Functionalization of the surface of a highly porous intervertebral implant produced by the additive method

Mgr inż. Ada Orłowska

Summary

The implementation of products manufactured using additive technologies for medical applications creates the need to develop methods to modify their surfaces to the specificity of the application. High-porosity spinal implants with Ti6Al4V provide better therapeutic effects due to the possibility of permanent bone connection. However, it is necessary to develop methods for surface modification to improve their interaction with the body.

The purpose of the study was to develop a hybrid method for modifying the surface of a highly porous intervertebral implant, which will improve implant functionality in the context of its short- and long-term interaction with the body. The work includes the development of sample forms that reflect the specificity of highly porous intervertebral implants, the verification of their properties after fabrication with SLM technology, and the development of modifications using electrochemical methods and biodegradable polymer coatings.

The samples were formed according to criteria determined on a basis of the review of the literature. The designed implant was characterized by an open structure and high porosity, ensuring the possibility of easy manipulation during implantation and a mechanical strength appropriate for the planned application.

The initial evaluation of the samples produced included tests aimed at determining the precision of the reproduction of the designed implant and its basic parameters, such as actual porosity, mechanical strength, and material structure. After positive evaluation, the samples were electrochemically modified using anodic oxidation (UA) and plasma electrolytic oxidation (PEO).

Electrochemical modifications were intended to create a stable oxide layer on the implant surface. Modified implants were evaluated in terms of homogeneity, surface topography and chemical composition, wettability, corrosive properties, and degradation under simulated tissue conditions. After the analysis of the results, samples after PEO were selected for further modifications, which were characterized by a hierarchical surface topography, which was enriched with Ca and P in the modification process, limited release of Ti, Al, and V into the simulated tissue environment, and stable corrosive properties.

In the next stage of modification, the PEO samples were covered with a coating of biodegradable polymer. Three types of coatings were used: chitosan (Cht) and chtitosan with the addition of berberine at low (ChtBBR low) and high (ChtBBR high) concentrations. The coatings were applied by immersion.

The polymer layers had a heterogeneous character resulting from the aggregation of the polymer in the cavities around the grains of the deposited powder, the presence of which resulted from the manufacturing technology used. Despite this, the coatings had a positive effect on the wettability of the implant surface, which after coating with polymer showed a hydrophilic character and significantly reduced the amount of metal ions penetrating the environment. The coatings were characterized by a long process of complete degradation >6 weeks, and variants enriched with the active substance with prolonged release of the substance into the environment. Cytotoxicity studies have shown a positive effect of the Cht and ChtBBR low layers on fibroblast cell viability. High concentrations of berberine showed toxic effects.

During the research, the most beneficial variant was found to be the one modified by plasma electrochemical oxidation with a chitosan coating without the addition of the active substance. The applied modification ensured a significant reduction in the amount of metal ions that penetrate the environment, a hydrophilic surface, and good conditions for cell proliferation.

The planned research plan was carried out in full. The results may contribute to the development of medical therapies for the cervical spine and will have a positive impact on the health and quality of life of patients.