ABSTRACT – Student Speech Contest

Photocuring-Assisted Extrusion Printing of Calcium Phosphate Tooth Root Scaffolds: From Ink Formulation to Process Optimization

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Traumatic dental injuries (TDIs) affect approximately 20% of children and adolescents, potentially leading to permanent tooth loss. Conventional dental implants are unsuitable for growing patients due to ongoing dentoalveolar development, highlighting the need for regenerative alternatives. Calcium phosphate (CaP) bioceramics, including β-tricalcium phosphate (β-TCP), hydroxyapatite (HAp), and their biphasic combinations (BCP), are promising candidates for tooth root regeneration due to their compositional similarity to natural mineralized tissues.

Photocuring-assisted extrusion printing, also known as UV-assisted direct ink writing (UV-DIW), enables the fabrication of patient-specific ceramic scaffolds with controlled geometries. However, successful printing requires careful optimization of ink rheology to ensure smooth extrusion, sufficient shape retention after deposition, and adequate interlayer adhesion. Furthermore, printing parameters and subsequent thermal processing must be optimized to minimize defects and achieve high densification and mechanical performance.

In this work, UV-curable CaP inks were developed using acrylate-based monomers, a dispersant, and a photoinitiator. The effects of ceramic composition, solid loading, and dispersant concentration on ink properties were investigated through rheological characterization and zeta potential measurements. Printing parameters were systematically optimized using a design-of-experiments (DoE) approach, while composition-specific sintering cycles were established to promote densification while limiting grain growth and undesirable phase transformations. Micro-computed tomography (micro-CT) was employed to assess dimensional accuracy and internal defects, while uniaxial compression testing was performed to evaluate the mechanical performance of the sintered scaffolds.

The optimized formulations exhibited pronounced shear-thinning behavior and suitable viscoelastic properties, enabling stable extrusion and high-fidelity printing. Micro-CT analysis revealed that printing architecture strongly influenced internal defect formation. In particular, alternating raster orientations reduced printing-induced defects and improved mechanical reliability. These findings highlight the importance of integrating ink formulation, printing strategy, and thermal processing to manufacture mechanically robust CaP scaffolds, providing a foundation for patient-specific tooth root regeneration.