Optimizing 3D Printed Scaffolds for Immune-Protected Cell Therapy

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BACKGROUND

- SLA/DLP: Precise, layer-by-layer printing for complex biomedical devices (Yang et al., 2018; Vedhanayagam et al., 2023)
- Materials: Customizable for pore size, strength, and degradation (Yang et al., 2018; Bukhari et al., 2025)
- Stimuli-responsive: Suitable for implantable devices (Bukhari et al., 2025)
- Injectable device with scaffold for cell protection and nutrient exchange (Bose, 2020)
- Proven in mice: Supports human cells and rat islets (Bose, 2020)
- Previous devices: Used hydrogels, nanofibrous membranes, and zwitterionic coatings for reduced scar tissue and safe cell containment (Liu et al., 2021; Wang et al., 2021)

RESEARCH QUESTION

How can the design of 3D printed scaffolds — including fiber spacing, pore size, and pattern — be improved to support better cell growth, enhance nutrient flow, and provide protection from the immune system?

OBJECTIVES

- Design scaffold: Biocompatible with fiber thickness (50–200 μm) and pore size (100–300 μm) for immune isolation and mass transport
- Optimize parameters: Adjust exposure time, bottom layer count, etc., for efficient processing of biomaterials like PEGDA

METHODS

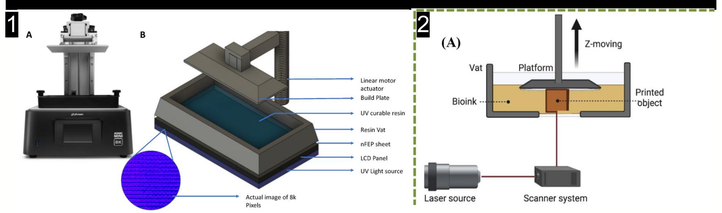

Figure 1. SLA Resin-based 3D printing system overview. (1A) Phrozen Sonic Mini 8K 3D Printer. (1B) Key parts of the SLA 3D printing system. (2A) Schematic of SLA printing process.

LIGHT MICROSCOPE RESULTS

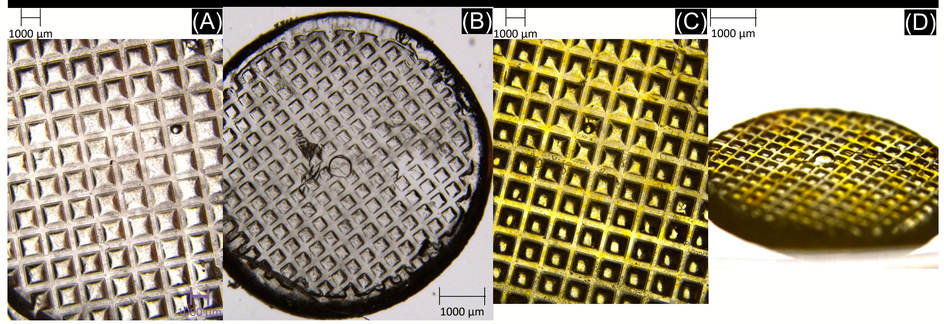

Figure 2. Dye (TPO) enhances printing resolution in scaffolds. Light microscopy images comparing scaffold print quality with and without dye under identical printing conditions. (A) Undyed scaffold, scaled-up geometry, 5 s exposure time with 4 bottom layers. (B) Undyed scaffold, small-scale geometry, 5 s exposure time with 4 bottom layers. (C) Dyed scaffold (TPO), scaled-up geometry, 5 s exposure time with 4 bottom layers. (D) Dyed scaffold (TPO), small-scale geometry, 5 s exposure time with 4 bottom layers.

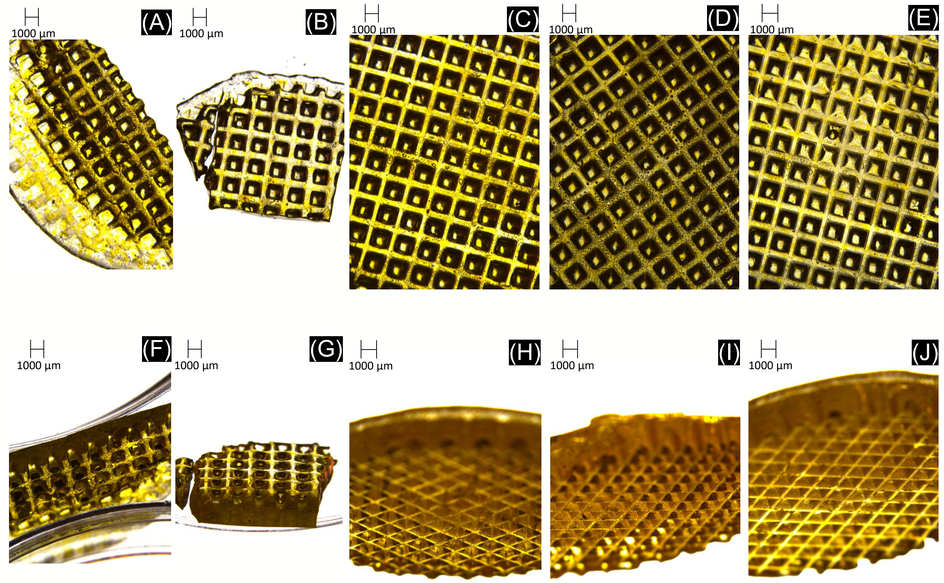

Figure 3. Effect of photoabsorber (TPO) dye and exposure time on scaffold print resolution and durability. Light microscopy images of dyed (TPO) scaffolds printed with four bottom layers at increasing exposure times. (A–E) Top-view images of scaled geometries at exposure times of 0.5, 1, 2, 3, and 5 s, respectively. (F–J) Corresponding cross-sectional views at 0.5, 1, 2, 3, and 5 s exposure times. Increasing exposure time improves structural integrity and feature resolution in dyed scaffolds.

DISCUSSION & OUTLOOK

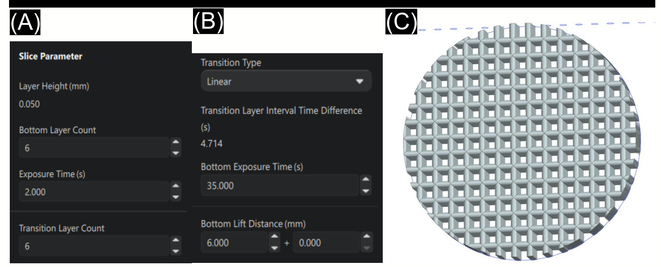

Figure 4. Optimization of 3D printing parameters and scaffold design workflow using ChituBox and Siemens NX. (A–B) Key 3D printing parameters optimized to achieve high print resolution and scalability. (C) Original 3D scaffold model design.

- Overall scaffold design is possible and best optimized at 2 seconds of exposure time with 4 bottom layers
- Scaffolds need to incorporate UV blocking dye to prevent overcuring and enhance printing resolution

Future Steps:

- Modify parameters to maintain high resolution for other biomaterials like PCL, PLA, or polystyrene
- Test different UV blocking dye concentrations to find the right balance between curing and maintaining open pores
- Conduct in vitro testing with HEK 293T cells to confirm cell adhesion and cell viability
- Perform tensile testing for scaffold durability and degradation over time
- Conduct in vivo testing in animal models to confirm biocompatibility and cell growth

REFERENCES

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