

The Role of Lattice Geometry in Optimizing Necrotic Cell Washout in 3D-Printed Femoral Head Models

SBHSE

School of Biological and Health Systems Engineering

Lilli Offenberger¹ Matthew Halanski, M.D.², Kuei-Chun (Mark) Wang, Ph.D.¹
¹School of Biological and Health Systems Engineering, Arizona State University, Tempe, AZ
²Phoenix Children's Hospital, Phoenix, AZ

ASU Ira A. Fulton Schools of Engineering
Arizona State University

Background

Avascular necrosis (AVN) of the femoral head is a type of osteonecrosis when there is a lack of blood supply to the proximal femur and the bone tissue dies as a result. The U.S. has 10,000 to 20,000 cases each year [1].

Introduction

Core decompression is a surgical procedure to remove or washout the dead tissue within the affected area [2]. This study aims to determine which stage of AVN and pig age yield the most effective necrotic cell washout process.

Methods

- Model Creation
 - Designed 9 models ranging in pig age and inner gyroid lattice size (small, medium, and large) to replicate stage of AVN and the effects on different pig ages
 - n = 3 per group
 - Resin or PLA printed
- Necrotic Cell Injection and Washout
 - Injected of necrotic cell solution into each model
 - Flushed model with a controlled washout liquid to simulate core decompression
- Data Analysis
 - 9 model combinations x 3 trials = 27 total trials
 - Two-way ANOVA
 - Washout Efficiency collected

Manufacturing Process

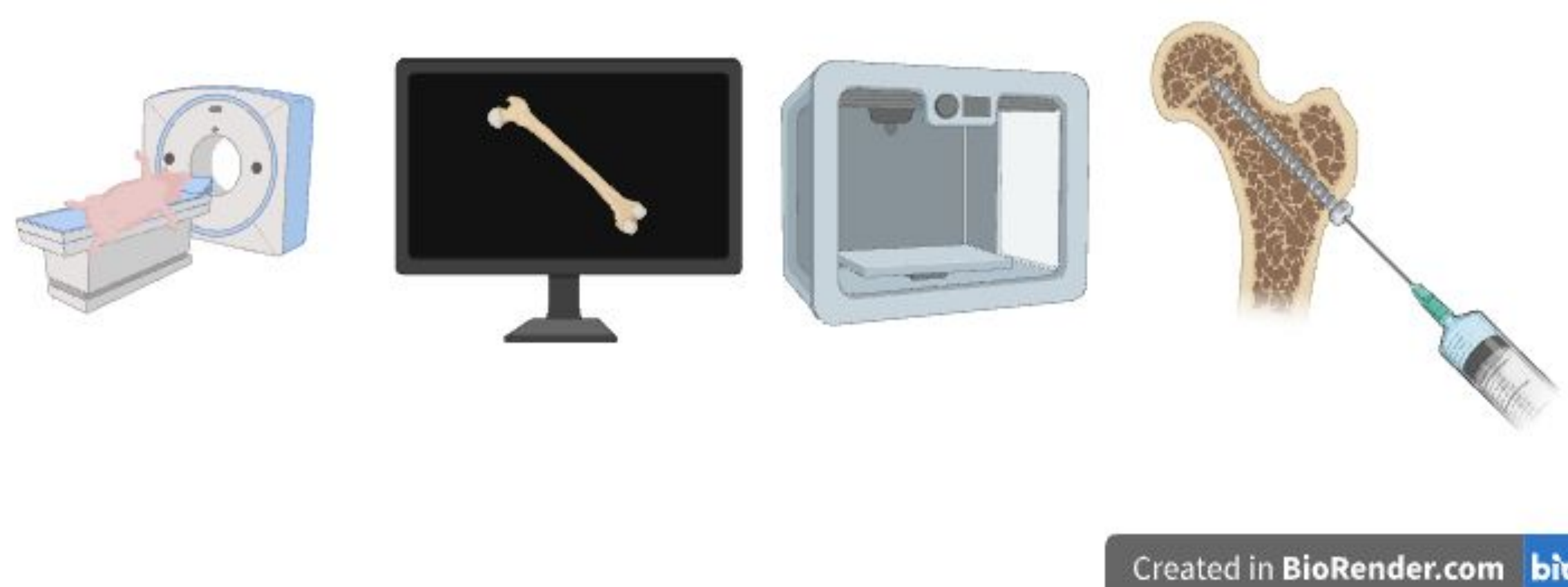


Fig. 1: An overview of the the process to make the physical models.

Physical Models

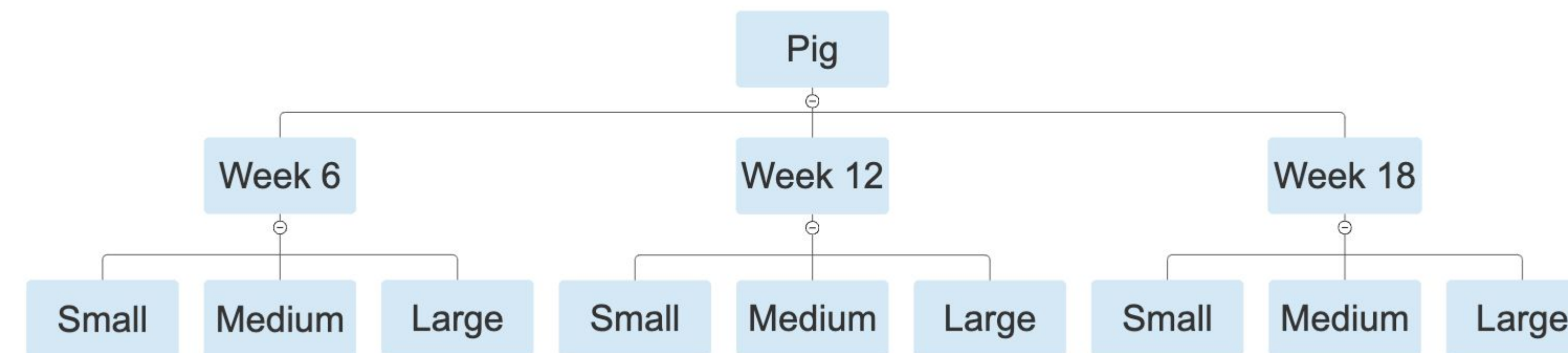


Fig. 2: The graph shows the pathway to how each model was built.



Fig. 3: This graphic shows the nine testing models that were used in this study.

Results

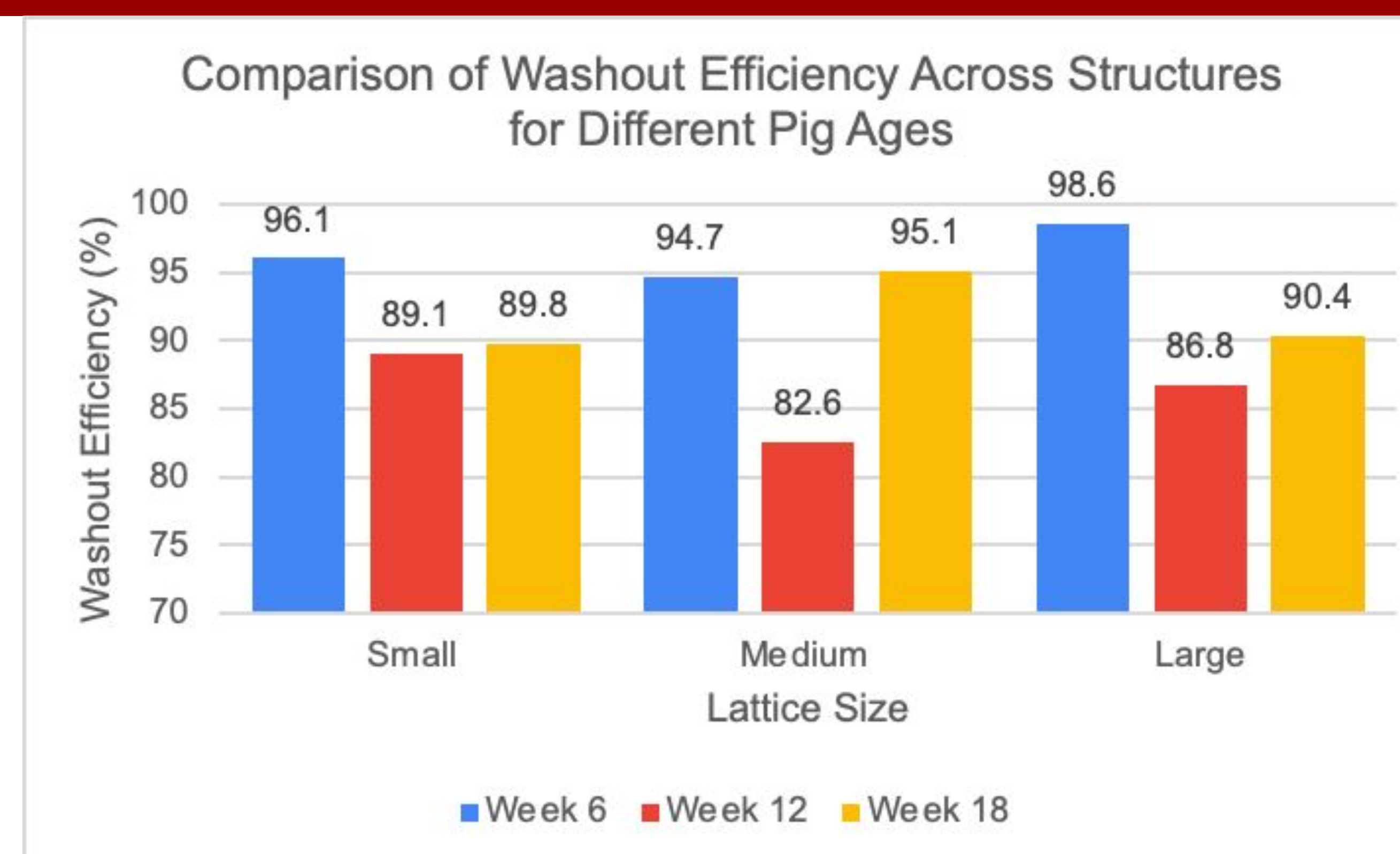


Fig. 4: Graph Showing the Results from Washout Efficiency vs. Lattice Size

- Week 12 pig model with medium lattice had the highest retention rate
- Week 6 pig models with small and large lattice demonstrated the best washout efficiency
- Two-way ANOVA Results:
 - Pig age has a statistically significant effect on washout efficiency ($p = 0.047$)
 - Lattice size does not have a statistically significant effect ($p = 0.911$)

Discussion

- Customizable lattice could enhance personalized medicine/treatment
- Large lattice structures allowed for better fluid flow to improve effectiveness of treatments meaning core decompression could be still effective in later stages of AVN
- Mixing materials for models (PLA and resin) can affect washout methods

Conclusions

- Results show that the pig's age shows significance on the washout process
- Models that had PLA and resin parts could have impacted the results

Future Steps

Step 1

Make all models out of resin

Step 2

Explore other lattice geometries

Step 3

Computational fluid dynamics modeling

Acknowledgements

I would like to acknowledge Matthew Halanski, M.D., Kuei-Chun (Mark) Wang, Ph.D., and Cameron Jeffers, M.S.E. for their guidance and support during this process.

References

- [1] W. Konarski *et al.*, "Avascular Necrosis of Femoral Head—Overview and Current State of the Art," *International Journal of Environmental Research and Public Health*, vol. 19, no. 12, p. 7348, Jun. 2022, doi: <https://doi.org/10.3390/ijerph19127348>.
- [2] J. Barney, N. S. Piuze, and Hossein Akhondi, "Femoral Head Avascular Necrosis," Nih.gov, Sep. 03, 2019. <https://www.ncbi.nlm.nih.gov/books/NBK546658/>