Development of a 3D-printable PMMA-based bone cement composition

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Introduction: Polymethyl methacrylate (PMMA) bone cement is widely used in orthopedic surgery for implant fixation, local drug delivery and defect filling. However, all commercially available bone cement requires manual mixing in the OR, which can lead to inconsistencies in material properties and surgical outcomes. In this study, a 3D-printable PMMA-based bone cement composition was developed and mechanically tested to enable precise, automated fabrication of bone cement structures.

Methods: To prepare the 3D printable PMMA bone cement, first a photocurable monomer base mixture was prepared using 6 g of Ethoxylated bisphenol A dimethacrylate and 4 g of methyl methacrylate. Then, 12 g of 350000 mw PMMA powder was added to this monomer mixture and mixed thoroughly. Compression test cylinders (1 cm x 0.5 cm, 6 per group) were 3D printed using this formulation and subjected to compression mechanical testing at 1 mm/min until failure. The 3D printed specimens with just the monomer base mixture served as a control group.

Results: Cylindrical test specimens were successfully fabricated using 3D printing from both the pure monomer base and a composite containing PMMA and the monomer base. For PMMA, the compression modulus was 1.2 GPa and the compressive strength was 80 MPa. The monomer base had a compression modulus of 1.34 GPa and a compressive strength of 70 MPa.

Discussion: We present a proof-of-concept demonstrating that PMMA bone cement can be produced via 3D printing. The photocurable resin contained 72 wt % PMMA constituents—a blend of PMMA powder and liquid methyl methacrylate (MMA). Due to the absence of a reliable photoinitiator for pure MMA, ethoxylated bisphenol A dimethacrylate (Bis-EMA), a component common in dental resins, was incorporated into the monomer system to enable vat photopolymerization. Although further formulation work is needed to integrate radiopaque fillers, the printed constructs retained mechanical integrity comparable to conventional PMMA, suggesting potential applications in customized orthopedic implants and patient-specific surgical planning.