Vascular Stent Design using 3D Printing Mechanics and Composite Materials

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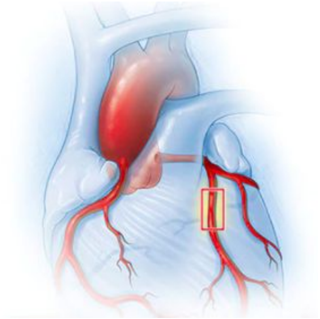
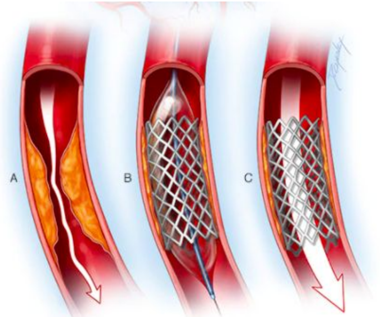
Background

Biology Background



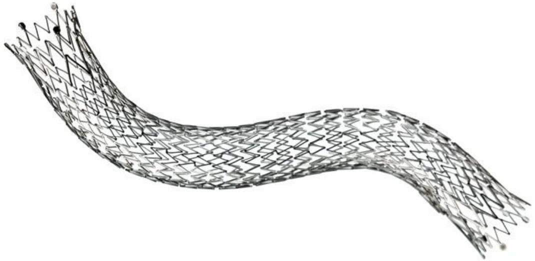
- Arteries and veins constitute the majority of the cardiovascular system.
    - A healthy circulatory system is essential for a healthy body.
- A blockage in the circulatory system could be lethal.
    - Vascular stenting is a common solution to restore blood flow.

Stenting



- Stents are expected to mimic the body's native vessel.
    - Must mimic the native vessel's size and flexibility .

Examples of Stents on the Market



LifeStent (Bard)
Bare Metal Stent

Helical design; meant to bend and compress, as well as twist with the forces of the body which is most optimal for the iliac region

Absolute Pro (Abbott)
Drug Eluting Stent

Braided design; Triaxial technology -- absorbs stored energy or stabilizes motion artifact; minimizes friction during insertion for ultimate precision

VENOVO Venous Stent System
Drug Eluting Stent

Woven design; Offers radial force, crush resistance and flexibility. Reduced risk of stent migration.

Need for Innovation

- Increased restenosis rates of vascular stents display a need for remodeling current designs.
- As of today, drug eluting stents offer the lowest restenosis rates.
- There are many financial and manufacturing time constraints that are associated with conventional patient specific stent production.
- Additive manufacturing may provide a solution to reduce cost for rapid prototyping.

Problem Statement

- **This study offers a cost effective prototyping to explore various design possibility, aiming for higher success rates for patients from vascular disease.**

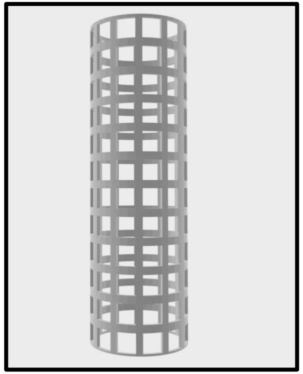
Materials and Methodology

Using Solidworks

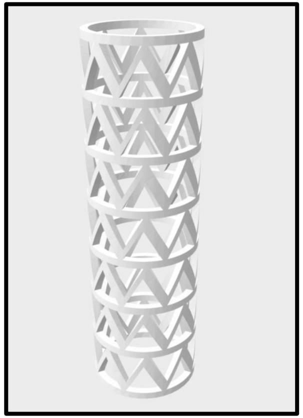
- Wrapping thickened plane design
    - “Flex” tool

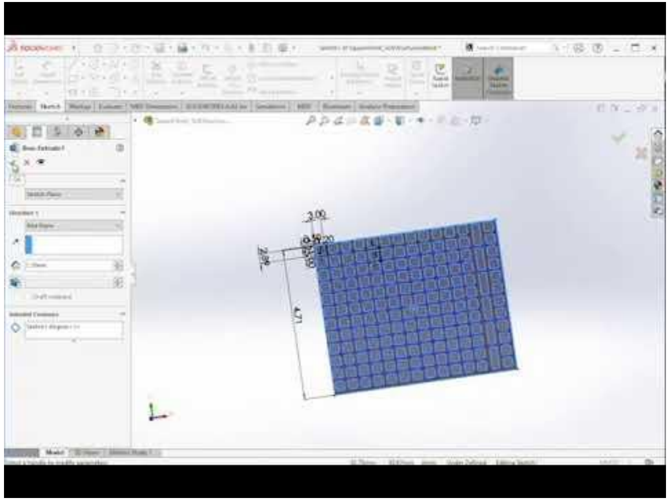
- Cylindrical cut-outs
    - “Circular Pattern”
    - “Linear Pattern”

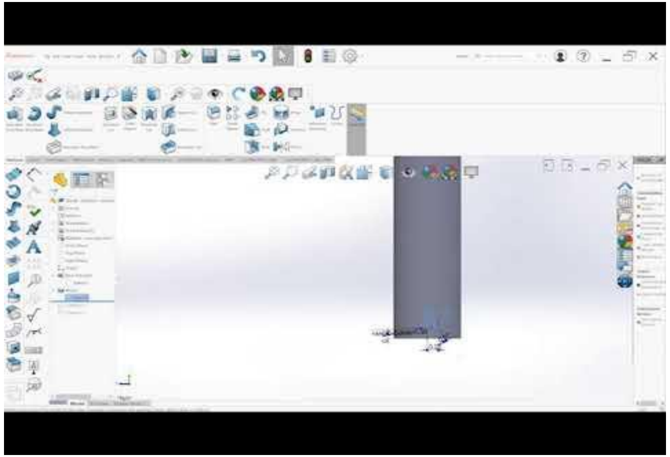
Square stent



Triangular stent

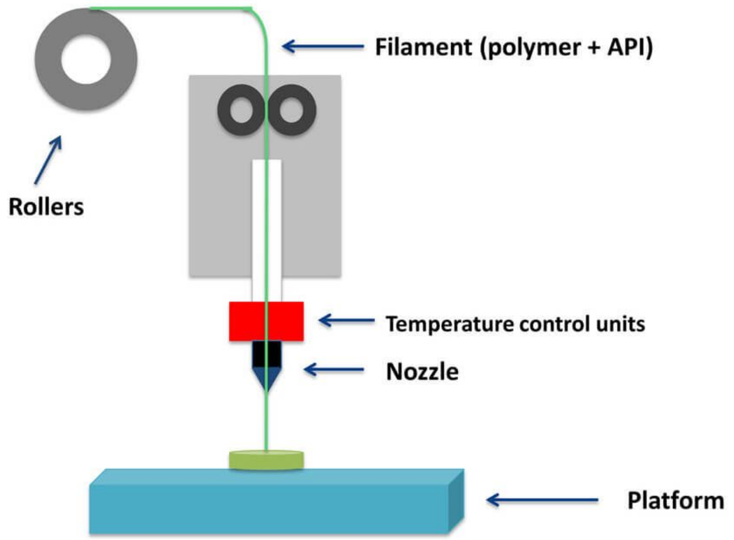






Design Strategy Justification

- Methods: SLA versus FDM
- Materials: Resin versus Onyx
- Square stent: compared vertical versus horizontal printing methods
- Triangular stent: tested structural integrity when printing at non-orthogonal angles to the printer nozzle and struts with varying thickness



Design Modifications

- Stents collapsed at the ends
- Additional length was added to the ends of each stent and removed after printing
- Increased strut thickness by 50% and 100% in square stent

Materials

Onyx

- Composite based micro carbon fiber filled with nylon
- Highly versatile
- High strength, toughness, chemical resistance
- Flexural strength: *3GPa*

Standard Photopolymer resin

- Composite based thermoset which changes properties when exposed to UV light
- High surface finish, however toxic in liquid and hard resin form
- Flexural strength: *2.2GPa*

Printing and Post-Printing Procedure

Results/Conclusion

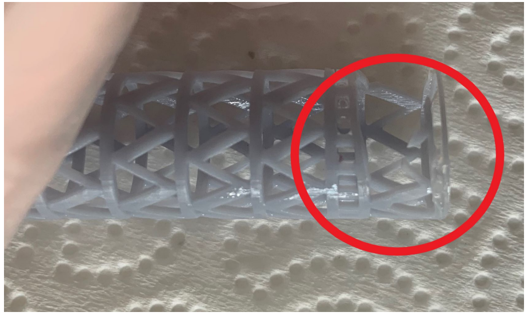
Results

A) Preprocesses ‘triangle stent’ with removable supports ->
B) Post processed ‘triangle stent’ refined

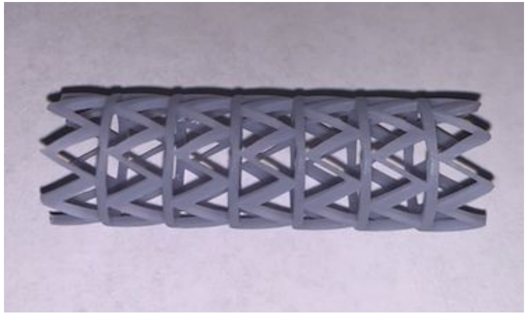
C) Horizontally printed Onyx ‘square stent’

D) Vertically printed Onyx ‘square stent’

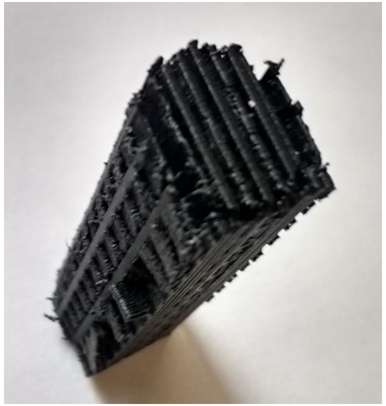
A)



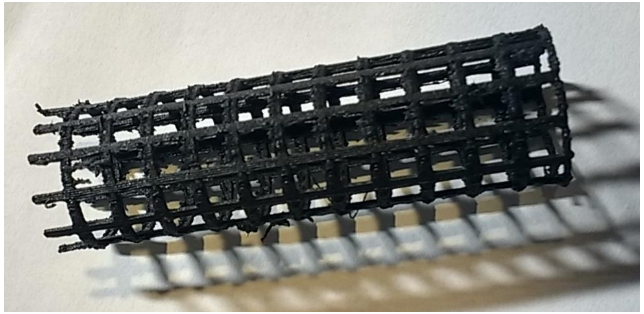
B)



C)



D)



Results

- Vertical printing proved to give the best results in maintaining intended shape.
  - This is given that the added structural supports work to ensure there is no tearing of the stent during processing
- FDM was slightly flexible and crush resistant, but was not clean and could not be refined or post processed.
  - This resulted in many fragments hanging off of the stent, and the center plug of the cells could not be extracted without breaking the struts
- SLA proved to have a much more precise outcome, and is structurally sound with minimal need for post processing.
- All designs required additional support structures as aforementioned.

Limitations

- No access to campus laboratory
  - Home restrictions
  - Missing specialized equipment
- Lack of standardized testing methods
- Output of FDM prints took from 1-3 weeks.

Future works

- Using a “flexible” resin compatible with our SLA printer
- Including new designs with altered struts and different lengths
- Developing an at-home procedure for flexibility testing

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Thank you for your time!

Any Questions?