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# Evaluation of computational cortical bone remodelling in an equine model

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**Key Words:** *Bone remodelling, equine mechanics, cortical bone.*

**Motivation:** Prediction of bone remodelling is hard to evaluate. Due to the similarities in geometry between human and equine joints, the U.S. FDA mandates that testing be done in equine models before progressing to human trials, therefore, the equine model is a good testing base for computational remodeling approaches. Like humans, horses also have cortical bone with haversian canals. We have available a unique equine dataset of bone growth markers with known boundary conditions in a controlled environment to evaluate computational bone remodelling predictions.

**Aim:** To evaluate a cortical bone remodelling algorithm based on the 'mechanostat' [1] by training it on 2 equine data sets and evaluating on 2 additional data sets.

**Dataset:** By alternating the biomarkers Oxylet and Fluorescein, bone growth was marked for each stage of training undertaken by 4 thoroughbreds including rest, trot, canter, gallop, and residual gallop (Figure 1 right). All horses were kept in the same conditions and were subjected to the same five-stage training program. Bone strain gauges were used to measure the boundary conditions for each stage of training specific to each horse. Bone strain was correlated to horse specific shape factors using linear regression at each speed. A 5 mm biopsy was taken from the dorsal mid-shaft aspect of the cannon bone of each horse for computational analysis (Figure 2).

**Model:** The haversian structure from each biopsy was segmented from micro CT data at a resolution of 10 microns. Using a snake-based edge detection algorithm in the open source software *ITK-SNAP* an STL mesh was created (Figure 1). A finite element voxel mesh was generated using Hypermesh that matched the STL surface and exported to Abaqus for displacement driven simulations. The displacement boundary for each horse at each speed was derived from the regression equations of Davies et al. [2]. Using Abaqus integrated with python scripting, we simulated bone evolution for each task and predicted the regions of bone growth. The model was tuned using two equine data sets and evaluated on two others.

We will present the results of haversian canal remodelling under different loading scenarios in addition to demonstrating the importance of exercise history and its effects on the

mechanostat. We will also present the results of probabilistic FE analysis to demonstrate the influence of loading conditions on the predicted remodelled haversian systems.

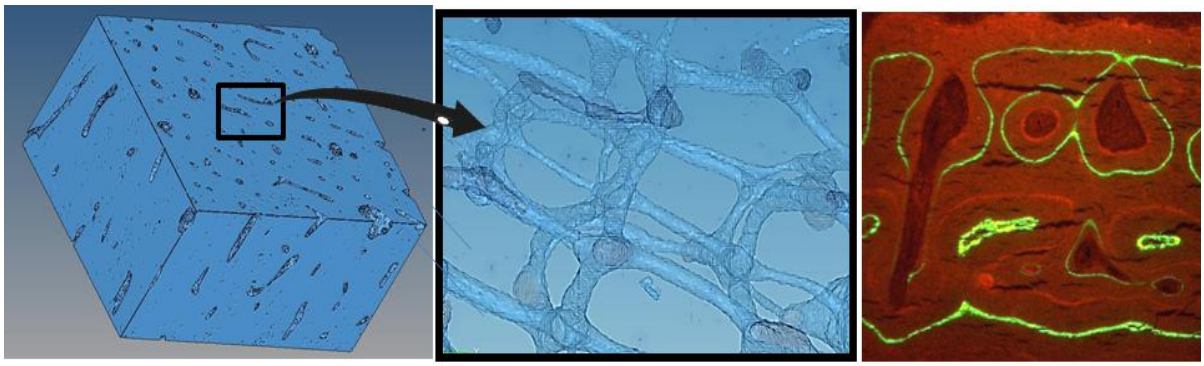

Figure 1. (Left) Representative segmented cortical bone block from dorsal aspect of mid-shaft cannon; and (middle) close-up of transparent haversian canals. (Right) Oxylet and fluorescein biomarkers showing regions of bone growth for specific training speeds.

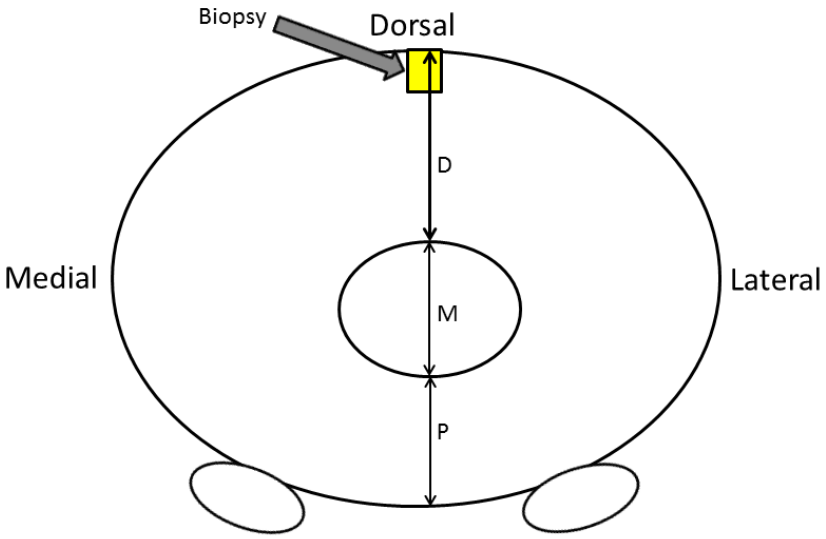


Figure 2. Cross section of mid-shaft cannon bone

$$\text{Shape Factor} = \frac{D^2 + D * P}{P * M}$$

Figure 2. Axial drawing of equine cannon bone showing location of biopsy for computational analysis from dorsal section.

## REFERENCES

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