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ROZPRAWA DOKTORSKA

Laserowe przetapianie proszków SLM w zastosowaniu na implanty ubytków żuchwy w oparciu o numeryczne badania przenoszenia obciążeń zgryzowych

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Abstract

The study aimed to develop a methodology for the personal design of extensive mandibular implants and their production from pure titanium using the additive method, for which selective laser melting (SLM) was chosen. The scope of research to verify the thesis of the study included developing a methodology for testing the transfer of occlusal loads in implant materials and the jaw by means of numerical simulations using the finite element method, optimizing the SLM selective laser melting process for the production of implants, and examining the impact of technological parameters on the material structure and properties. Simulation studies of the influence of modeling conditions on the load-bearing capacity of the implant were performed, and the support conditions and loads crucial for the transfer of occlusal loads were distinguished. The tests exhibited a significant underestimation of stresses if the bone union on the implant/mandibular surface was established. It has been proven that mandibular implants should be designed to exclude bone/implant adhesion so the stiffness of the bone screw fixation allows for displacement on the implant/bone surface within the permissible range, which determines the formation of bone union. Notably, the exclusion of support in the joint on the occlusal side, which is closer to physiology and creates more stringent criteria for assessing the load-bearing capacity and strength of the implant material, occurred to be more critical. It should be emphasized that the presented study proved that the currently worldwide used conditions for testing the load-bearing capacity of mandibular implants significantly underestimate the loads transferred by the implant and bone tissue and the risks of implant destruction. The work used advanced materials testing methods, which allowed for assessing the properties of pure titanium, whose chemical composition and structure depended on technological parameters. Sample testing applied on a macro scale and hardness testing on the microscale, X-ray tests of internal stresses, and tribological tests showed that pure titanium produced from powder using the SLM method exhibited different mechanical and corrosion properties depending on the direction of the laser beam. The study documented that the high mechanical properties with reduced ductility were related to the oxygen content, which depended on the time between successive laser beam passes. The dissertation indicates the need for further research on the use of oxygen reinforcement of titanium through better control of SLM technological parameters and optimization of heat treatment parameters. Based on micro-computed tomography examinations of the manufactured implant, it was found that the dimensional deviations were within the acceptable range and no oversized pores were detected.