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Abstract

Electropolishing of porous β-Ti21S implant: balancing mechanics and biocompatibility

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A porous β-Ti21S scaffold with a triply periodic minimal surface (TPMS) Gyroid and bowtie auxetic structure was designed and fabricated using via powder bed fusion (L-PBF) technology for potential application in total hip replacement prostheses. In a previous study [1], material and geometry were studied from mechanical and biological perspectives to enhance biocompatibility. However, a major challenge in additively manufactured (AM) metal implants is the presence of adhered, partially melted powder particles. These surface-adhered particles pose two critical issues: (1) they can detach post-implantation, triggering inflammatory reactions and bone resorption, potentially leading to implant loosening; and (2) they induce localized stress concentrations, which may initiate cracks under cyclic loading, thereby compromising the scaffold's fatigue performance [2]. To improve surface quality and eliminate residual powders, electropolishing was applied to both bulk and porous samples. Electropolishing removes material via an electrochemical reaction between an anodic workpiece and a cathodic electrode, with process parameters varying by material. Achieving uniform roughness in lattice structure L-PBF components is particularly challenging due to the intricate geometry and internal porosity of the implant. Furthermore, balancing mechanical and biological responses to surface roughness remains a key concern. Surface roughness has been associated with cell adhesion [3], proliferation [4], and differentiation [5], whereas smoother surfaces reduce notch effects and improve fatigue performance [6]. This issue is even more critical for porous additively manufactured structures, where cracks may originate from internal regions that are inaccessible to traditional polishing methods. This study aims to optimize electropolishing parameters to achieve an optimal surface roughness that balances mechanical durability and biological performance, thereby enhancing the applicability of porous titanium alloy scaffolds in bone tissue repair.

AUTHOR'S STATEMENT

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