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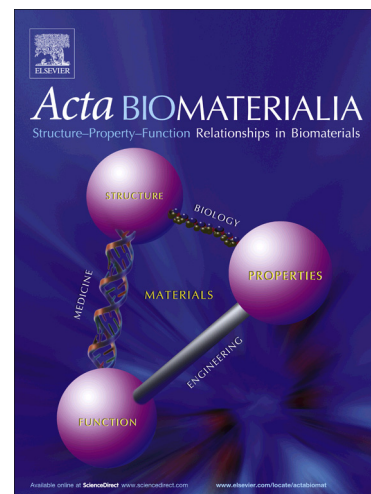
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Mechanical characterization of structurally porous biomaterials built via additive manufacturing: experiments, predictive models, and design maps for load-bearing bone replacement implants

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Abstract

Porous biomaterials can be additively manufactured with micro-architecture tailored to satisfy the stringent mechano-biological requirements imposed by bone replacement implants. In a previous investigation, we introduced structurally porous biomaterials, featuring strength five times stronger than commercially available porous materials, and confirmed their bone ingrowth capability in an *in-vivo* canine model. While encouraging, the manufactured biomaterials showed geometric mismatches between their internal porous architecture and that of its as-designed counterpart, as well as discrepancies between predicted and tested mechanical properties, issues not fully elucidated. In this work, we propose a systematic approach integrating computed tomography, mechanical testing, and statistical analysis of geometric imperfections to generate statistical based numerical models of high-strength additively manufactured porous biomaterials. The method is used to develop morphology and mechanical maps that illustrate the role played by pore size, porosity, strut thickness, and topology on the relations governing their elastic modulus and compressive yield strength. Overall, there are mismatches between the mechanical properties of ideal-geometry models and as-manufactured porous biomaterials with average errors of 49% and 41% respectively for compressive elastic modulus and yield strength. The proposed methodology gives more accurate predictions for the compressive stiffness and the compressive strength properties with a reduction of the average error to 11% and 7.6%. The implications of the results and the methodology here introduced are discussed in the relevant biomechanical and clinical context, with insight that highlights promises and limitations of additively manufactured porous biomaterials for load-bearing bone replacement implants.

Statement of significance

In this work, we perform mechanical characterization of load-bearing porous biomaterials for bone replacement over their entire design space. Results capture the shift in geometry and mechanical properties between as-designed and as-manufactured biomaterials induced by additive manufacturing. Characterization of this shift is crucial to ensure appropriate manufacturing of bone replacement implants that enable biological

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