Developing a 3D Bioprintable Blood Vessel Model

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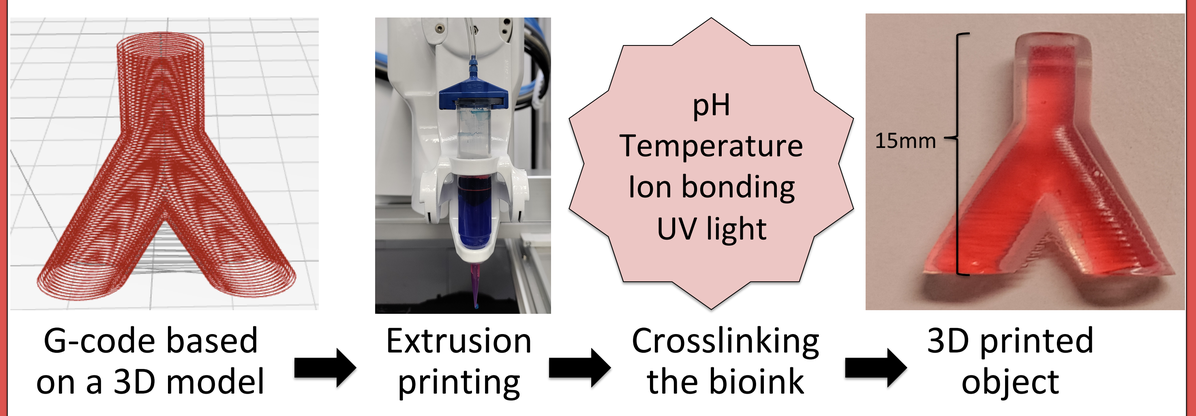
The main goal of this project was to show that the Brinter triaxial bioprinting tool can be used to print hollow vessel models.

What is 3D Bioprinting?

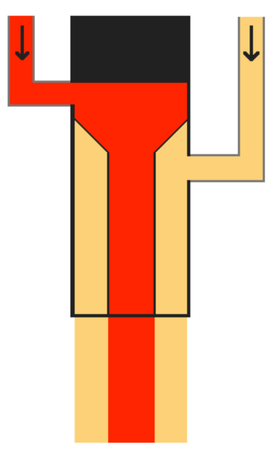
Bioprinting is 3D printing that uses biomaterials to print 3D structures. Many methods are used to print biomaterials but extrusion is the most common one. Biomaterials usually need a crosslinking step to stabilize the printed shape.

Living cells can be added to bioinks to create 3D cell cultures and tissue models that are more representative of real cell conditions than their 2D counterparts.



Steps of a typical bioprinting workflow. On the right a branched tube printed using UV curable silicone.

Coaxial Printing Method



The triaxial tool has a nozzle that consists of three different gauge needles inside one another. Three different materials can be pneumatically extruded through the nozzle to create a triple layered tube.

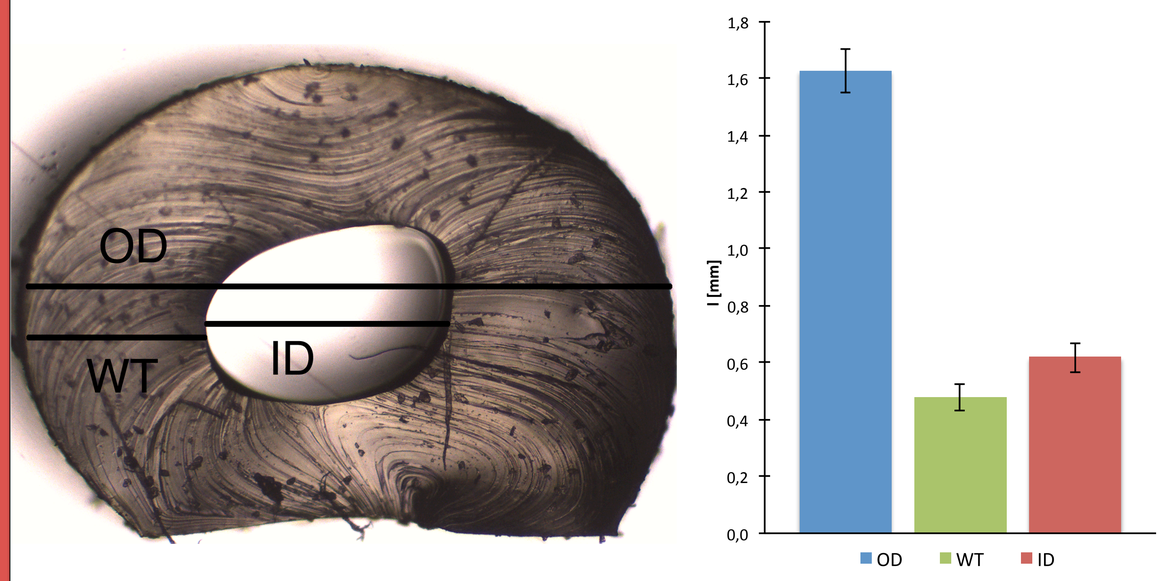
Pressures of each material can be adjusted individually. This project mainly used the two outer channels.

Schematic showing how a coaxial needle can be used to combine two different materials into a tube with outer and inner layers.

Silicone Vessel Model

Silicone was extruded from the outer needle of the triaxial nozzle and poloxamer was extruded through the inner channels for support before crosslinking.

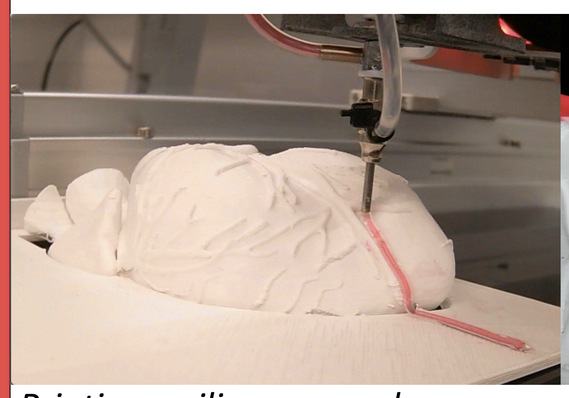
After the silicone was crosslinked using UV light poloxamer could be removed. This process was used to print hollow silicone tubes.



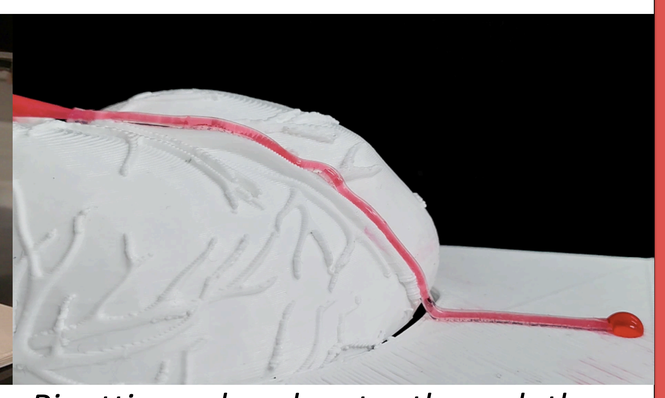
Cross section of a silicone vessel that was printed using the triaxial print tool and its dimensions including outside diameter (OD), inside diameter (ID) and wall thickness (WT).

Printing on Other Models

Silicone vessels can not only be printed on the flat print bed but also in full 3D space and on uneven surfaces if their 3D models are available. Alongside Brinter's modular nature this makes it possible to print vessels as a part of a complex larger object. It also allows freeform printing inside support gels.



Printing a silicone vessel on a natural scale human heart model.

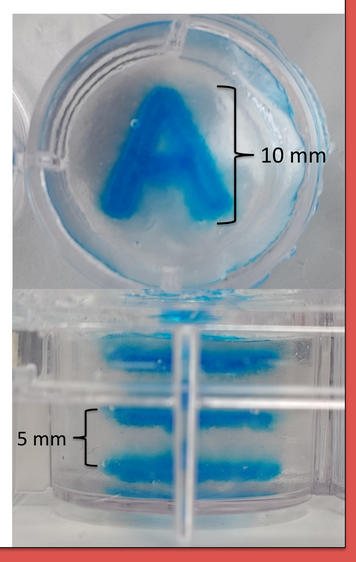


Pipetting colored water through the vessel after printing.

Gelatin Support Bed

The main problem when printing many biomaterials like collagen is their poor structural rigidity. One method to combat this is printing inside of a support gel.

Food grade gelatin was gelled with PBS and mechanically blended into a slurry to create a pH neutralizing support that can be melted at 37°C. The slurry allows the printing needle to move freely while also supporting hydrogel structures.



Stacked poloxamer characters printed inside the gelatin support gel.

Collagen

Collagen is the most abundant protein in the human body. Thanks to its excellent biocompatibility it has great potential in bioprinting. Acidified collagen is crosslinked by neutralizing it at 37°C.

Collagen could not be printed accurately using the pneumatic triaxial tool due to its lower viscosity and long crosslinking time compared to silicone.

However a screw driven Visco Bio tool could be used be used to print collagen tubes layer by layer via a 100 µm single channel steel nozzle.

5x5 mm hollow collagen tubes removed from the melted support gel after a 1h crosslinking time.

Collagen printed inside gelatin support gel using the triaxial tool. Low viscosity and long crosslinking time caused collagen to spread before stabilizing.

Conclusions

All large scale bioprints will need some sort of a vasculature solution. It was shown that the triaxial tool can be used to print hollow silicone vessels individually and as a part of other models. Pneumatic extrusion and large nozzle size made the triaxial tool too inaccurate for collagen but collagen tubes could be printed using a screw driven tool and a gelatin support bath.