Supplementary Information - PISA Printing Perfusable Microcapillaries

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Additional Experimental Procedures

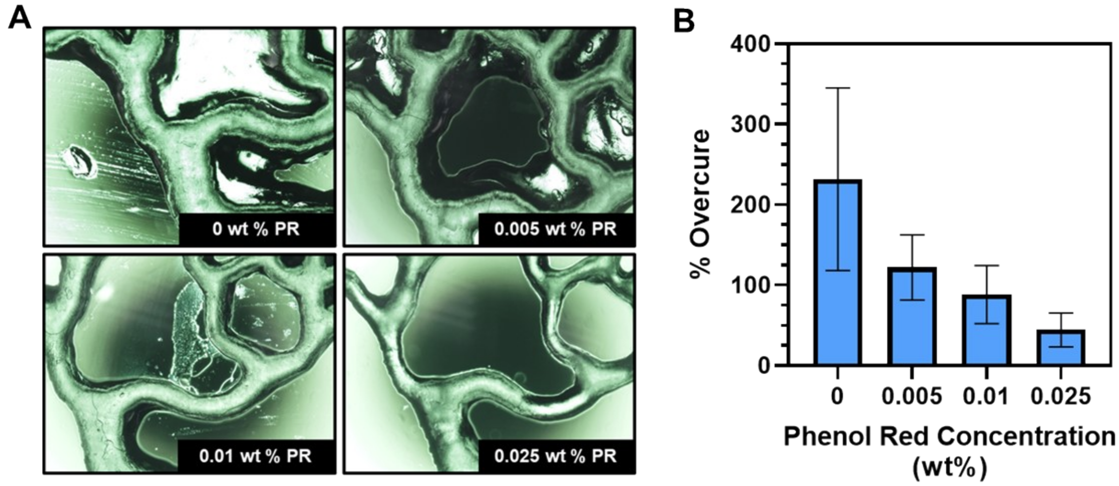
Direct PISA printing of hollow channel capillaries. In this study, perfusable microchannels were attempted to be printed directly by using CAD file designs with hollow channels built into the part. To do this, the DAAM resin was prepared as described in the experimental procedure and was printed using normal exposure times of 20 s per layer for 50 um thick layers on the Phrozen Sonic Mini 8KS DLP printer. To try and minimize exposure times or reduced light scattering to avoid overcure into the channels, LAP concentration was varied from 0.75 wt. % - 1.25 wt. % with respect to solids at a fixed phenol red concentration of 0.015 wt. %. Alternatively, phenol red concentration was varied from 0.015 – 0.025 wt. % with respect to solids at a fixed LAP concentration of 0.085 wt. %. Again, the intended goal was to either reduce cure time or minimize light scatter to avoid overcuring into the parts.

Results and Discussion

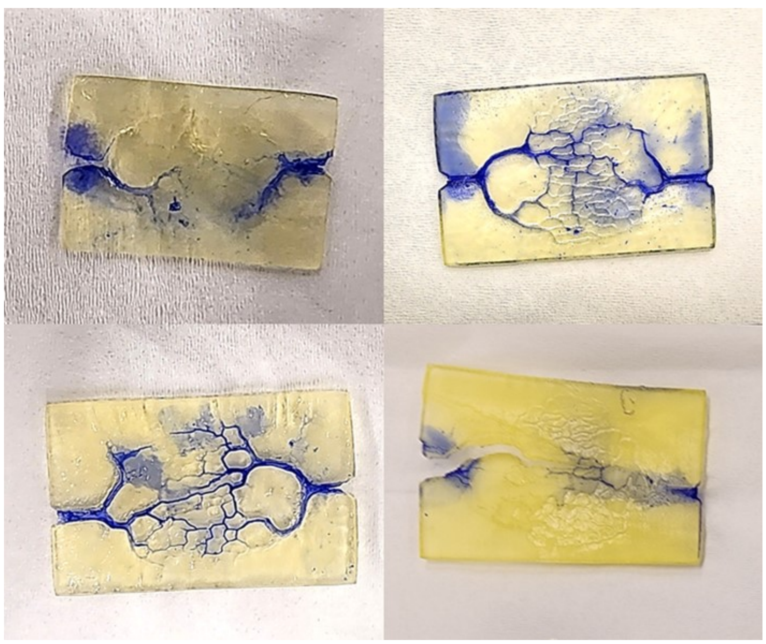
Results for photoabsorber / resolution trials are shown in ESI Figure 1. As shown in the optical images (ESI Figure 1A) and corresponding overcuring data (ESI Figure 1B) as determined by ImageJ* analysis, the features became smoother, tighter and more defined. In the images, it can be observed that the overcuring that occurred between blood vessels branches or filaments (ESI Figure 1A, top-left) for no photoabsorber was noticeably absent at the highest photoabsorber concentrations (ESI Figure 1A, bottom-right). ImageJ* analysis (ESI Figure 1B) showed a nearly seven-fold decrease in the % degree of overcuring from 0 wt. % photoabsorber to the high concentration of 0.025 wt. % (down to ~30 % overcure). This shows it is essential to have a sufficient amount of photoabsorber in the resins to promote fine feature sizes and small part designs.

Results for direct PISA printing of hollow microchannels is shown in ESI Figure 2. This composite image shows various attempts at the direct printing method, displaying the lack of perfusability of the part. While some dye solution made it through a few select channels, most of the channels were blocked due to backfill and curing of the resin into the channels during the DLP printing process. Using a combination of the high photoinitiator concentration (1.25 wt. %) and modest photoabsorber concentration (0.015 wt. %), cure times were able to be reduced to just 15 s per layer. However, this was still not enough to prevent overcure into those regions. Still, the fact that some dyed liquid did find pathways through the parts indicates that a more optimal design or combination of printing parameter may make the direct printing method possible going forward.

**ImageJ analysis was performed using the scale bars of images that were obtained from an Olympus light microscope. The scale bars were used as a reference to set the scale (in microns) of the image based on number of pixels for a given length of line in the software. Nearly 100 lines were drawn across the cured diameters of the vessels in similar regions across the different compositions (varying photoabsorber concentration) resins. This was compared to the corresponding theoretical diameter in reach region to determine a degree of overcuring or % overcuring in comparison. This was done for each photoabsorber concentration.*



ESI Figure 1. Results of phenol red photoabsorber studies. (A) Light microscope images of printed blood vessels at different photoabsorber concentrations. As observed, the visible overcuring shown with no photoabsorber (top,left) was noticeably absent at the highest photoabsorber concentration (bottom,right). The blood vessels features were also smoother and more clearly defined. (B) Degree of overcuring as a function of photoabsorber concentration as determined using optical images and ImageJ analysis. As photoabsorber concentration was increased, the degree of overcuring showed a nearly seven-fold reduction from no photoabsorber (0 wt. %) to the highest photoabsorber concentration (0.025 wt. %).



ESI Figure 2. Resulting perfusability tests for CAD designs containing hollow microchannels embedded within the part. As shown, most of the channels were blocked and the dyed solution was not able to perfuse due to the many overcured or blocked channels. Despite this, the fact that some dye was able to make it through suggests that a proper combination of optimized design and curing conditions could make this a possible method to explore in future studies.