Transactions on Additive Manufacturing Meets Medicine
Trans. AMMM, 2025, Vol. 7, No 1, Suppl. 1, Article ID 2158, 1 Page

Infinite Science Publishing

Abstract

Mechanical properties and biocompatibility of bioresorbable ceramic bone implants printed by lithography-based manufacturing

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Critical-sized bone defects often require surgical intervention due to their limited healing capacity. The use of autologous bone grafts for the treatment of these defects is still considered as gold standard in surgery. However, these grafts reveal different limitations underscoring the need for synthetic alternatives. Lithography-based ceramic manufacturing (LCM) offers the potential to fabricate patient-specific scaffolds with an optimized architecture that facilitates mechanical strength as well as an effective integration in terms of vascularization and the ingrowth of new bone from peri-implant tissue. Bioresorbable ceramics, such as hydroxyapatite (HA) and tricalcium phosphate (TCP) are considered to promote bone regeneration by mimicking native bone minerals, while degrading during new tissue formation. The aim of this study is to compare LCM printed bone constructs based on different materials (HA 480, TCP 300, Lithabone, Lithoz) and internal scaffold architectures, evaluating their mechanical properties and the cellular response of human mesenchymal stem cells (hMSCs) or the osteoinductive properties, which has not yet been reported. The study explores three distinct scaffold designs. Gyroid represents a shell-based, continuous minimal surface structure, while NaCl and Voronoi are beam-based architectures. Scaffolds with three distinct lattice structures and two pore sizes (1.6 mm and 1.16 mm) were printed via LCM (CeraFab, Lithoz; Vienna, Austria). The scaffolds were designed as cylinders (9 mm diameter, 3 mm height) with a uniform porosity of 50%. Mechanical compression testing (Zwick/Roell, Ulm, Germany) was conducted at a compression speed of 2 mm/min with a preload of 5 N. For biocompatibility testing of the scaffolds, hMSCs were seeded at a density of 2×10^6 cells/scaffold and cultured for 14 days followed by analyzing the cell response using different methods. Scaffolds with a NaCl structure and a pore size of 1.6 mm exhibited the highest compressive strength (HA480: 3053 +/- 827 N; TCP300: 3107 +/- 2303 N) independent of the material and in agreement with the increased wall thickness of this scaffold design. Scanning electron microscopy (SEM) revealed material-dependent differences in surface microstructure of the scaffolds. HA480 exhibited a slightly smoother surface structure compared to TCP300, which may influence cellular adhesion along with other material related factors, such as the calcium phosphate crystalline structure. After 14 days, viability staining confirmed a high cellular viability and confluent colonization of all scaffold types by hMSCs. First results from DNA quantification to quantify the cell numbers on the different scaffold types indicated comparable cell numbers after 14 days. Osteogenic differentiation was assessed via staining for calcium deposition (OsteoImage™) and PCR analysis of osteogenic markers (collagen type 1, alkaline phosphatase and osteocalcin).

AUTHOR'S STATEMENT

Authors state no conflict of interest./ Informed consent: Informed consent has been obtained from all individuals included in this study./ Ethical approval: The research related to human use complies with all the relevant national regulations, institutional policies and was performed in accordance with the tenets of the Helsinki Declaration, and has been approved by the local ethical advisory board of the university medical center in Kiel (Approval number - D459/13) and included the consent of the individual donors./ Research funding: This work was supported by WIR!-BlueHealthTech- BlueBioPol FKZ 03WIR6207A.

DOI: 10.18416/AMMM.2025.25062158