




Abstract

Manufacturing Calcium Phosphates Scaffolds Using 3D-Printed Lost Molds[†]

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Bone tissue engineering (BTE) is centered around the fabrication of scaffolds for the active treatment of large, critical-sized bone defects. Consisting of porous structures of different sizes and shapes, scaffolds allow for cell attachment and growth, while stimulating tissue regeneration and supporting the applied mechanical loads. Scaffolds can be fabricated using different materials, such as metals, polymers and ceramics. Porous metal structures are difficult to manufacture and generate permanent rigid structures, which can lead to stress shielding. Biocompatible polymers can be used to manufacture porous scaffolds with controlled porosity and pore shape. While some polymers are resorbable, they can be difficult to fully metabolize after degradation. Their mechanical properties can be tailored, but a low porosity is required to achieve trabecular bone compatibility. Finally, ceramics are chemically and structurally similar to bone, and also display similar mechanical properties. However, they can be difficult to manufacture into porous structures with controlled porosity.

In this paper, an innovative method for producing ceramic scaffolds, with controlled porosity and pore shape, was developed. The lost molds of the scaffolds (10 × 10 × 5 and 10 × 10 × 10 mm) were initially 3D printed in PLA, using a fused filament fabrication (FFF) printer. The pore shape, dimensions and scaffold porosity were controlled using triply periodic minimal surfaces (TPMSs), including primitive and gyroid surfaces. Pore size ranged from 800 to 400 μm, and porosity from 40 to 60%. Scaffold properties can be uniform or graded according to the scaffold height. The pore shape of the scaffolds was also mixed, mimicking bone trabecular distribution. Both hydroxyapatite (HA) and β-tricalcium phosphate (β-TCP) suspensions were produced, and their rheological properties analyzed. When their properties were optimized, they were cast into the molds. In the third step, the molds were eliminated, and the scaffolds were sintered using an appropriate thermal cycle.

Scaffold characterization included porosity determination, using the Archimedes method, morphology analysis, and scanning electron microscopy (SEM), and the determination of mechanical properties, using compression testing. The produced scaffolds displayed properties that were compatible with trabecular bone replacement. These could

be tailored by controlling scaffold porosity and pore shape, including along the load application direction. This manufacturing process allows for pore shape and porosity control thanks to the nature of the TPMS structures.

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