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Abstract

Holistically tailored implants: Interactions between additively manufactured metallic implants and bio-printed tissue

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Within the framework of the DFG research unit 5250 "Mechanism-based characterization and modeling of permanent and bioresorbable implants with tailored functionality based on innovative in vivo, in vitro and in silico methods" an integrated solution for the manufacturing, characterization, and simulation-based design of additively manufactured (AM) medical implants is developed and validated. This solution considers the local physiological conditions of the hard tissue. Achieving this objective requires a comprehensive approach that combines interdisciplinary expertise in materials science and engineering, medical engineering, and numeric simulation. The interdisciplinary consortium implements innovative in vitro and in vivo testing methods to examine the mechanical, biological, and corrosive processes and their interactions.

The authors focus on the mechanical-corrosive behavior of permanent implants made of PBF-LB manufactured Ti6Al4V alloy with customized functionality. To address local bone structures and reduce stress-shielding, the stiffness of the implant-bone interface is adjusted using cellular, triply periodic minimal surface (TPMS) structures. The impact of cellular structuring on microstructure, defect formation, topography, and corresponding property profile is analyzed. Furthermore, a simultaneous instrumentation approach employing digital image correlation (DIC), acoustic emission (AE) analysis, and infrared thermography (IRT) is applied to assess PBF-LB manufactured TPMS structures of Ti6Al4V alloy. DIC and IRT are used to detect damage localization, while all measurement techniques, especially AE analysis, enable monitoring of the cascade-like damage evolution from strut to strut.

To extend this approach towards a holistic solution for wound treatment of hard and soft tissue, the existing concepts can be expanded by tissue engineering and bio-printing. Various studies exist on the fabrication of load-bearing and individually adjustable hydrogels [1], printable extracellular ink for wound healing [2], and planar skin layers using handheld printers [3]. Thus, treatment of damaged hard tissue by a pre-customized metallic implant and of damaged soft tissue by bio-printing in the surgical wound to promote wound healing would be possible. From a materials science point of view, it remains unanswered to what extent bio-printing affects the surfaces regarding corrosion, especially in the case of bioresorbable implants, and whether corrosion products or ions influence the process of supported wound healing.

AUTHOR'S STATEMENT

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