Student Speech Contest 2025

Bioinspired Triply Periodic Minimal Surface (TPMS) Calcium Phosphate Scaffolds for Bone Tissue Regeneration

Name of the student. Giulia Verlato

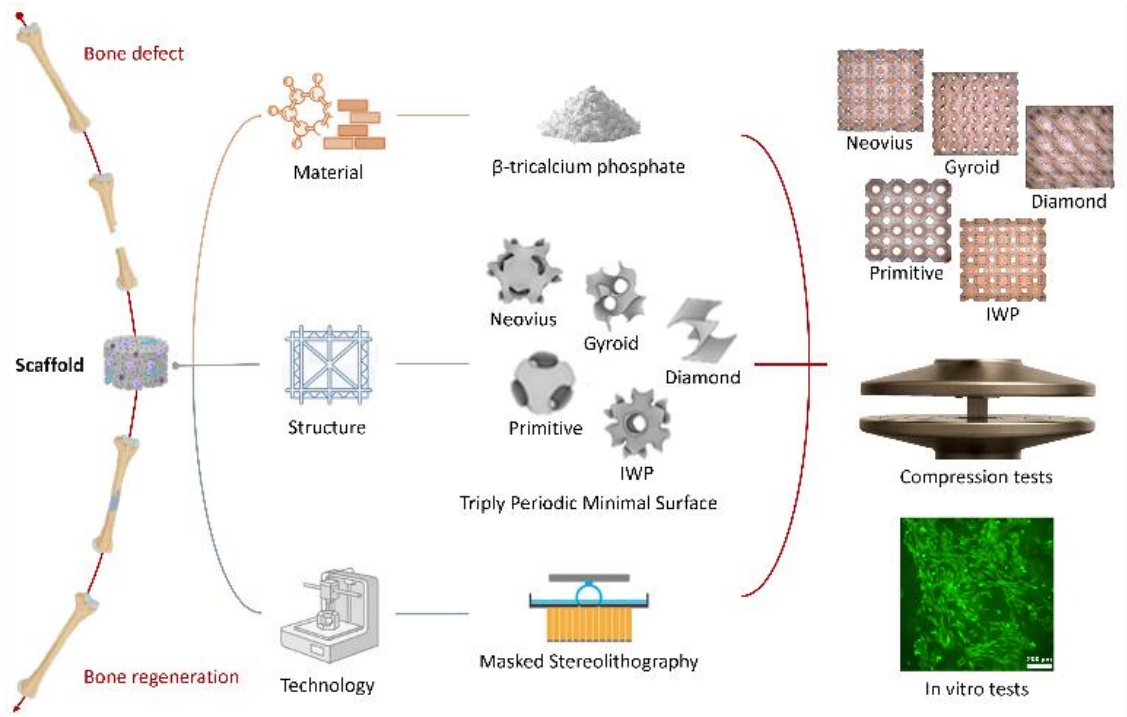
Contact mail. giulia.verlato.1@phd.unipd.it

Institution(s) / lab. University of Padova, Department of Industrial Engineering, CERAMGLASS group

Project. Advanced additive manufacturing of hydroxyapatite and tricalcium phosphate bioceramics of triply periodic minimal surface (TPMS) porous structures for bone tissue engineering

Topic / keyword. TPMS, tricalcium phosphate, stereolithography, bone tissue engineering

Abstract.



Bone defects resulting from trauma or age-related conditions such as osteoporosis present a significant and increasing clinical challenge. Although autologous bone grafts remain the clinical gold standard, their application is constrained by donor site morbidity and limited tissue availability. This study proposes a bioinspired synthetic alternative: calcium phosphate scaffolds with triply periodic minimal surface (TPMS) architectures, fabricated using high-resolution masked stereolithography (mSLA). Five TPMS geometries (Neovius, Gyroid, Diamond, Primitive, and IWP) were designed and 3D printed in β-tricalcium phosphate (β-TCP), followed by sintering. Structural and mechanical properties were evaluated via scanning electron microscopy (SEM), X-ray diffraction (XRD), helium pycnometry and uniaxial compression testing. Among the tested architectures, Neovius demonstrated the most favorable mechanical performance and was selected for further optimization. Critical fabrication parameters (including sintering temperature, UV exposure duration, designed porosity and unit cell size) were systematically varied. Optimal conditions yielded scaffolds with approximately 6 MPa compressive strength at ~80% porosity. Neovius scaffolds were also fabricated in hydroxyapatite (HA) and β-TCP/HA composites. Pure β- TCP scaffolds exhibited superior mechanical stability. Biocompatibility was assessed in vitro using Live/Dead assays with human adipose-derived stem cells (hADSCs), revealing robust cell viability and proliferation, with Neovius outperforming Primitive in the early-stage cellular response. These results demonstrate the promise of β-TCP Neovius scaffolds, optimized via mSLA, as mechanically competent and cytocompatible constructs for bone tissue regeneration.

References.

Paredes C, Martínez-Vázquez F, Elsayed H, Colombo P, Pajares A, Miranda P. Evaluation of direct light processing for the fabrication of bioactive ceramic scaffolds: Effect of pore/strut size on manufacturability and mechanical performance. *Journal of the European Ceramic Society*. 2021;41:892-900. doi:10.1016/j.jeurceramsoc.2020.09.002.

Barba D, Alabort E, Reed RC. Synthetic bone: Design by additive manufacturing. *Acta Biomater*. 2019;97:637-656. doi:10.1016/j.actbio.2019.07.049

Bouakaz I, Sadeghian Dehkord E, Meille S, Schrijnemakers A, Boschini F, Preux N, Hocquet S, Geris L, Nolens G, Grossin D, Dupret-Bories A. 3D printed triply periodic minimal surfaces calcium phosphate bone substitute: The effect of porosity design on mechanical properties. *Ceramics International*. 2023;50. doi:10.1016/j.ceramint.2023.10.238.