Electrochemical behavior of metallic implants in inflammatory conditions

Aydin Bordbar Khiabani* and Michael Gasik

Department of Chemical and Metallurgical Engineering, School of Chemical Engineering, Aalto University, Espoo, Finland

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INTRODUCTION: This extensive study explores the significant impact of inflammation on the electrochemical corrosion of metallic implants, which can compromise their integrity and function, often leading to foreign body reactions. To mitigate these issues, the research introduces the promising Ti-Nb-Zr-Si (TNZS) alloy, 3D patterned Ti Gr2 and Ti Gr23 layers, alginate coating on 3D patterned Ti biomaterials, and Mn_3O_4 coating on anodized Ta.

EXPERIMENTAL: The TNZS alloy was synthesized by introducing Nb, Zr, and Si elements into titanium, while commercially purchased Ti2 and Ti23 alloys were utilized. Patterned layers were prepared on the flat counterparts of Ti2 and Ti23 using the LPBF by respective commercial powders. Alginate coatings with and without octacalcium phosphate (OCP) were developed on the patterned Ti layers. Electrophoretic deposition (EPD) was employed to apply Mn_3O_4 nanoparticles onto anodized tantalum. Electrochemical tests were conducted in a three-electrode system. Specimens were exposed to phosphate-buffered saline solutions, mimicking normal conditions or inflammatory environments by introducing H_2O_2, HCl, bovine serum albumin, and calcium L-lactate hydrate. Various electrochemical techniques, including open circuit potential, potentiodynamic polarization, and electrochemical impedance spectroscopy, were employed to assess corrosion behavior and passive layer stability.

RESULTS AND DISCUSSION: In this study, the newly developed TNZS alloy demonstrated superior corrosion resistance compared to Ti 2 and Ti23 under normal, inflammatory, and severe inflammatory conditions. The high corrosion resistance of TNZS was attributed to the presence of silicide phases in its microstructure, known for their exceptional stability in acidic environments containing H_2O_2 [1]. Furthermore, the study demonstrated that patterned Ti layers exhibit enhanced corrosion resistance in comparison to untreated flat Ti with a similar composition, owing to modifications in surface topography and wettability [2]. The application of alginate hydrogels, both with and without octacalcium phosphate (OCP), onto patterned Ti groups demonstrated enhanced corrosion resistance, particularly in biological media, with notable improvement when OCP was included. Despite a decrease in corrosion resistance during inflammatory conditions, the hydrogel coatings effectively shifted the corrosion potential to nobler values, reducing corrosion susceptibility in all conditions. The inclusion of OCP particles additionally enhanced electrical charge transfer resistance at the substrate-coating interface [3]. The findings further confirmed that the anodic/EPD coating displayed a denser microstructure and superior bond strength compared to the anodic coating, providing effective protection for tantalum against corrosion in acidic inflammatory conditions. Additionally, the Mn_3O_4 coating safeguarded Ta from H_2O_2 oxidant-mediated damage by preserving catalytic activity and suppressing reactive oxygen species ROS generation in an acidic pH environment [4].

CONCLUSIONS: In conclusion, the study emphasizes the importance of understanding the electrochemical behavior and corrosion resistance of biomaterials in inflammatory conditions, showcasing promising potential for advanced orthopedic implant materials.

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*Corresponding author E-mail: aydin.bordbarkhiabani@aalto.fi