3D Printing for Bone Tissue Engineering Applications

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Outline

I. Problem
II. Objective
III. Previous Studies
IV. Proposed Development
    A. Design Criteria
    B. Synthesis and Fabrication
    C. Experiment
V. Concluding Remarks

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Problem

- There are 1.3 million surgeries for bone damage annually
- Most common broken bone
  is the clavicle
- Most Common type of break is a fracture

Problem

- Traditional scaffold manufacturing methods
  - Electrospinning
    - Use of electrical charge to create nonwoven scaffolds
  - Solvent Casting
    - Dissolution of polymer-ceramic particle mixture
  - Freeze Drying
    - Synthetic polymer is dissolved then poured into moulds with liquid Nitrogen

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Objective

Use 3D Printing with Hydrogel Composites

- Low cost
- Rapid manufacturing of personalized scaffolds
- Potentially solve donor shortage problem

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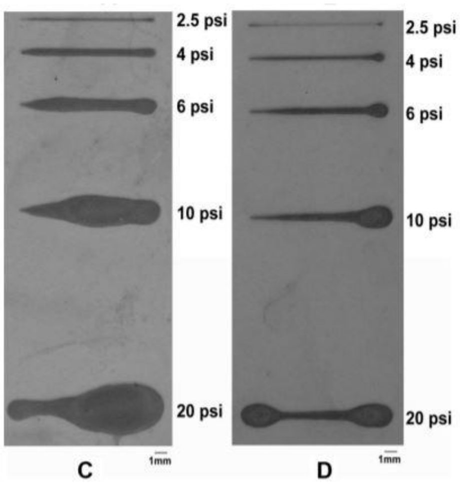
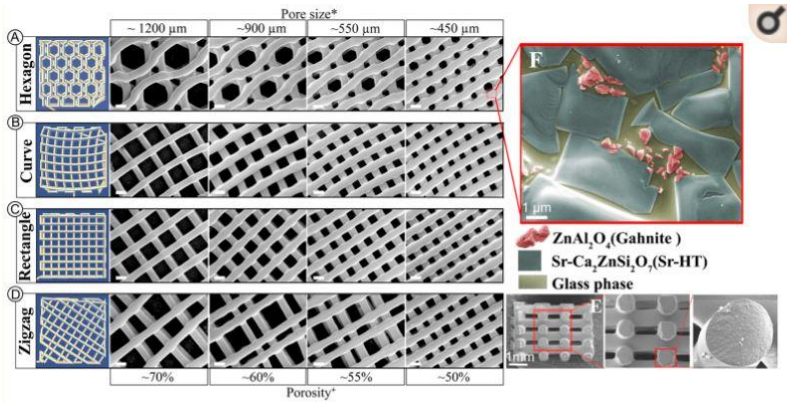
Previous Studies

- 3D printed collagen scaffolds
  - Direct-write printing
  - Adjustable variables
  - Created 104 customized layers
- 3D printed ceramic and composite scaffolds
  - Inkjet printing
  - Freedom to vary porosity
  - Achieved close mechanical strength of cortical bone
    - Experimental: 122 MPa
    - Cortical: 100-150 MPa





[1] Smith CM, Christian JJ, Warren WL, Williams SK. Characterizing Environmental Factors that Impact the Viability of Tissue-Engineered Constructs Fabricated by a Direct-Write Bioassembly Tool. Tissue Engineering. 2007;13(2)373-383
[2] Roohani-Esfahani SI, Newman P, Zreiqat. Design and Fabrication of 3D printed Scaffolds with a Mechanical Strength Comparable to Cortical Bone to Repair Large Bone Defects. Sci Rep. 2016;6:1-8

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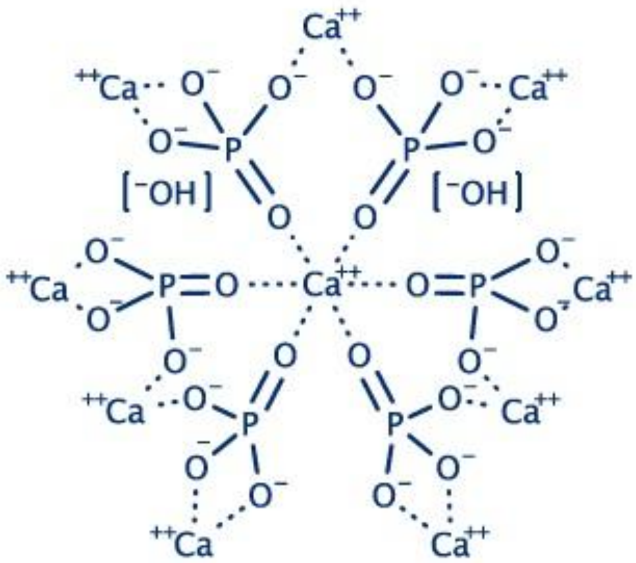
Design Criteria

- Biocompatibility
- Biodegradability
- Pore interconnectivity, pore size, and porosity
- Mechanical properties similar to natural human bone
- None/minimized inflammatory response

Synthesis & Fabrication

Biomaterial Selection

- Bioceramics
  - Nano-Hydroxyapatite
- Polymer/Protein
  - Fibroin



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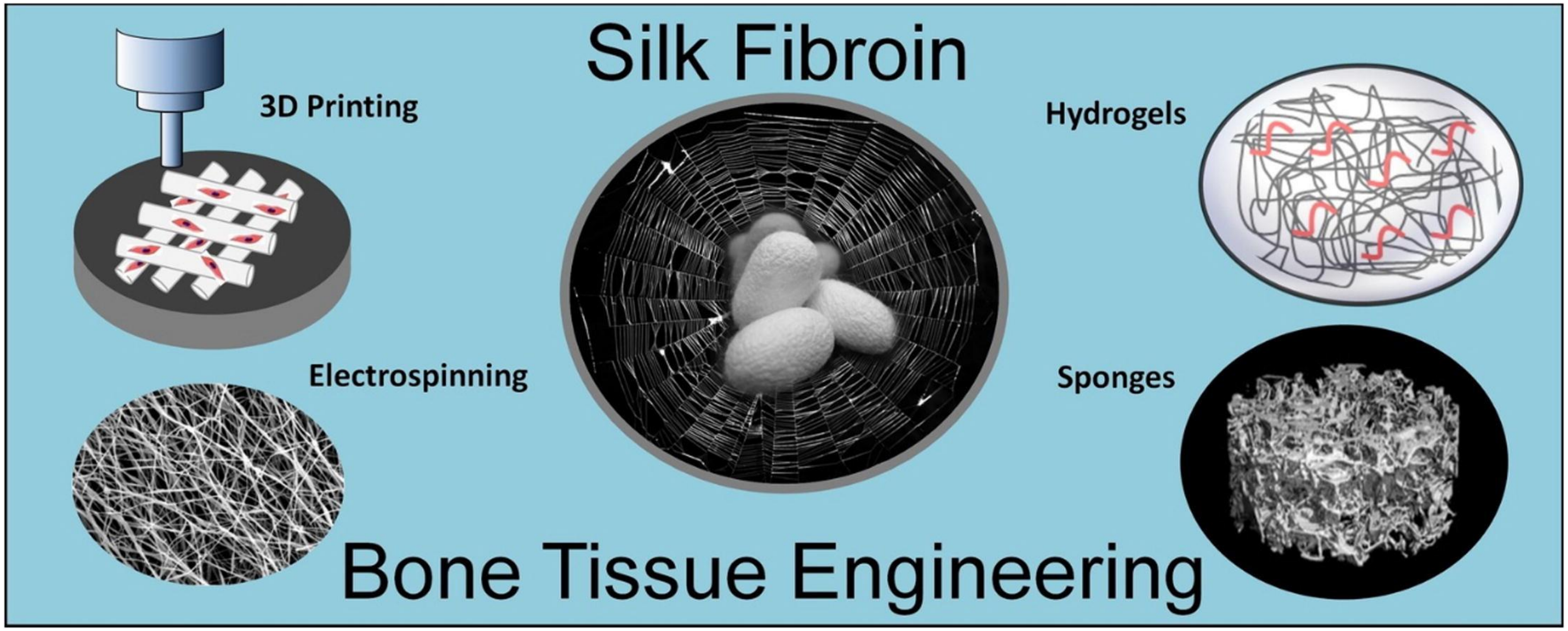
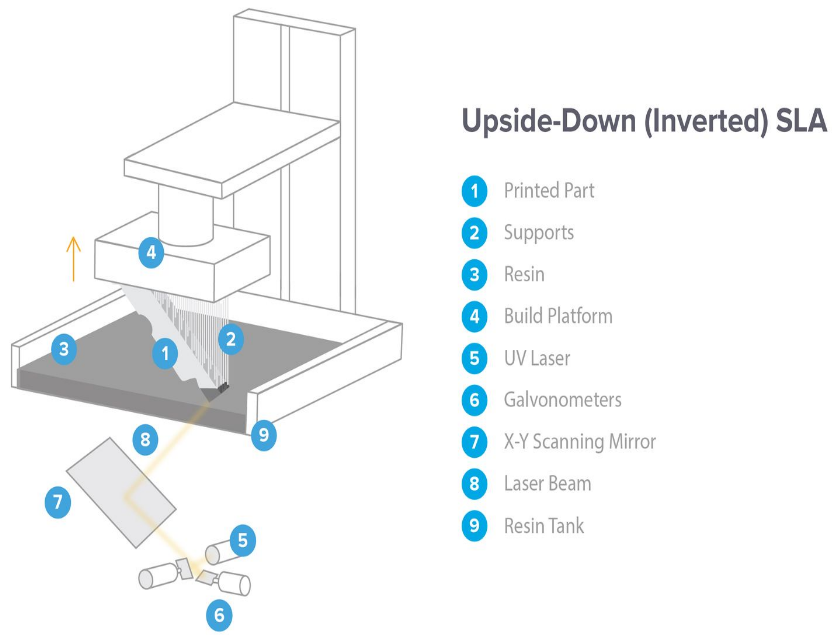
Synthesis & Fabrication



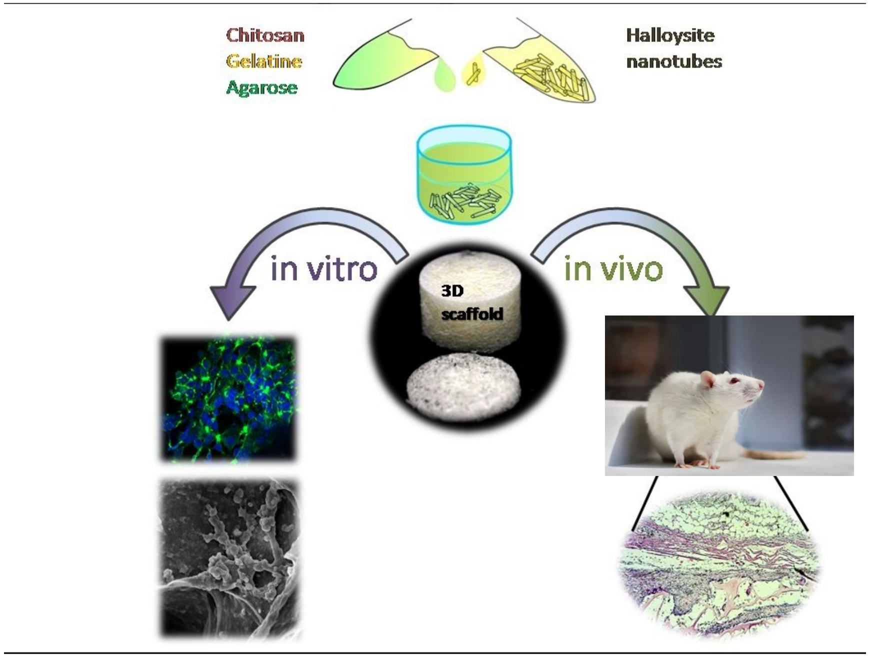
Synthesis & Fabrication

Stereolithography (SLA) Printer



Experiment

- In Vitro
  - A test within a cell culture
  - 3D print scaffold and implant it with a cell culture
- In Vivo
  - A test within a live subject such as an animal
  - Apply for IACUC approvals
  - Obtain female rats and induce fracture with anesthetics and immune suppressors



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Concluding Remarks

- Limitations
  - Though 3D printing materials have low stability and take lots of time to make
  - Nano-HA is printable but it is quite hard to make
    - Would require surface modifications to make it:
      - Adhere, Proliferate, & Grow better
    - This would allow us to increase biocompatibility and osteoplastic potential
  - Fibroin as a polymer is beneficial but has drawbacks
    - There aren't enough modifiable amino acid side chain groups compared to other collagens or scaffolds

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Concluding Remarks

- Future Works
  - Change the ratio of nano-HA/polymer (or protein)
  - Change the polymer or protein
  - Improve 3D printing resolution
  - Reduce post processing work

Questions?

Contributions

Dylan: Significance of Problem

Vishant: Experiment & Limitations

Chelsea: Objective, Design Criteria

Brittany: Previous Studies

Darian: Synthesis & Fabrication, Future Work