



3D Printing Scaffold for Cardiovascular Tissue Regeneration

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OBJECTIVE

Find the limitations of the TissueScribe 3D printer in order to print a hydrogel gelatin scaffold that provides structure and stability for cardiovascular tissue regrowth.

BACKGROUND

Cardiovascular Disease is one of the leading causes of deaths worldwide. One of the ways to limit CVD is to repair damaged tissue. However, the regeneration capacity of the heart is limited. We are continuing a capstone project from last year and working with Dr. Horton to reliably 3D print a tissue scaffold capable of supporting cardiovascular cells and their growth and structure.

METHODS

GCode

- Create simple GCode to print simple lines using water.
- Create GCode to print layer one of 30 x 30 mm scaffold.
- Upload into Ultimaker Cura to verify design.
- Troubleshoot extrusion rate and speed.

```
G92 E0
G21
M105
M109 T1 S32 ;set nozzle temperature to 32 degrees
G91 ;absolute positioning
M83 ;absolute positioning for extrusion
M107 ;fan off
;M190 S25 ;set bed temperature to 25 degrees

G0 X10 Y0 Z0 E0
G1 X-5 Y5 Z0 E1.75 F85; move left 5 and up 5, extrusion is 1.75 and feed rate is 85mm/min
G0 X0 Y5 Z0 E.5
G1 X10 Y-10 Z0 E1.75
G0 X5 Y0 Z0 E.5
G1 X-15 Y15 Z0 E1.75
G0 X0 Y5 Z0 E.5
G1 X20 Y-20 Z0 E2.25
G0 X5 Y0 Z0 E.5
G1 X-25 Y25 Z0 E2.75
G0 X0 Y5 Z0 E.5
G1 X30 Y-30 Z0 E2.75
G0 X0 Y5 Z0 E.5
G1 X-25 Y25 Z0 E2.25
G0 X5 Y0 Z0 E.5
G0 X20 Y-20 Z0 E2.25
G0 X0 Y5 Z0 E.5
G1 X-15 Y15 Z0 E1.75
G0 X5 Y0 E.5
G1 X10 Y-10 E1.75
G0 X0 Y5 E.5
G1 X-5 Y5 E1.75
```

Figure 1: Gcode for the first layer of the scaffold. Using absolute position, the gcode prints a 30mm x 30mm scaffold at a feed rate of 85 mm/sec.

Printing

- Prepare 5% gelatin solution and place in warm water to liquify solution in order to load into syringe.
- Wait 15 minutes to achieve an almost solid viscosity before printing.
- Upload GCode to 3D Cultures TissueScribe (3D printer)

Materials & Design

- **Gelatin:** biocompatible and relatively cheap and readily available. 5% concentration is physiological.
- **18 gauge needle:** optimal size to ensure the gel coming out was thin and not coalescing together.
- **3 layers & diagonal:** This geometry best mimics the cardiovascular tissue
- **15mm x 15mm:** The maximum size for cardiovascular cell viability. However, the TissueScribe is unable to operate consistently and difficult to optimize at this resolution. Therefore the working design is 30mm x 30mm.
- **Printing Parameters:** *Feed rate:* 85 mm/min. *Extrusion rate:* differs for each line depending on length. *Wait time:* 15-20 minutes.



Figure 2 (left): 3D Cultures TissueScribe Printer. 10 mL syringe with 18 gauge needle is inserted into printer loaded with 5% gelatin hydrogel solution.

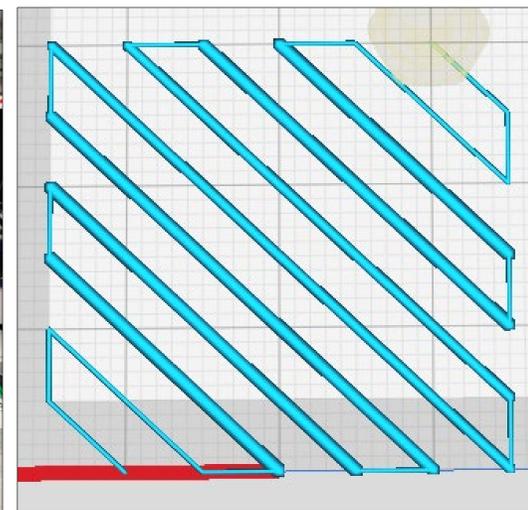


Figure 3 (right): Image from Ultimaker Cura that allows us to preview scaffold based on Gcode. The light blue lines represent the extrusion or gelatin being printed. This is the first layer of our scaffold with diagonal lines and a 30mm x 30mm square base.

RESULTS

1 layer of 30 mm x 30 mm gelatin scaffold was successfully presented and shown in the figure below (Figure 4). It was determined that waiting 15-20 minutes before printing after loading the gelatin into the syringe created the optimal viscosity for printing. Furthermore, the most effective feed rate was found to be 85 mm/min allowing for a smoother consistency and thin lines. After consistent testing, we discovered that the TissueScribe 3D printer operated best on a slightly larger scale of 30 mm x 30 mm rather than the aforementioned 15 mm x 15 mm.



Figure 4: First layer of scaffold printed with dimensions of 30mm x 30mm using 5% gelatin hydrogel, 18 gauge needle, and feed rate of 85 mm/min. There are definite uniform lines, and no blobbing.

CONCLUSION

A GCode was successfully written to control the path traveled by the syringe, its speed, and the rate of extrusion of the gelatin. The TissueScribe was able to print uniform and definite lines. Scaffold can be further developed with the incorporation of BDDGE to mechanically strengthen the scaffold for cardiovascular cells. Also, future work includes decreasing the dimensions to 15mm x 15mm and adding additional layers.