4-8-2017

Development of a Low-Cost Platform for 3D Bioprinting Applications

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Abstract

Due to the fast pace advancements in 3D printing technologies, it is now possible to bring to life three-dimensional models designed on a computer. The growing availability of user-friendly, high-resolution printers, presents us with the opportunity to adapt this tool for multiple biological purposes. Our aim is to develop a mechanism on a customized commercial 3D printer to deliver a hydrogel material to act as a scaffold for cell proliferation. Compared with non-biological printing, 3D bioprinting involves several complexities, such as the choice of materials, cell types, growth and differentiation factors, and technical hurdles related to the sensitivities of living cells and the formation of tissues. The modified 3D printer efficiently delivers biological ink substances such as alginate, collagen, chitosan, gelatin, and fibrin to create a biocompatible scaffold that will host cell proliferation. The scaffold can then be suspended in a solution with a cell line to initiate cell differentiation and self-assembly of the selected tissue. The project will allow for a cheaper more effective strategy for class research projects, medical drug testing, disease research, and potentially tissue/organ implantation. Establishing a functional platform and experimenting with the bioprinting of cartilage and other tissues enhances our understanding of cell and tissue biology and can have a significant impact in clinical settings. Developing an affordable mechanism will allow this technology to be demonstrated in undergraduate labs for a better understanding of how engineering tools can be applied to solve biological problems.

Disciplines

Biology

Comments

Presented at the Tri-Beta Honor Society Regional Meeting at Frostburg State University on April 8, 2017.

DEVELOPMENT OF A LOW-COST PLATFORM FOR 3D BIOPRINTING APPLICATIONS.

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Our aim is to develop an affordable platform for the 3-dimensional printing of biocompatible structures that may be used as scaffolds for tissue engineering.

Abstract

Due to the fast pace advancements in 3D printing technologies, it is now possible to bring to life three-dimensional models designed on a computer. The growing availability of user-friendly, high-resolution printers, presents us with the opportunity to adapt this tool for multiple biological purposes. Our aim is to develop a mechanism on a customized commercial 3D printer to deliver a hydrogel material to act as a scaffold for cell proliferation. Compared with non- biological printing, 3D bioprinting involves several complexities, such as the choice of materials, cell types, growth and differentiation factors, and technical hurdles related to the sensitivities of living cells and the formation of tissues. The modified 3D printer efficiently delivers biological ink substances such as alginate, collagen, chitosan, gelatin, and fibrin to create a biocompatible scaffold that will host cell proliferation. The scaffold can then be suspended in a solution with a cell line to initiate cell differentiation and self-assembly of the selected tissue. The project will allow for a cheaper more effective strategy for class research projects, medical drug testing, disease research, and potentially tissue/ organ implantation. Establishing a functional platform and experimenting with the bioprinting of cartilage and other tissues enhances our understanding of cell and tissue biology and can have a significant impact in clinical settings. Developing an affordable mechanism will allow this technology to be demonstrated in undergraduate labs for a better understanding of how engineering tools can be applied to solve biological problems.

Table 1: Materials & Equipment

M3D Micro 3D Printer ($300)	32 AWG Resistance Wire	Gelatin from Porcine Skin
New Era Syringe Pump ($275)	Phosphate Buffer Saline	Sodium Alginate
Caretouch Luer Lock Syringes (10 ml)	Blunt tip needles (18g-23g)	Calcium Chloride
Tygon tubing (1/32 ID)	PDMS Sylgard 184	Computer + M3D software
Sketchup CAD software	F4 Silicone Insulating Tape	Four Linear Regulated Power Source
PolarPak cooling gel Heat sinks	Digi-sense Digital Thermometer	Aluminum Foil

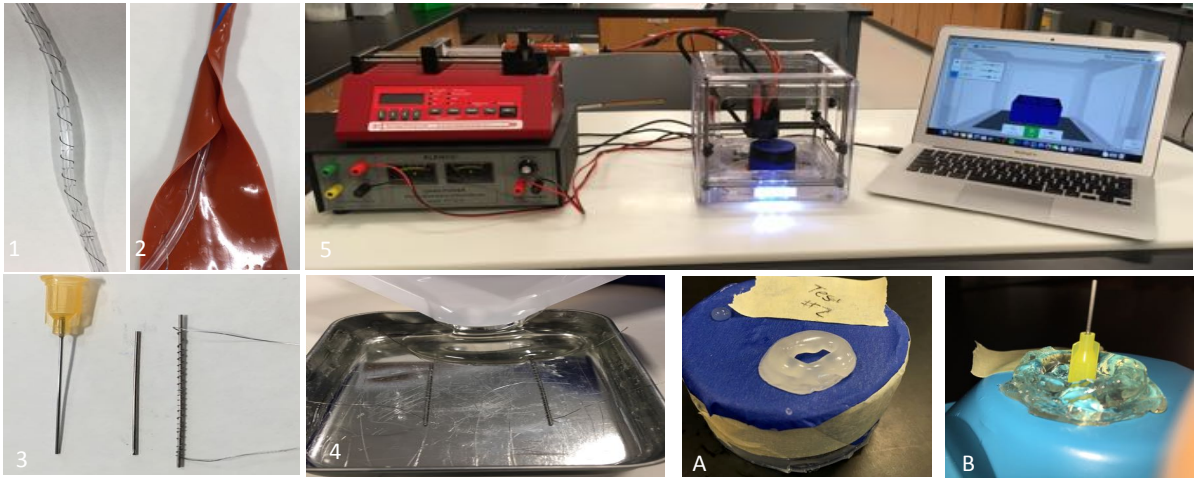

Figure 1: *In picture #1 the Tygon tubing is wrapped in 32 AWG resistance wire to maintain a certain temperature while printing. In picture #2 the tubing and wire are wrapped in silicone tape to insolate the heat generated by the wire. In picture #3 the delivery needle is removed from its plastic housing and wrapped in 32 AWG resistance wire to also help maintain a certain temperature while printing. In picture #4 these tips are then covered with PDMS to insolate the heat generated from the wire. In picture #5 the delivery mechanism is all set up and ready to print the CAD image with hydrogel.*

Methodology

Delivery mechanism

A commercial M3D printer is equipped with a hydrogel delivery mechanism attached to a syringe pump so it may print structures designed on a CAD software (Picture #5). A blunt-tip needle acts as the extruder for the bioink that prints into a scaffold structure. The blunt-tip needle is attached to the silicone tube and sealed into place so that no leakage can occur. One side of the tube has only the needle tip and the other side has the tip still attached to the luer lock connection so that the 10.0 mL syringe can be attached once ready to print. The needle tip and tube are wrapped in heating wire (Pictures #1 and #3) and connected to a power source to maintain a certain temperature so the hydrogel does not harden within the tube and at the tip. The tubing is then wrapped with silicone tape (Picture #2) to insulate the heat generated from the resistance wire. The is coated in silicone (Picture #4) to hold the heating wire in place and for insulation. The syring is wrapped in layer of aluminum foil and silicone tape for insulation.

Printing

In order to force any kind of printing material out of the syringe at a consistent rate, a syringe pump is used with the setting of ~130 µL/min using a 23 gauge blunt tip needle with an internal diameter of 0.33 mm. The hydrogel is primed through the tube before being placed on the syringe pump so that once the print starts it is ready to go with no gaps in hydrogel. Before printing starts, the 3D printer needs to be calibrated to the new "print bed" because the stock print bed has been removed. The hydrogel is printed onto an upside down petri dish that is filled with the inside of an ice pack and frozen. The blunt tip needle is lined up with the new print bed to make sure it is centered, everything is leveled, and the height away from the bed is made sure to be right. Miscalibration of any of these factors will result in an overall failure of the print, so everything needs to be double checked before printing. These cold temperatures allow for the immediate hardening of the hydrogel bioink when printing so that layers can build on top of each other without complications. Over time, the design being printed should come out in a scaffold made of hydrogel that can later be used to host cell proliferation.

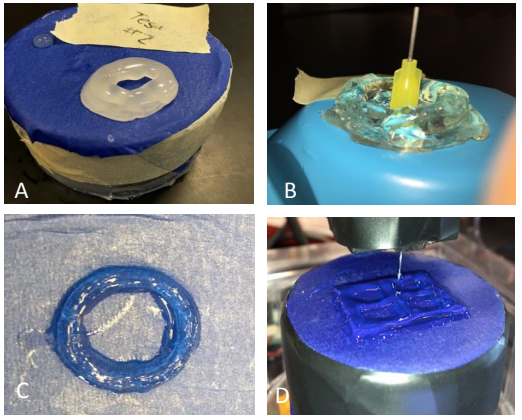

Figure 2: *Photo A shows one of the first tests showing that the hydrogel delivery mechanism worked. Photo B Shows another print of the same file showing that height can be achieved using hydrogel as ink. Photo C shows the precision achived by the 3D printer by printing a better looking circle. Photo D shows the printing of a four-square showing that more complex shapes can also be printed.*

Future Directions

- Design an efficient and replicable delivery mechanism that can be attached to an inexpensive commercial 3D printer to print hydrogel material into a scaffold.
- Slight modifications to move towards the use of a power source to maintain certain temperatures without worry of them dropping.
- Experiment with different shapes and how they print using a hydrogel material.
- Utilize scaffolds for cell proliferation and differentiation into tissues for future research.

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