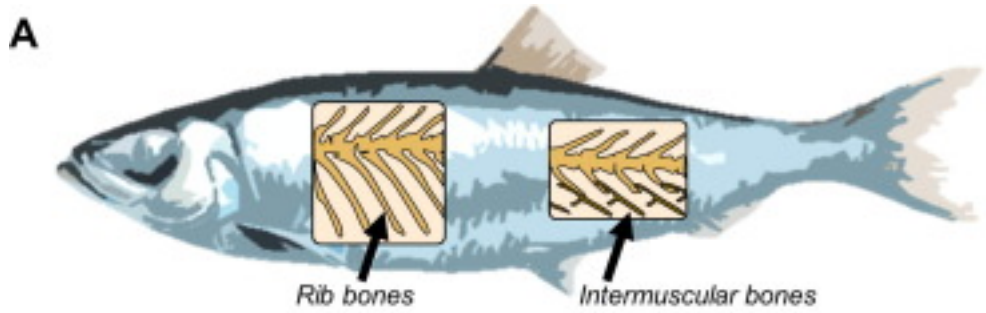
NANO-CT IMAGE PROCESSING AND MICROMECHANICAL MODELING OF INTERMUSCULAR BONE IN HERRING

BY: LARA ABDELMOHSEN

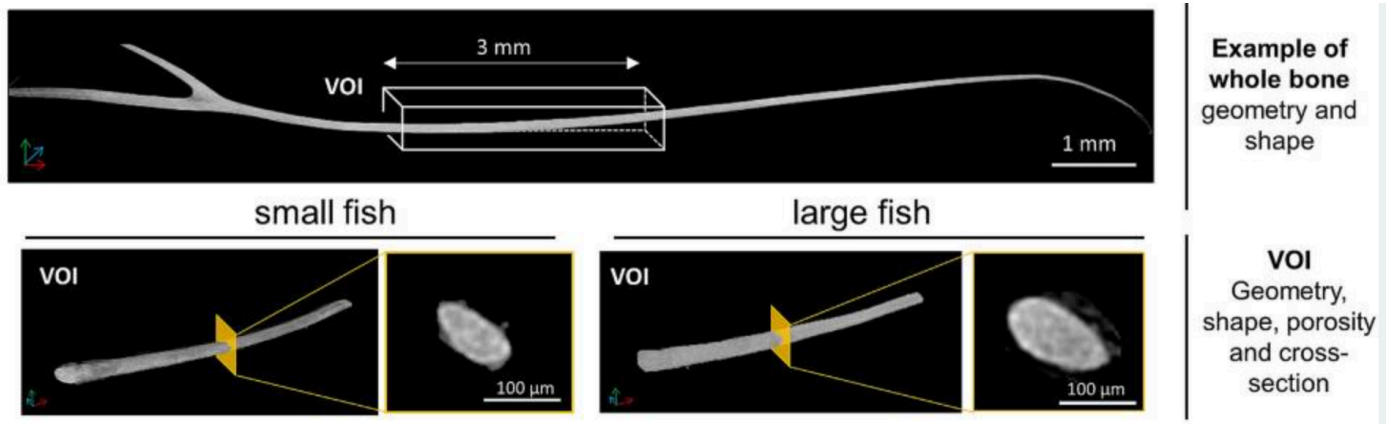
INTRODUCTION



- Intermuscular bone: A type of tissue exclusive to teleosts, such as North Atlantic Herring.
  - Formed by the intramembranous ossification of myoseptal tendons, making it less cartilaginous.
  - Unique dual properties of soft and hard tissue! Strong and Elastic!
- Teleost intermuscular bones exhibit unique mechanical properties due to the relationship between their structure and function.
  - To transmit mechanical forces between muscle and bone >>swim effectively through different types of currents in the ocean

GOAL OF THIS STUDY

Use Nano-CT imaging on intermuscular bone from herring previously subjected to mechanical tensile testing to further investigate the microstructure of intermuscular bone and analyze the changes in mechanical properties and porosity related to aging and other potential factors.



METHODOLOGY

Open .VOL files in boneJ and save as stack of TIFFs

- Multiply pixel values by -0.7 using the attenuation calculations

Open TIFFs in MIMICS and segment bone from pores

- Render 3D volume

Qualitative analysis of images

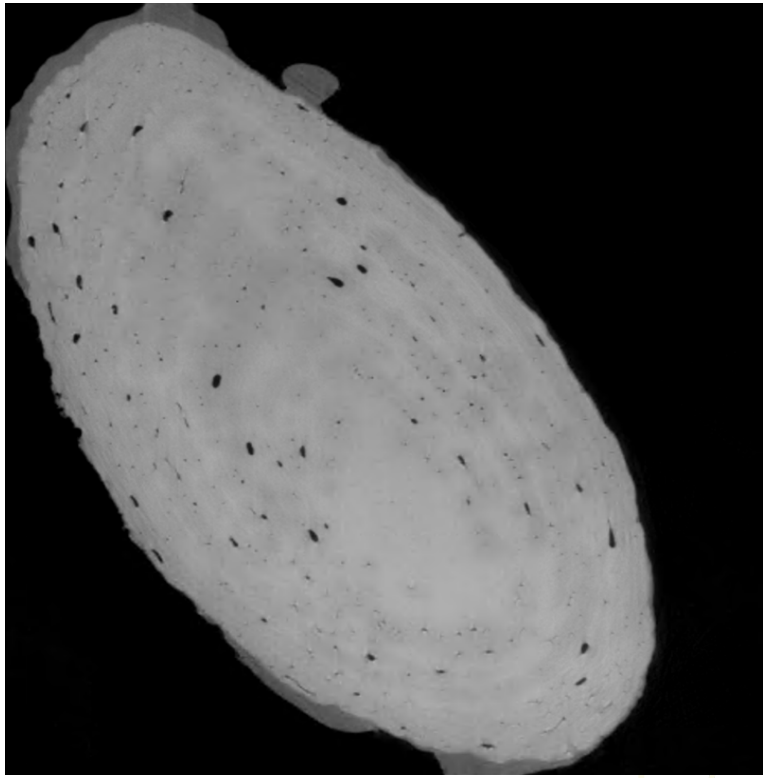
- Radial patterns, band size, pore density

Choose a representative volume 25x25x2

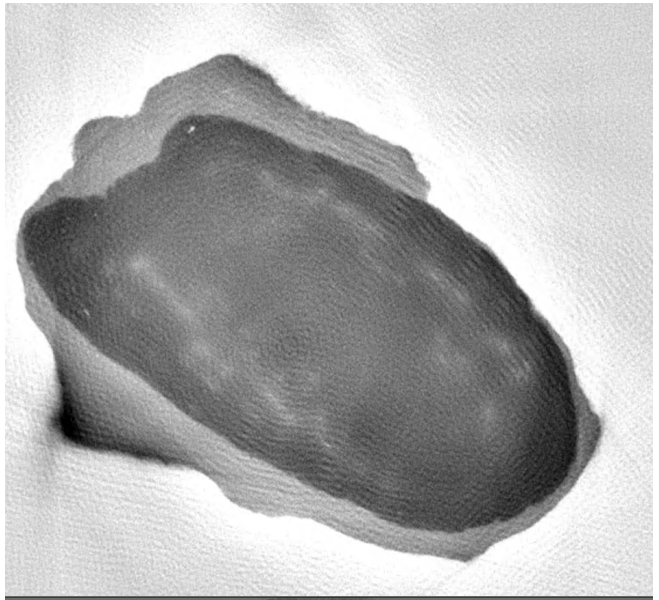
- Incorporates individual constituents of the composite intermuscular bone > best area for modeling.

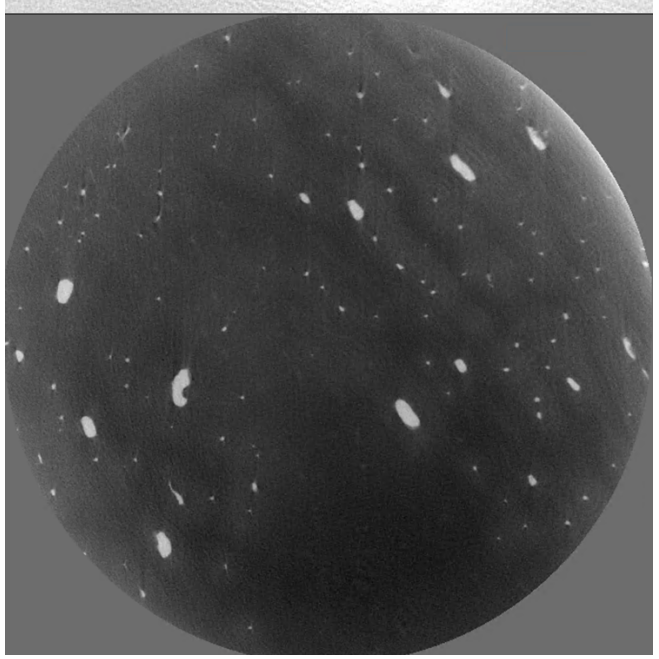
Homogenization and Method of Cells

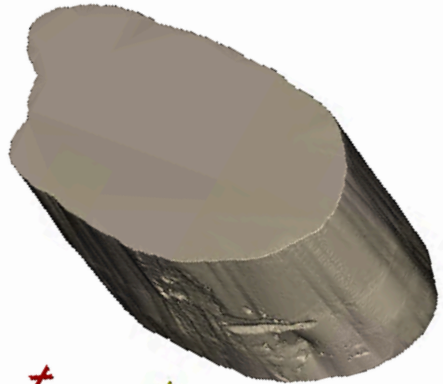
- Micromechanical Analysis



RESULTS







DISCUSSION

- High resolution CT scans power the ability to model bone more precisely
- Applying micromechanical modeling to a large data set of nano-CT scan data
  - analyze the relationship between density and material properties such as elastic modulus and looking deeper at other structural components in bone
- If the proposed aims are achieved, the concepts, methods, technologies and treatments that drive this field could potentially improve - microstructure of bone has a significant influence on its mechanical properties
  - Treatment of bone disease such as osteoporosis
  - Chronic kidney disease
  - Development of biomaterials

CURRENT PROGRESS

- Currently developing the micromechanical MAC/GMC code
  - outputs the stiffness matrix >>elastic modulus for each component in the representative element.
  - In this study, it will output the elastic modulus for the bone, pores and air in the intermuscular bone.
  - The expectation is that the stiffness or elastic modulus values for each bone can be used to see if there is a significant relationship between microstructures and mechanical properties using the large and small intermuscular bone samples with different microporosities and densities.
  - The data will be analyzed using an ANOVA test to compare the results of the two cohorts for statistical significance.

ACKNOWLEDGEMENTS

- Dr. Anthony Lau
- Calvin Ockuliz
- Benjamin Hezrony
- TCNJ MUSE
- Collaborators:Claire Acevedo, Jean-Philippe Berteau

REFERENCES

1. Nie, C. H., Wan, S. M., Liu, Y. L., Liu, H., Wang, W. M., & Gao, Z. X. (2019). Development of Teleost Intermuscular Bones Undergoing Intramembranous Ossification Based on Histological-Transcriptomic-Proteomic Data. International journal of molecular sciences, 20(19), 4698. https://doi.org/10.3390/ijms20194698
2. NICOLE DANOS, ANDREA B. WARD, The homology and origins of intermuscular bones in fishes: phylogenetic or biomechanical determinants?, Biological Journal of the Linnean Society, Volume 106, Issue 3, July 2012, Pages 607–622, https://doi.org/10.1111/j.1095-8312.2012.01893.x
3. Fiedler, I., Zeveleva, S., Duarte, A., Zhao, X., Depalle, B., Cardoso, L., Jin, S., & Berteau, J. P. (2019). Microstructure, mineral and mechanical properties of teleost intermuscular bones. Journal of biomechanics, 94, 59–66. https://doi.org/10.1016/j.jbiomech.2019.07.009
4. Khoury, B. M., Bigelow, E. M., Smith, L. M., Schlecht, S. H., Scheller, E. L., Andarawis-Puri, N., & Jepsen, K. J. (2015). The use of nano-computed tomography to enhance musculoskeletal research. Connective tissue research, 56(2), 106–119. https://doi.org/10.3109/03008207.2015.1005211
5. Lau, A. G., Kindig, M. W., Salzar, R. S., & Kent, R. W. (2015). Micromechanical modeling of calcifying human costal cartilage using the generalized method of cells. Acta Biomaterialia, 18, 226–235. https://doi.org/10.1016/j.actbio.2015.02.012