3D Photopolymerization Printing of UV-Transparent Molds for Crosslinking Silk Fibroin Biocomposite Prototype Constructs

Srikar Samavedam, BSE Biomedical Engineering
Mentors: [1]Vincent Pizziconi, PhD and [2]Erwin Kruger, MD
[1]School of Biological and Health Systems Engineering (SBHSE), [2]Mayo Clinic

Introduction

- The demand for non-metallic internal fixation devices, such as bone screws, plates, and pins, is rising due to the need to reduce complications associated with metallic implants, such as infection, corrosion, and mechanical failure, and to eliminate removal surgeries, ultimately improving patient outcomes.
- This approach utilizes stereolithography (SLA) 3D printing to photopolymerize clear resins, enabling precise fabrication of complex 3D net-shaped, UV-transparent molds.
- These molds are designed to crosslink synthetic and natural polymers, forming a key component of a non-metallic, polymer-ceramic biocomposite implant.
- **Research Objective:**
    - Design and 3D print a UV-transparent mold using photo-crosslinkable resin, intended to serve as a casting mold for crosslinking biopolymers, such as, silk fibroin, which will ultimately be used in prototyping non-metallic, regenerative surgical bioware.

Methods

Formlabs 2 3D Printer

- The Formlabs Form 2 workflow starts by creating a precise 3D model in SolidWorks, then importing it into PreForm software for slicing and support generation. Printing occurs layer-by-layer with a laser curing each resin layer, followed by post-processing in IPA, UV curing, and finishing for a polished surface.


Fig 3b. Post-processing in IPA


Fig 3a. Cure Box (UV light- (365-405 nm)

Photocrosslinking

- Photocrosslinking typically uses UV light (100-400 nm) to activate a photoinitiator that generates reactive species, forming covalent bonds between polymer chains to create a solid, crosslinked polymer network with enhanced strength and stability.
- A 3D model is used to print a clear resin mold with threads on the Formlabs 2 printer (Fig. 1). Post-processing includes IPA washing to remove uncured resin, UV curing for strength, support removal, and minor finishing for a polished surface (Fig. 3b), followed by additional photocuring in a Cure box (Fig. 3a) for 2 to 4 hours, with checks every 30 minutes. After cooling, the crosslinked mold is removed and used for photocrosslinking methacrylated silk fibroin biopolymer prototypes.

Experimental Results


Fig 1. Formlabs 2 3D Printer


Fig 2. Components of Formlabs 2 3D Printer


Figure 4. Design of Clear Resin Mold with Screw Threads


Fig 5. Initial Photocrosslinked 3D Wax Resin in Glass Tube Mold (30 min)


Fig 6. Fully Cured Wax Mold Crosslinked under UV light (365nm & 400nm)


Fig 7. UV transparent mold containing 3D wax resin before curing


Fig 8. Post-cured mold after 2 hours


Fig 9. Initial mold with 3D wax resin before curing (4 hours)


Fig 10. Post-cured mold after 4 hours

Conclusion

The objective of this project was to design and 3D print a photocrosslinkable resin mold for casting photocrosslinked silk fibroin, contributing to the development of a non-metallic, bone fixation prototype for regenerative surgical bioware. This research addresses promising approaches for the development of alternative implant fixation device to metallic implants which often lead to complications such as infection, corrosion, and the necessity for secondary removal surgeries.

Utilizing stereolithography (SLA) 3D printing with photopolymerizable wax and clear resins, 3D UV transparent molds were created with smooth, detailed surfaces, ideal for casting applications. The curing process relied on UV light (365nm,405nm) to activate the photoinitiator within the wax resin, following a four-hour curing protocol with checks every 30 minutes to ensure even polymerization. Observations of blue residue in some instances suggest potential for further refinement in curing consistency.

Preliminary findings support the effectiveness of SLA-printed molds for silk fibroin casting and provide a solid base for advanced, non-metallic, biocomposite prototype development. This may include silk fibroin-hydroxyapatite (HA) composite prototype designs for enhanced mechanical properties. Future improvements will focus on optimizing mold design for efficient part removal, testing alternative release agents, modifying cure time, and conducting mechanical testing on silk fibroin and silk-fibroin-HA constructs to assess their suitability for regenerative orthopedic applications.

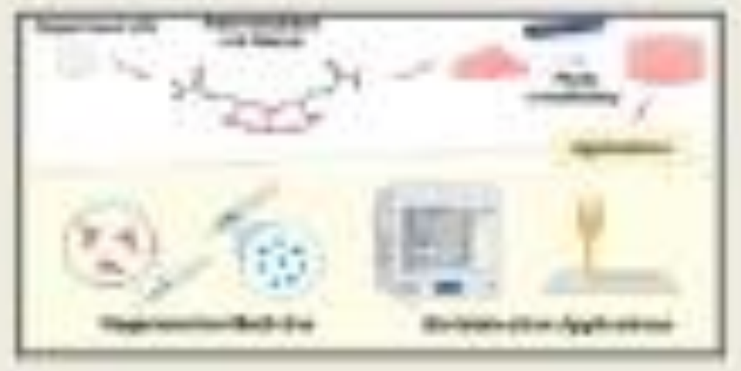
Fig 11: Overview of Final 3D Biofabrication Process [1]

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