EFFECT OF Ta_2O_5 LAYER ON THE ANTIBACTERIAL AND PHYSICOCHEMICAL PROPERTIES OF NiTi ALLOY

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Introduction

Shape memory alloys are widely used for implants such as plates for osteosynthesis, orthodontic wires or self-expanding stents, because of their biocompatibility and self passivating properties. However, they require additional surface improvement to prevent harmful nickel migration. This can be achieved through different methods, such as layering [1]. A promising method for applying thin films is the Atomic layer deposition (ALD), which allows the fabrication of films with homogeneous, controlled thickness [2,3]. Some of NiTi biomedical devices implanted by minimally invasive methods should be clearly visible under X-ray light. Nickel-titanium alloy does not meet this requirement, despite its several advantages. An additional challenge is to develop a layer that is resistant to susceptibility to deformation during the implantation procedure. Therefore, a tantalum oxide Ta_2O_5 layer applied by ALD method was proposed [4,5]. In addition, the effect of the resulting layer on bacterial biofilm formation was investigated due to complications that may arise from the spread of infection. A biofilm is a cluster of microorganisms consisting of bacteria and fungi. Approximately 60-70% of microorganisms settling on the implant surface are related to existing nosocomial infections [6].

Materials and Methods

The test material was superelastic NiTi (55,6% Ni) for implants with an austenite finish temperature A_f = 34℃. Disks with a diameter of 14 mm were cut from 0.8 mm thick sheet metal. The alloy chemical composition fulfills the requirements of ASTM 2063-18. Next, the specimens were electropolished in 3.5-mol H_2SO_4 solution at 0.75 A/cm^2 and 18 V for 5 min [7,8]. After this treatment, all of them were cleaned for 10 min in an ultrasonic bath in 96% ethanol. Then, a part of them were passivated to produce an additional intermediate surface layer between the NiTi alloy and the tantalum oxide layer (TABLE 1).

TABLE 1. NiTi substrate preparation alternatives.

No.	Passivation method
I	initial state - electropolished NiTi
II	digestion with Kroll's reagent and boiling for 2 hours in 30% H_2O_2

The Ta_2O_5 layer was obtained using $Ta(OC_2H_5)_5$ and water as precursors. The process was carried out in 400 cycles and 300°C [9]. At the end, such material was sterilized in an autoclave, to remove microorganisms. The adhesion of the layer to the substrate, wettability, surface tension and pitting corrosion resistance were investigated. Moreover, bacterial strains were used for microbiological studies.

Results and Discussion

The corrosion resistance results indicated that the material could be used for implants (FIG. 1). Before coating, each of the variants had very good corrosion resistance. After the layer was applied, the polarization resistance of all variants increased, but only in the case of perhydrol there was no breakthrough of the passive layer.

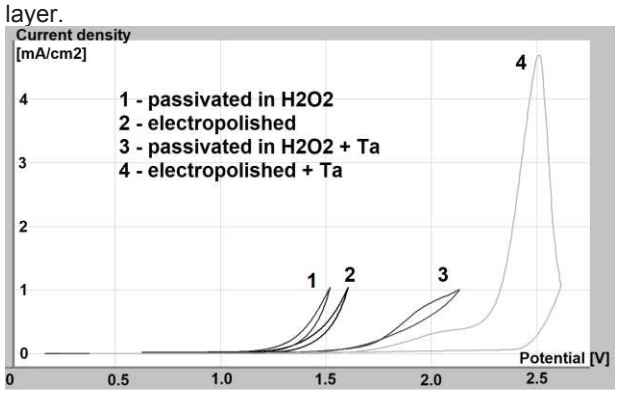

FIG. 1. The corrosion resistance of NiTi uncoated and coated by Ta_2O_5 layer.

Adhesion test data (TABLE 2) showed differences depending on the surface preparation.

TABLE 2. Results of Ta_2O_5 layer adhesion tests.

No.	Coating damage	F [N]
I	Delamination Lc2	20,73
	Complete break Lc3	27,27
II	Delamination Lc2	11,28
	Complete break Lc3	13,41

Surface wettability study concluded that the ALD coating reduces the wetting angle, making the surface more hydrophilic, which may have a negative effect on hemocompatibility. However, further biological studies are required. Also, the various effects of the layer on bacterial adhesion were confirmed.

Conclusions

The effect of surface preparation of NiTi alloy for implant application on the physicochemical properties of tantalum oxide layer applied by ALD method was investigated during this study. Differences in bacterial adhesion to NiTi alloy with and without Ta layer were observed.

Acknowledgments

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