Characterization of Mechanical Properties of Solvent-Cast 3D-Printed Peptide-polymer Scaffolds for Osteochondral Tissue Regeneration

Santiago Lazarte[1], Diana E. Hammerstone[2], John W. Tolbert[2], Tyler French[2], Andrew Kitson[3], Tomas Babuska[4], Lesley Chow[2,3], Brandon A. Krick[4]

[1]Department of Chemical and Biomedical Engineering, FAMU-FSU College of Engineering, Tallahassee, FL USA
[2]Department of Materials Science and Engineering, Lehigh University, Bethlehem, PA USA
[3]Department of Bioengineering, Lehigh University, Bethlehem, PA, USA
[4]Department of Mechanical Engineering, FAMU-FSU College of Engineering, Tallahassee, FL, USA

Introduction

- Biomaterials used for tissue regeneration usually lack the properties and function of the target tissue.
- Desired properties can be achieved by 3D-printing different materials on the same construct.
- Solvent-Cast 3D printing (SCP) uses a polymer dissolved in a solvent as an "ink". The "ink" is extruded and the solvent evaporates, leaving a polymer filament.
- Scaffolds with different concentrations of peptides and polymers were 3D-printed with SCP.
- Changes in the chemistry of the inks and architecture of the 3D printed structures will change the bulk properties of the scaffold.

Materials and Methods

Customized Microindenter

- A customized microindenter was used to perform quasistatic compression experiments (see Fig. 1).
- The load head consists of a rectilinear cantilever beam of known stiffness, K. A capacitive displacement probe (Lion Precision, CPL290) measures deflection of the cantilever.
- The cantilever has a spherical probe at the end for contacting the center of a thin, rigid aluminum plate on the surface of scaffolds of

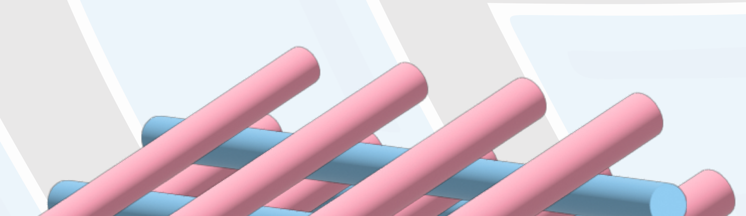
Scaffolds

- Scaffolds were printed with different concentrations of polymer-peptide conjugates and different polymer ratios.
  - Ratios: 100:0, 90:10, 80:20 ratios of 80 kDa and 25 kDa PCL respectively.
  - Concentrations: 3, 6 , 12 , 18 mg/mL of peptide (Hyaluronic Acid and E3) with 370 mg/mL of PCL.
- The scaffolds had a spacing of 260 µm and a filament diameter of approximately 40 µm. They were printed with an offset orthogonal pattern.

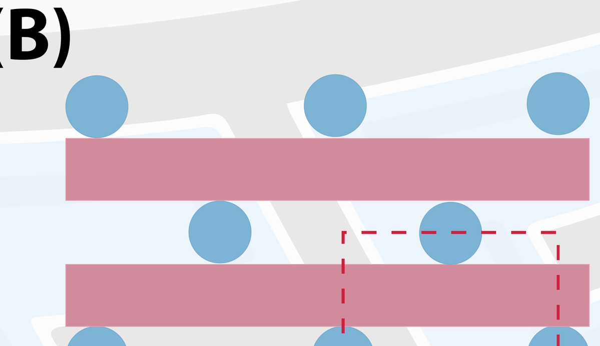
Mechanical Testing

- Tensile tests were performed to measure the elastic modulus of the individual filaments (E).
- Quasistatic compression experiments were performed on the printed scaffolds to calculate the effective compressive modulus (E*).
- The scaffold was modeled as Euler-Bernoulli beams as springs in series and parallel.

(A)



(B)



$$K_{L1} = k_1 + k_2 + \cdots + k_n = k_i \cdot N_x \cdot N_y$$

Equation 3: Spring constant addition - Parallel

$$\frac{1}{K_T} = \frac{1}{K_{L1}} + \frac{1}{K_{L2}} + \cdots + \frac{1}{K_{LN}}$$

Equation 4: Spring constant addition - Series

$$K_T = \frac{K_i \cdot N_x \cdot N_y}{N_z - 1} = \frac{3 \cdot \pi \cdot E \cdot D^4 \cdot N_x \cdot N_y}{L^3 \cdot (N_z - 1)}$$

Equation 5: Bulk Stiffness

$$E^* = \frac{3 \cdot \pi \cdot E \cdot D^5}{L^5}$$

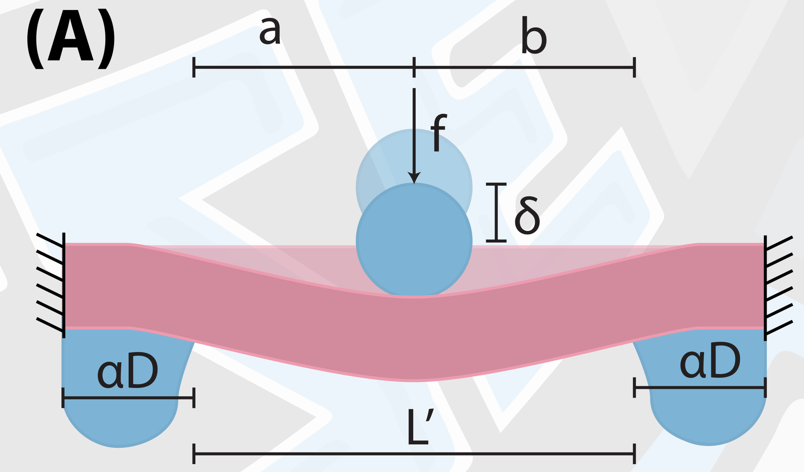
Equation 6: Effective Modulus

Discussion

Non-ideal scenario

- Contact area between fibers and fiber shape will affect the model

(A)



$$K_T = \frac{E^* \cdot A}{T} = \frac{E^* \cdot (N_x - 1) \cdot L^2 \cdot (N_y - 1)}{(N_z - 1) \cdot D}$$

$$K_T = \frac{3 \cdot \pi \cdot E \cdot D^4 \cdot N_x \cdot N_y}{L'^3 \cdot (N_z - 1)}$$

$$E^* = \frac{3 \cdot \pi \cdot E \cdot D^5}{\ldots}$$