Micro-CT Imaging and Mechanical Properties of Ovine Ribs

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Introduction

The use of ovine animal models in the study of injury biomechanics and computational modeling has increased in recent years. One particular area of study in which ovine models and other ruminants have been cited is in blast and ballistic related injury. Sheep have been used in injury physiology studies, with applications in behind armor blunt trauma (BABT), spinal cord injury, and acute lung injury, due to their similar physiology and human-like size [1-3]. Ovine computational models exist in the literature, however, there is a gap in the mechanical properties and meso-scale structural geometries of such models [1]. To ensure biofidelity, ovine computational models require representative anatomy, as well as a robust and species-specific material characterization. The objective of this study is to collect mechanical and anatomical properties of the ovine rib using microtomography (micro-CT), three-point bending mechanical testing, and high-rate tensile coupon testing.

Methods

Mechanical Testing: Quasi-static three-point bend testing was completed on ovine rib samples on ribs 3 through 10, from 3 separate rib cages (n = 31). All samples were collected from young (approx. 1 year) ovine rib samples obtained from a local abattoir. The resulting force-displacement data was analyzed to obtain the stiffness, maximum, yield and failure loads and associated displacements (Figure 1). The resulting data was fit with a standard least squares statistical model.

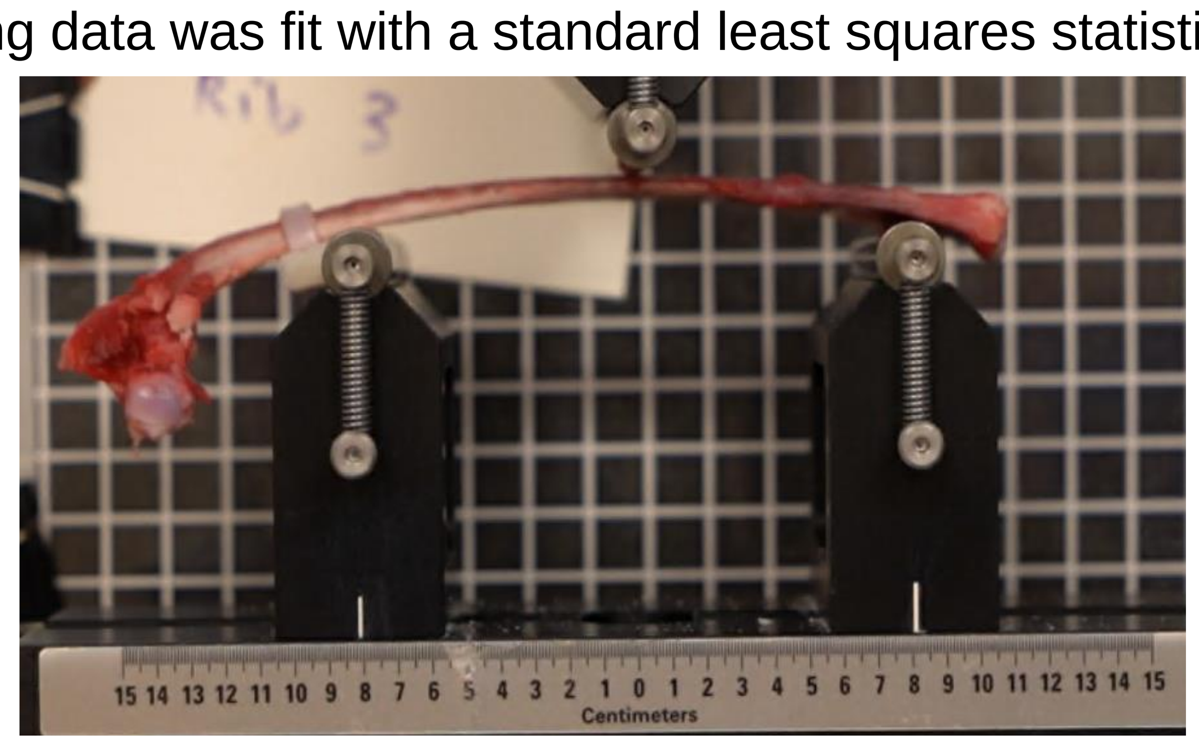

Figure 1: Three-point bend mechanical testing set-up for rib mechanical testing

Tensile high-rate testing was also conducted. Samples were prepared by cutting out the rib bone using a die cut and then split (Figure 3). Specimens (N=7) were loaded at two strain rates, 50 and 200 1/s, using a drop tower set-up.

Figure 2: ASTM D638 Type V dog bone samples for high-rate testing

Imaging: Using micro-CT, specimens were cut into approximately 38 mm sections and scanned. From these scans, the cortical bone thickness and cross-sectional area were measured and used to calculate the moment of inertia (MOI) midway through the length to enhance the mechanical testing data (Figure 3). The MOI was calculated at the point of fracture in ribs 3 through 10. The geometric

Methods (continued)

data was fit with a standard least squares statistical model.

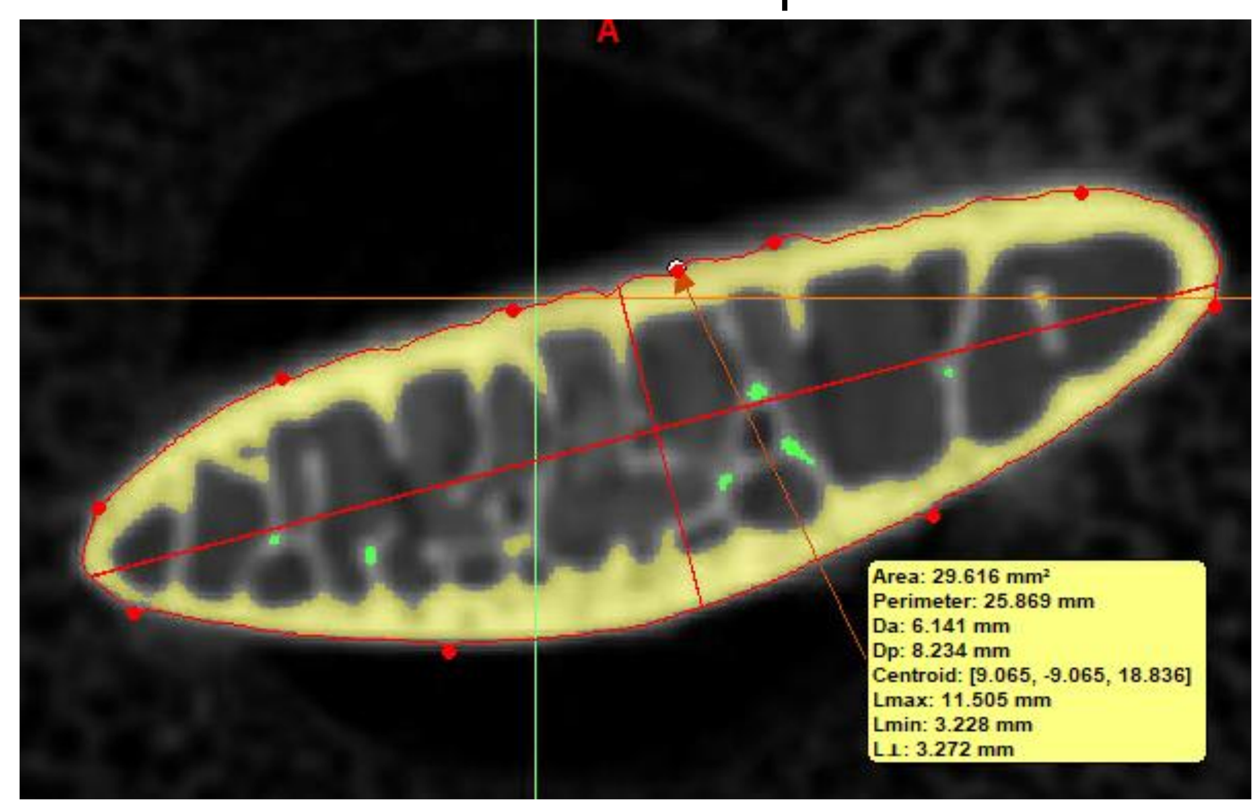

Figure 3: Micro-CT Image with axial cross-sectional measurements

Results and Discussion

Mechanical Testing:

- Elastic Modulus: 4.06 ± 1.60 GPa (Figure 4)
- Rib number did not affect E ($p > 0.05$)
- Animal affected E ($p < 0.05$)
- Rate sensitivity between high-rate and quasi-static experiments (25% increase in E)
- No clear difference between 50 and 200 1/s due to brittle nature of ribs and machine loading limitations

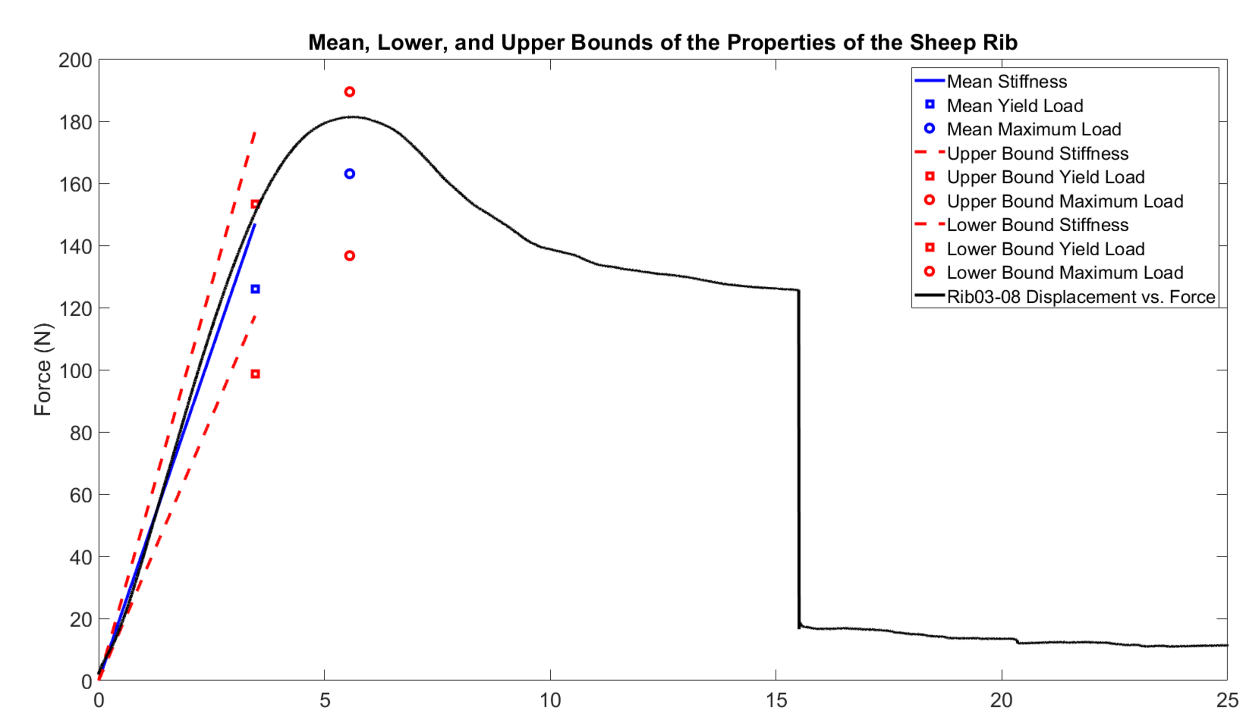

Figure 4: Mean force-displacement curve and properties of quasi-static tests

Imaging:

- Cortical bone thickness varied depending on cross section region and position along length of rib ($p < 0.05$)
- Cross-sectional area did not change ($p > 0.05$)
- Supported through observation of how the cortical thickness varied along the length of the bone.
- Moment of Inertia: 129.8 ± 49.4 mm^4

The data collected in this study will be used in the subsystem validation of an ovine finite element model for use in the study of BABT.

Acknowledgements

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References

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