Enabling Permeability Testing in Hydroxyapatite-Polycaprolactone Scaffolds

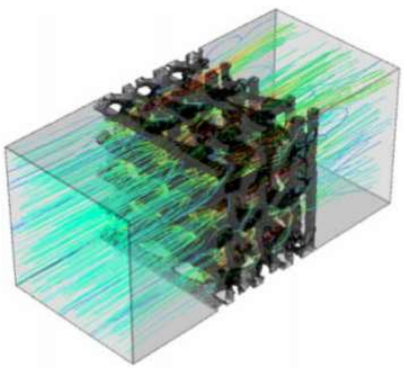
Maddie Shafer, Dr. David Prawel, Nelson Isaacson

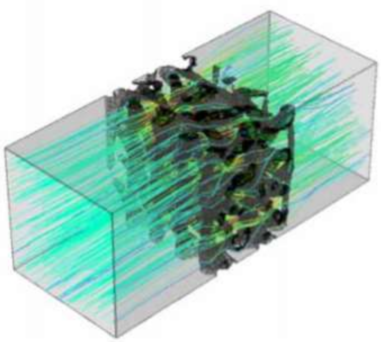
Department of Biomedical Engineering

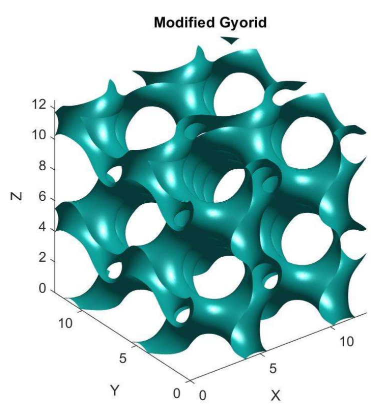
Colorado State University, Fort Collins, CO, USA

WALTER SCOTT, JR.
COLLEGE OF ENGINEERING
COLORADO STATE UNIVERSITY

Introduction







- Osteogenesis (bone growth) partially depends on the movement of fluid through the bone.
- Synthetic scaffolds assist in bone growth, must enable high fluid flow.
- Permeability is a measure of fluid flow through scaffolds.
- **This research project creates a device to measure permeability of 3D printed Hydroxyapatite Scaffolds.**
- My device will help determine the best porosity for our scaffolds.

Experimental Setup

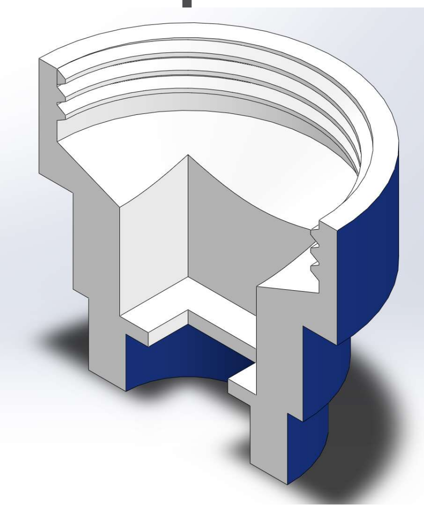


Figure 1. CAD Model of designed permeability chamber

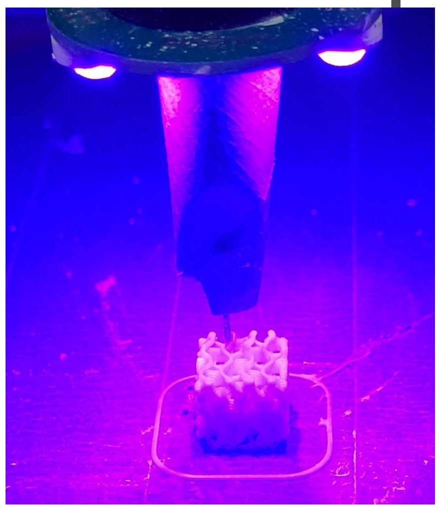


Figure 2. 80% porous HAp scaffold printing

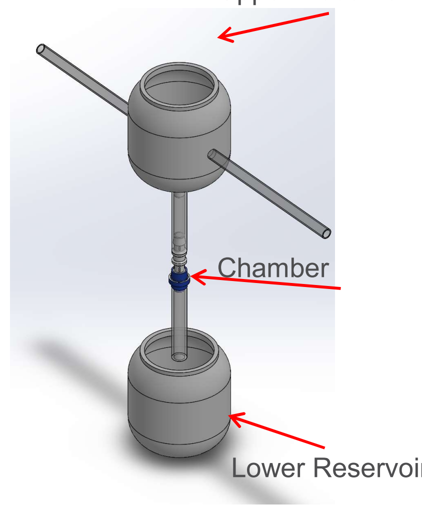


Figure 3. CAD of permeability testing rig

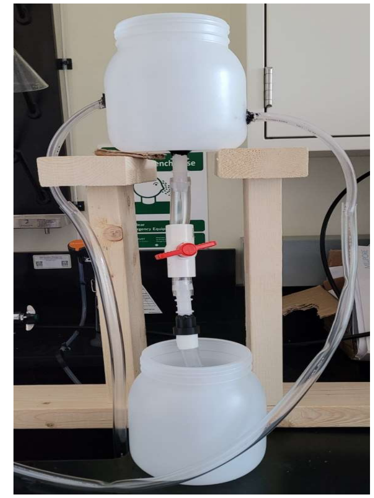


Figure 4. Constructed permeability rig

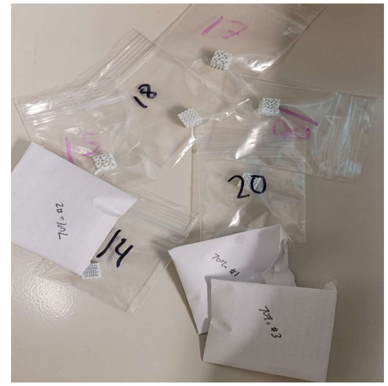
- Permeability depends the most on porosity, pore interconnectivity and size, the shape and cross section of the scaffold and the mass flow rate.
- My goal was to design a controlled system to measure mass flow rate.
- Mass flow rates consider density, velocity, and the cross-sectional area.

$$k = \frac{\Delta x}{A \cdot M_{B2}} \cdot \frac{2\pi^2 r^4}{(M_{B1}/M_{B2})^2 - 1}$$

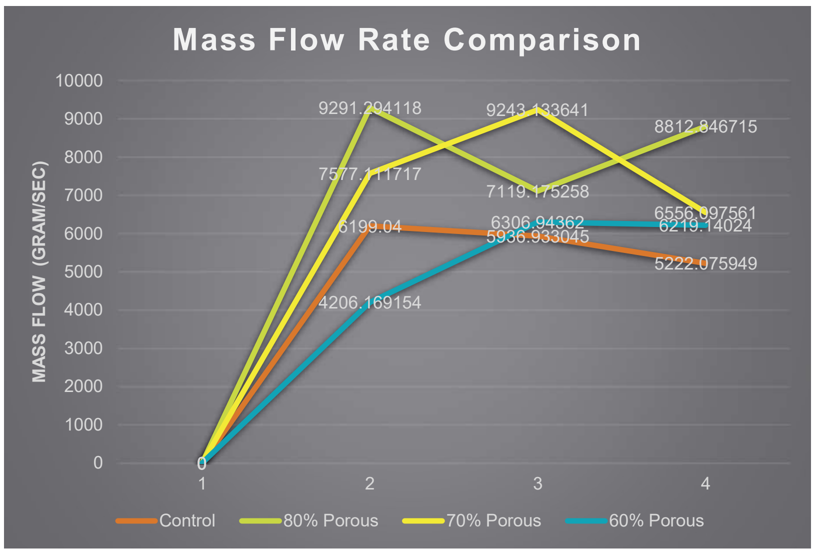
Figure 5. Modified form of Bernoulli's Equation and Darcy's Law solved for permeability

Initial Test Results

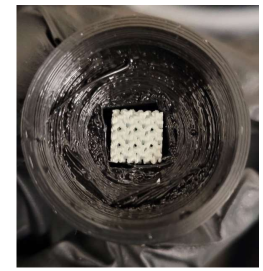
- Greater than expected variance in mass flow rate.
- Need to adjust control flow rate.

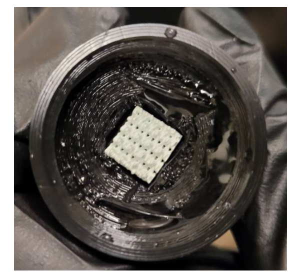


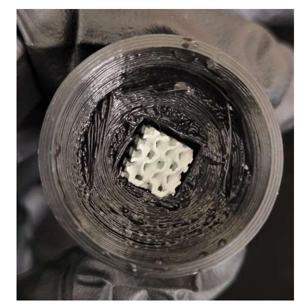
Mb [Kg/s]	
Control	5.936933
S80	6.305829
S70	5.844086
S60	3.703063



- Flow rates in initial testing appear contradictory
- Tests will continue with a larger sampling rate
- What can be learned from the current data?

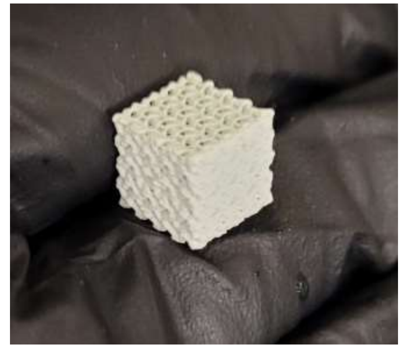






Testing and Results

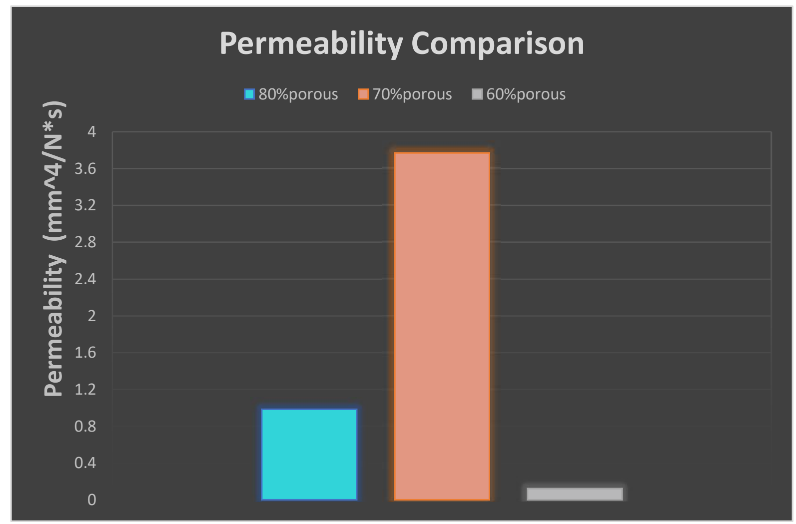
- Initial results are inconclusive, but testing will continue to refine our method.
- Indication towards 60% porosity is highest.
- Variance in data prevents certainty of calculations.



k [mm⁴/N*s]	
Control	-
S80	0.9858
S70	3.7724
S60	0.1214

```
clc
clear
P = 0; % Porosity constant, produces feasible and differing scaffolds
N = 1; % Determines period of oscilations
deltaX = 8; %length scaffold mm
A = 64; %cross section mm
MB1 = 5936.933045 % mass flow w/o scaffold g/s
MB80 = 6305.829023 % mass flow rates w/ 80% scaffold g/s
MB70 = 5844.08573 % mass flow rates w/ 70% scaffold g/s
MB60 = 3703.063254 % mass flow rates w/ 60% scaffold g/s
r = 4.05 % radius water outflow mm
k1 = (deltaX/(A*MB80))*((2*3.24^2*r^4)/((MB1/MB80)^2 -1)) %generating perm eq
k2 = (deltaX/(A*MB70))*((2*3.24^2*r^4)/((MB1/MB70)^2 -1))
k3 = (deltaX/(A*MB60))*((2*3.24^2*r^4)/((MB1/MB60)^2 -1))
```

- Flaws or faults in the scaffold could cause inconsistency.
- Slight differences in scaffolds, some fit better than others in the chamber.
- 70% porous scaffold showed signs of moving in the chamber.

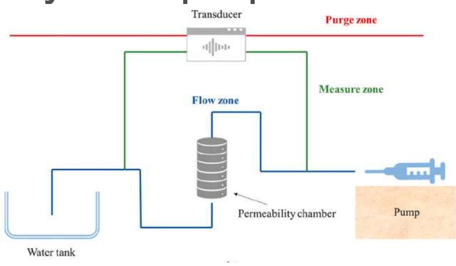


Conclusions

- The goal was to design a controlled system that could measure the mass flow rate.
  - This was a success, however, now my method must be tuned.
- A greater sampling rate is needed.
- Permeability values have a high variance.
- 60% porous scaffold is highest permeability but more testing needs to be done.

Where to go from here?

- More testing to improve accuracy?
- Pump system proposal



- A limited scope of permeability was approached, more characteristics must be considered.
- Above all else… WONDER!

What benefits did you get from you SURE experience?

Through my SURE experience, I can safely say I have never been more certain that I am exactly where I am meant to be.

There is nothing more invigorating than being in the lab and I have learned so very much. Beyond the very specific items I've learned pertaining to this project, I have learned to wonder. The words why and how have never been so important.

I thought I knew what would be required of me as an engineer, my eyes have been opened. My time has been spent reading countless papers, designing parts, enduring extensive bouts of trial and error, and overall, just learning so very much. This has been one of the most enriching experiences of my life and I am so very grateful that I got to be a part of SURE.

References & Acknowledgements

[1] Lopez Ambrosio, Katherine Vanesa. “Hydroxyapatite Structures Created by Additive Manufacturing with Extruded Photopolymer”. ProQuest Dissertations Publishing, 2019.

[2] M. R. Dias et al., “Permeability Analysis of Scaffolds for Bone Tissue Engineering,” *Journal of Biomechanics* 45, no. 6 (April 5, 2012): 938–44

[3] Jessica Kemppainen, “Mechanically Stable Solid Freeform Fabricated Scaffolds with Permeability Optimized for Cartilage Tissue Engineering.,” March 2008

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Thank you

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