Student Speech Contest 2025

DLP printing reactive scaffolds for bone regeneration

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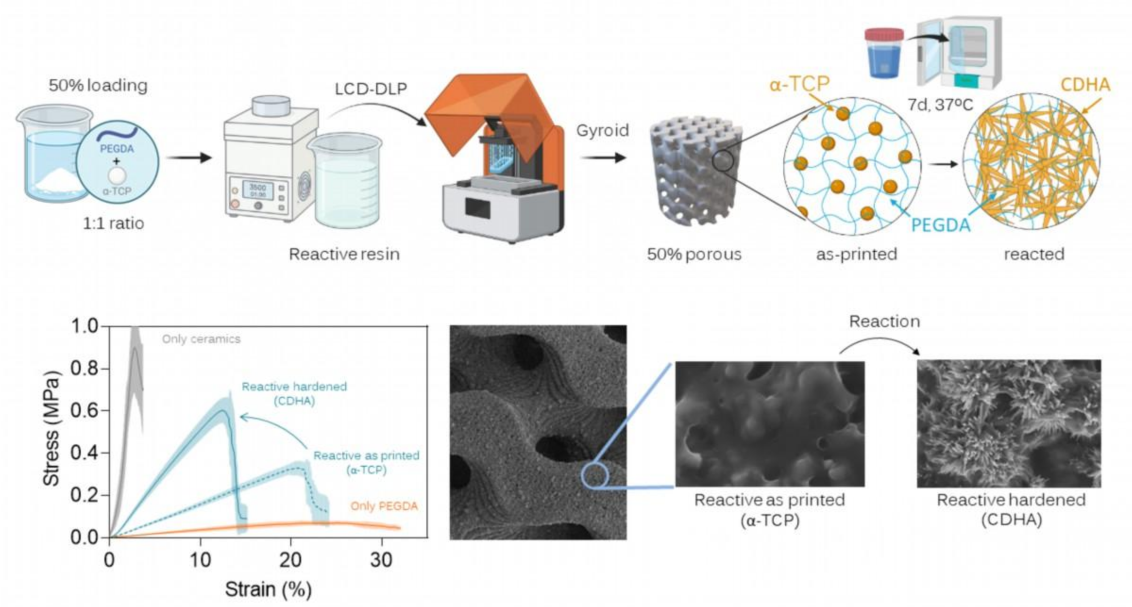
Project. BAMBBI: Bio-inspired AntiMicrobial Bone BIoceramics. Deciphering contact-based biocidal mechanisms

Topic / keyword. Digital light processing, calcium deficient hydroxyapatite, composite.

Abstract.



Roughly 2 billion people suffer muskuloskeletal diseases annually, implying a high amount of bone grafting procedures which is fast pacing growing in demand. Among the different families of bone grafts, synthetic bone grafts are the fastest growing group, using artificially produced materials. Additive manufacturing (AM) has been growin in popularity for the fabrication of synthetic bone grafts, as it can create grafts personalized for each patient's needs. Recently, Digital Light Processing (DLP) printing has emerged as an affordable AM technique that enables the fabrication of hierarchical and complex structures that closely mimic natural bone compared to other techniques. Throughout the literature, ceramic DLP printing, which entails loading liquid resins with ceramic fillers, frequently require high-temperature post-processing leading to brittle ceramic bodies and dimensional changes that jeopardize the surgical procedures. On the other hand, few research has been carried to create composite structures consisting of biocompatible polymeric frameworks reinforced with ceramic particles. However, the latter structures often consist in dispersed ceramic particles, limitting their reinforcement.

This study introduces a novel approach to obtain interpenetrating composites, giving continuity in both ceramic and polymer phases. To achieve so, a novel composite biocompatible and photocurable resin has been formulated introducing reactive α-tricalcium phosphate (α-TCP) particles to a Polyethylene Glycol diacrylate (PEGDA)-based resin, confering the novel composite grafts the ability to enhance the structure reinforcement by self-reacting and transforming into nanocrystals of calcium deficient hydroxyapatite (CDHA) post-printing. This transformation to CDHA creates high-aspect ratio nanometric crystals that intertwine between each other, enabling the mechanical interlocking of the obtained nanotopography of CDHA crystals. This reaction, obtained after the printing process, gives synergistic effects with the polymer framework, capable of tuning their mechanical properties and also mimicking the composition of natural bone by obtaining a bioactive surface that enhances the cellular response and, potentially, the clinical outcome when compared to traditional DLP-printed grafts. This approach combines the high resolution of DLP with the capability of in situ transformation of α-TCP to CDHA in photopolymerizable systems. Furthermore, the ability to tune the scaffold's mechanical properties over time, rendering them manageable as-printed and potentially hardening after implantation under physiological conditions, combined with the capability of creating intricate and complex structures, provides an additional advantage, allowing for the optimization to meet the specific clinical needs.