Transactions on Additive Manufacturing Meets Medicine
Trans. AMMM, 2024, Vol. 6, No 1, Suppl. 1, Article ID 2074, 1 Page

Infinite Science Publishing

Abstract

3D printing functionally graded structures with different cellular architecture

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Functionally graded structures are widely observed in nature, including in bone, plants, bamboo and seashells [1]. Drawing inspiration from these biological systems, this study integrates thermoplastic polyurethane (TPU) with 3d printing techniques and varied cellular architectures (scaffolds) to examine their deformation behaviour under compressive loading, which will inform the design of soft tissue implants. To evaluate the mechanical properties of 3d-printed TPU scaffolds, this study investigates varying cellular architecture based on rectilinear and gyroid patterns. Building upon previous research [2], TPU-based scaffolds manufactured using the Flashforge Creator 3 Pro printer and TPU filament from Bilby 3D Pty Ltd, featuring a highly porous gyroid lattice were identified as a model for scaffolds that have a high flexibility requirement (e.g. breast implants).

In this study, functionally gradient structures of gyroid and rectilinear patterns with porosities of 90%, 94%, and 96% were explored and compared to their constant porosity counterparts. These porosities were incorporated into 18 groups (each group containing five specimens) formed by 2-graded and sandwich structures with different stacking sequences. 2-graded structures consist of two stacked porosity layers, whereas sandwich structures incorporate a high-porosity outer layer and a denser core. All samples underwent static compression (ASTM D1621) and fatigue testing (ASTM E606).

Results indicate that rectilinear 2-graded structures exhibit approximately a 38% increase in stiffness in their initial deformation region, while maintaining comparable stiffness in the later deformation, compared to their constant porosity counterpart. Also, rectilinear-gradient samples exhibited a decline during dynamic loads after 1000 cycles, while gyroid-gradient groups showed relatively stable performance in the fatigue test.

This research underscores the potential of integrating cellular architectures with functionally graded structures to optimize mechanical performance, paving the way for future advancements in medical applications.

AUTHOR'S STATEMENT
Authors state no conflict of interest. Animal models: n./a. Ethics approval: n/a. Research funding: This work was supported by the ARC ITTC for M3D Innovation at QUT (IC 180100008).

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DOI: 10.18416/AMMM.2024.24092074