Developing bioinks for commercial mSLA printers and a method for quantifying print quality

Chau-Minh Phan,[1,2] David Wulff,[1,2] Lyndon Jones[1,2]

[1]Centre for Ocular Research & Education, School of Optometry & Vision Science, University of Waterloo, Canada
[2]Centre for Eye and Vision Research (CEVR), 17W Hong Kong Science Park, Hong Kong

Introduction

- 3D printers capable of printing hydrogel materials are prohibitively expensive, slow, and not scalable for large-scale fabrication.
- Traditional 3D printing uses an extrusion-based approach in which materials are ejected from a nozzle tip, but this process is extremely slow.[1]
- Masked SLA (mSLA) 3D printers use light to photo-polymerize materials layer-by-layer at a time, creating high resolution prints in less time.[1]
- It may be possible to use mSLA 3D printers for printing photopolymerizable hydrogel materials.

Purpose

- To develop bioinks for commercial mSLA printers to produce high-quality prints and methods for assessing print quality.

Methods

- Bioink formulations consisted of 10% GelMa (gelatin methacrylate),[2] LAP (Lithium phenyl-2,4,6-trimethylbenzoylphosphinate), and a yellow food-grade dye (to minimize unwanted light leakage).
- A commercial mSLA (masked stereolithography) printer, the Photon Mono X (AnyCubic, Shenzhen), was retrofitted with a custom temperature and humidity control kit.
- Printing process was performed at 40ºC and 90% humidity to ensure that the GelMa remained in a liquid state.
- A set of matrix cubes of varying sizes with holes was printed and used as a standard control for comparing different formulations.
- Images of the cubes were taken with a camera, top-down and side-review, analyzed with the ImageJ software and compared with the original CAD designs to derive an overall print quality score.
- Two print variables, exposure time (5 s to 40 s) and yellow dye concentration (1 – 7%), were analyzed in this study.

Results

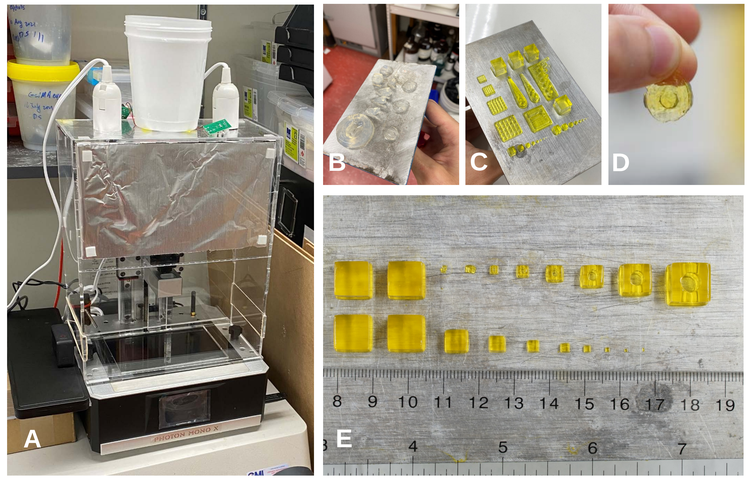

Figure 1 A Retro-fitted mSLA 3D printer with humidity and temperature control. **B** A sample 3D print without yellow dye and **C** with a yellow dye. **D** a model 3D printed contact lens. **E** A set of 3D-printed matrix cubes standards used to assess the quality of different bioinks.

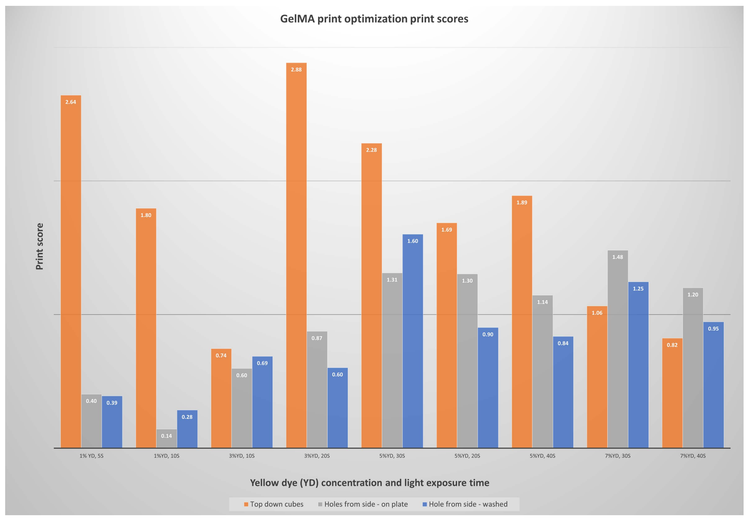

Figure 2 Print scores of the standard cubes for different yellow dye concentrations and exposure times

- Additionof the dye was critical to producing high-resolution prints. In the absence of dye, the printed cubes had edge deformations or did not properly resolve internal structures
- Best resolution with the highest print scores were obtained at either 5% yellow dye concentration and 30 seconds exposure time, or 3% yellow dye concentration and 20 seconds exposure time.
- A prototype contact lens with a 200 µm thickness was able to be 3D printed using the developed print methods and parameters, with a total print time of approximately 20 minutes.
- However, print designs with a very low surface area at the base (such as a contact lens) have a high rate of failure due to the prints falling off the print plate during the printing process.
- The yellow dye can be removed post-printing by washing the print in phosphate buffered saline or by bleaching with UV light.

Conclusions

- The current study demonstrated that a low-cost commercial 3D mSLA printer could be used with bioinks for 3D bioprinting.
- Further work is necessary to improve the print resolution and reliability.
- We hypothesize that each different bioink formulation will require different print parameters, so a standardized process to assess print quality, could immensely facilitate the optimization process.
- Future work will optimize this 3D printing method with other polymers.

References

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 Email contact for correspondence: c2phan@uwaterloo.ca