometry of nails is conditional upon the age of a child and a diameter of the medullar canal. The idea of the elastic osteosynthesis consists in the introduction into the medullar canal the opposite curvature nails – fig.1. This way of stabilization enables three points of contact between nails and the medullar canal. As a result of that while loading the bone micro movements that accelerate the bone union are stimulated [1]. This is a little invasive method that ensures a fast fracture healing [2].

The initial condition of the implant surface can be changed even during the technological process as a result of a passive layer damage. Generally it is stated that a roughness of a surface is related to the corrosion resistance of the material. The better the roughness the better corrosion resistance is. Furthermore, the corrosion issues should be also considered with respect to the features of the environment of implantation as well as physical and chemical properties of the implant. Thus, the type of corrosion and its intensity depend on: the chemical and phase composition of the biomaterial, the type of loading, geometrical features of the implant and the osteosynthesis technique. As a result of corrosion, the elements can infiltrate the tissue environment [3]. The local influence of metallic ions or corrosion products on tissues is called a metalosis [4].

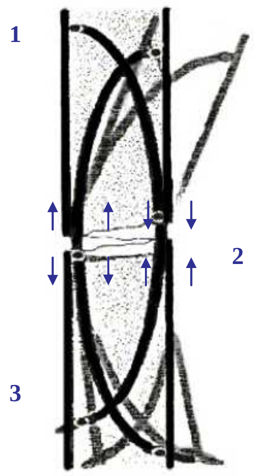

Figure 1. Axial forces ensuring the strain in the fracture gap [1]

2. METHODS

Research were performed on nails made of the austenitic stainless steel (Cr-Ni-Mo) before and after implantation. The first stage of the work was the microscopic evaluation of surface damages of the intramedullary nails after different times of implantation. That allowed to establish the type and the amount of damages caused by the implantation and removal of the nails. The implantation time was in the range 12 to 14 weeks. The evaluation of the mechanical damages included microscopic observations of the nails with the use of the stereoscopic and scanning microscope. Next on the basis of these observations the characteristic sections of the nails were selected for potentiodynamic tests.

Corrosion resistance tests of the 316LVM stainless steel of electrochemically polished and passivated surface were performed with the use of the potentiodynamic tests (VoltaLab, type PGP 201). The test consisted in the recording of the anodic polarization curves. Samples from the nails in the initial state and after the specific time of implantation were selected for the tests. Before the tests the samples were cleaned with the ethyl alcohol in the ultrasound washer. The tests were performed in the Tyrode's physiological solution – table 2, at the temperature of 37 ± 1ºC and pH=6,8 ÷7,4. Measurements started after the corrosive potential had been established, which took place after about 60 minutes. The change of the potential rate was equal to 1 mV/s.

3. RESULTS

The observations mechanical and corrosive damages of the intramedullary nails surface were done with the use of the scanning electron microscope DSM 940. Both the nails which haven't been implanted and the implanted ones were observed – fig. 2. It has been stated that the mechanical damages of the intramedullary nails were initiated mainly during their implantation into the bone. Damages caused by surgical tools were the main reason of the corrosive pits. The mechanical damages were recognized as the deep, long dents and continuous scratches.

On the basis of the preliminary microscopic observations three groups of damages were marked off. The first group included the nails which were implanted in the body for 12÷14 weeks. The second group was implanted for 15÷16 weeks and the third one - up to 42 weeks. The largest surface damages (deep scratches) were observed in the second group. The damages of the nails surface in the first and the third group were qualitatively comparable. The results of the pitting corrosion resistance were obtained on the basis of the anodic polarization curves – table 1 and 2.

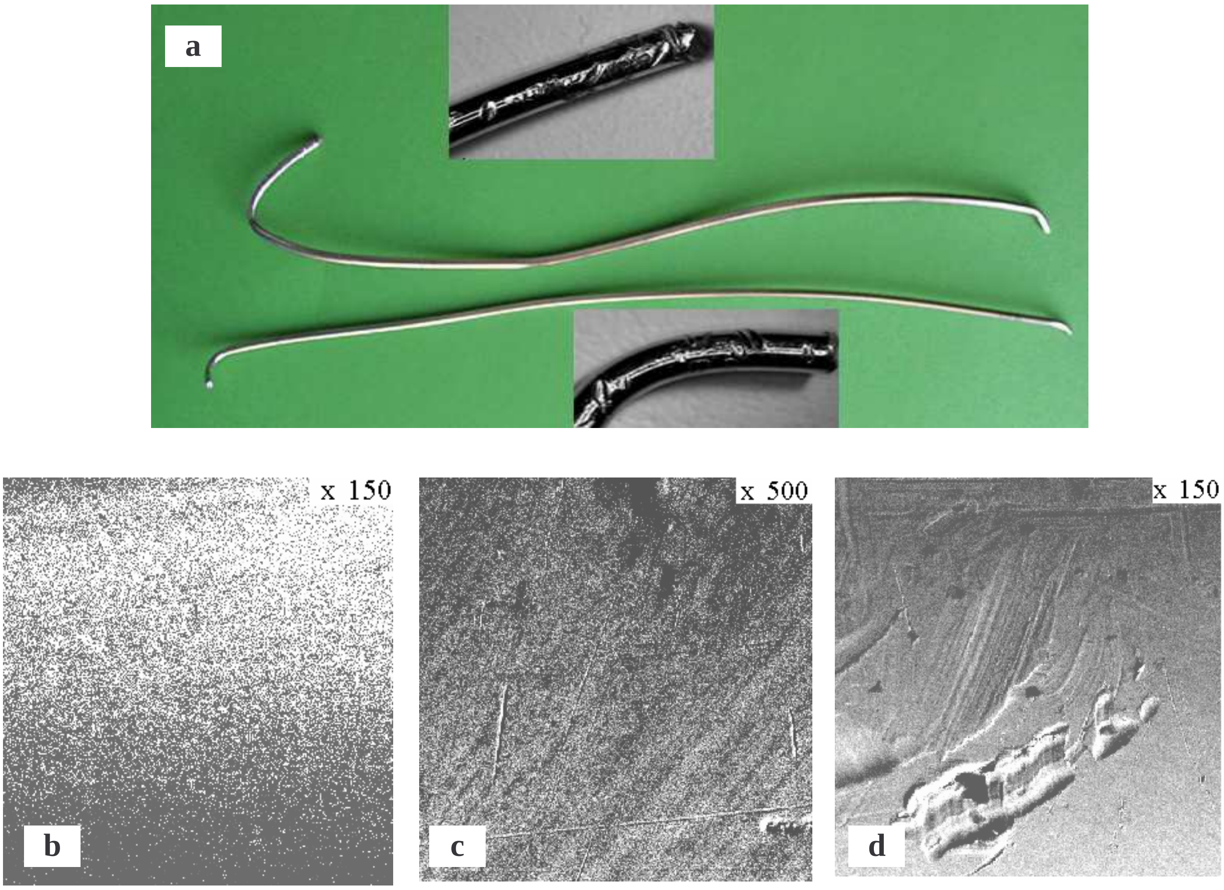

Figure 2. Example of the intramedullary nails surface: a – nails after implantations, b – initial state surface, c – after implantation – middle part, d – after implantation – end of the nail

After establishing the corrosive potential the samples were polarized up to the potential for which the current intensity reached 1 mA. For the first group the corrosive potential was in the range E_{kor} = -37 ÷-71 mV, however the breakdown potential was in the range E_{np} = +828 ÷ +875 mV. For the second group the corrosive potential was in the range E_{kor} = -64 ÷-68 mV, however the breakdown potential was in the range E_{np} = 324 ÷ 519 mV. The differences in the breakdown potentials are resulting from the amount of the mechanical damages of the surfaces. In the third group the corrosive potential was in the range E_{kor} = -70 ÷-72 mV and the breakdown potential E_{np} = 618 ÷ 760 mV. For this group of nails (the longest implantation time) somewhat higher breakdown potentials were related with the smaller amount and depth of the mechanical damages.

The repassivation of pits on the surface ensued for the potential in the range E_{cp} = +27÷+115 for the first group, E_{cp} = -58÷+70 for the second, and E_{cp} = +160 for the third one.

Table 1.
Results of research on the pitting corrosion resistance of intramedullary nails made of the 316L stainless steel in the initial state

Consolidation state	Specimens preparation	Corrosion potential, E_{kor}, mV	Average value of corrosion potential $E_{kor\ śr}$, mV	Breakdown potential E_{np}, mV	Average value of breakdown potential $E_{np\ śr}$, mV
consolided	Electrolytically polished + passivation	-28÷+37	+16	+687 ÷ +1016	+956

Table 2.
Results of research on the pitting corrosion resistance of intramedullary nails made of the 316L stainless steel after electrochemical polishing and passivation

No of the group	Nail diameter	Implantation time	Corrosion potential E_{kor}, mV	Repassivation potential E_{cp}, mV	Breakdown potential, E_{np}, mV
I	2,2	12	-71	+115	+828
	2,0		-37	+27	+870
	2,0	14	-59	+70	+875
II	3,0	15	-64	+53	+324
	2,2	16	-68	-58	+519
III	2,2	42	-72	+160	+618
			-70	+160	+760

4. CONCLUSION

On the basis of the research it has ben stated that the mechanical damages of the nails surface are the results of the incorrect preparation before implantation, especially during the prebending. The surface damages in the form of deep scratches are the sites of the pitting corrosion initiation. The corrosive rate depends on the amount and the size of the surface damage as well as on the implantation time. The quality of implantation has an influence on the course of corrosive processes of implants related to the unfavorable periimplantive reactions and postoperative complications.

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