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Design and Fabrication of Stiffness Reduced Metallic Locking Compression Plates through Topology Optimization and Additive Manufacturing

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Abstract : Bone fixation implants currently used to treat traumatic fractured bones and to promote fracture healing are built with biocompatible metallic materials such as stainless steel, cobalt chromium and titanium and its alloys (e.g., CoCrMo and Ti6Al4V). The noticeable stiffness mismatch between current metallic implants and host bone associates with negative outcomes such as stress shielding which causes bone loss and implant loosening leading to deficient fracture treatment. This paper, part of a major research program to design the next generation of bone fixation implants, describes the combined use of three-dimensional (3D) topology optimization (TO) and additive manufacturing powder bed technology (Electron Beam Melting) to redesign and fabricate the plates based on the current standard one (i.e., locking compression plate). Topology optimization is applied with an objective function to maximize the stiffness and constraint by volume reductions (i.e., 25-75%) in order to obtain optimized implant designs with reduced stress shielding phenomenon, under different boundary conditions (i.e., tension, bending, torsion and combined loads). The stiffness of the original and optimised plates are assessed through a finite-element study. The TO results showed actual reduction in the stiffness for most of the plates due to the critical values of volume reduction. Additionally, the optimized plates fabricated using powder bed techniques proved that the integration between the TO and additive manufacturing presents the capability of producing stiff reduced plates with acceptable tolerances.

Keywords : additive manufacturing, locking compression plate, finite element, topology optimization
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