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Rheology and Printability of UV-Assisted Direct Ink Writing Calcium Phosphate Inks

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Traumatic dental injuries (TDIs) affect approximately 20% of children and adolescents, posing significant clinical challenges. Current treatment options, such as tooth autotransplantation and orthodontic alignment, are constrained by limited donor tooth availability, compatibility issues, and the risk of root resorption, while osseointegrated titanium implants are not suitable for growing patients due to ongoing dentoalveolar development. A bioengineered, patient-specific dental root scaffold via additive manufacturing and bioceramics presents a promising solution.

Calcium phosphates (CaP) are widely used in mineralized tissue regeneration due to their structural resemblance to dentin and bone. This study focuses on developing β-tricalcium phosphate and hydroxyapatite-based inks for UV-assisted direct ink writing (DIW), a technique that enhances mechanical integrity and printing precision while minimizing warping and cracking during drying. To improve the printing process, we investigated the rheological properties and printability of these inks, analyzing the effects of solid loading, dispersants, and key printing parameters (nozzle size, pressure, velocity, layer height, and line spacing).

Effective DIW relies on key rheological properties, including shear-thinning behavior for continuous extrusion and reduced nozzle blockage, and shape retention after deposition, where the material transitions from a viscous liquid to an elastic solid. Yield stress, critical for preserving a structure's shape and stability, was assessed using shear stress-strain diagrams to identify the flow point—the transition between solid-like and liquid-like behavior. Viscosity was analyzed through flow-sweep tests, while suspension stability was evaluated using zeta potential measurements. Simple line patterns were printed and analyzed using an optical microscope to assess printability, while nano-focus computed tomography (nano-CT) was used to evaluate dimensional accuracy and defect formation during printing and post-processing.

This study provides valuable insights into the formulation and processing of CaP-based inks for UV-assisted DIW, paving the way for the development of bioengineered dental root scaffolds with enhanced structural integrity, precision, and clinical applicability. By optimizing ink composition and printing parameters, this study establishes a foundation for improving scaffold performance and ultimately advancing regenerative dental therapies for growing patients.

Keywords: β – tricalcium phosphate, Hydroxyapatite, Rheology & Printability, UV-Assisted DIW, Tooth root regeneration