HOW DOES BONE TISSUE MICROSTRUCTURE RELATE TO *IN VIVO* BONE STRAINS IN THE GOAT RADIUS THROUGH ONTOGENY?

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INTRODUCTION

Past hypotheses concerning a link between form and function in vertebrate limb bones have generally sought to explain how the architecture of both trabecular and cortical bone reflect habitual loading within the limb skeleton. The goal of this study is to examine how ontogenetic changes in limb bone geometry and certain microstructural features within the cortex of the limb bone diaphysis in the goat radius relate to ontogenetic changes in the measured strain environment in the radius.

METHODS

In vivo bone strain data were collected from the cranial, caudal, and medial midshaft surfaces of the goat radius in animals of three age/size groups: 'small' (<6 kg), 'intermediate' (6-11 kg), and 'adult' (>15 kg) [1]. In the weeks prior to strain data collection, fluorescent bone labels were given to the animals to be incorporated in to the growing/ remodeling bone. After the strain data were collected, cross-sectional histological thin-sections were prepared from each radius at the site of strain gauge attachment. Using a microscope equipped with a digital camera, digital images were taken of the thin-sections from each goat using plain, fluorescent, and circularly polarized light microscopy to quantify bone porosity, secondary osteon density, periosteal growth rates, and the orientation of the collagen fibers, which were classified as either being aligned primarily longitudinally (L), transversely (T), or intermediate between the two (I).

The mean and maximal normal cross-sectional strain distributions were mapped on to each bone's cross-section. Using the strain distribution and the anatomical bone axes, each cross-section was divided into eight sub-divisions (Figure 1) and the above histological variables measured in each, using custom MATLAB software.

RESULTS AND DISCUSSION

Measurements from the single 'small' goat examined thus far provide interesting preliminary results. The greatest porosity generally occurs in cranial sub-divisions 1, 2, and 3 (Table 1), which are loaded in tension during maximal strain in the radius midshaft (Figure 1). A lower percentage of longitudinally oriented collagen fibers were observed in caudal sub-divisions 6 and 7, where maximal compression occurs (Table 1). However, there was also a caudal sub-division loaded in compression (6) with a high pore density and a cranial sub-division loaded in tension (3) with a similar collagen fiber profile as sub-division 6. At least in the midshaft of this goat's radius, there are no distinguishing microstructural differences between regions of the bone loaded in tension or compression. Because measurements were made from a young goat, no secondary osteons were observed. However, preliminary observations from older, larger goats show a greater frequency of remodeling in the radius with a greater number of secondary osteons in the caudal regions of the radius. High periosteal growth rates laterally and low growth rates cranially (Table 1) do not correspond to differences in the underlying strain environments in these regions, but are consistent with the growing radius maintaining a higher second moment of area in the medio-lateral, than in the cranio-caudal direction, which has been argued to increase load and bending predictability in the goat radius [1].

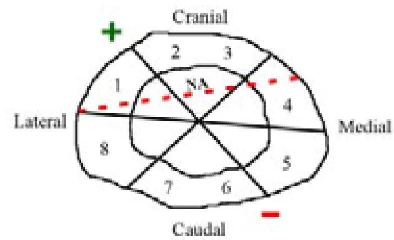

Figure 1: Goat radius divided into eight sub-sections for histological analysis. The dashed line labeled 'NA' represents the position of the neutral axis of bending when longitudinal strains are maximal; loading the cranial and caudal surfaces in tension and compression, respectively.

Further inclusion of more samples from goats over a wider range of ages/sizes would allow for stronger conclusions and possible identification of a link between bone architecture and the mechanical environments in which bone growth and remodeling occur.

REFERENCES

1. Main RP and AA Biewener. *J Exp Biol* **207**, 2577-2588, 2004.

Table 1: Measurements of periosteal growth rate, porosity, and collagen fiber orientation in the different goat radius sub-divisions.

	Numbered Sub-division of the Goat Radius Cross-section							
	1	2	3	4	5	6	7	8
Periosteal growth rate (μm/day)	8.7 ± 0.8	2.7 ± 0.7	4.0 ± 0.4	4.1 ± 0.3	5.6 ± 0.5	5.1 ± 0.5	6.7 ± 0.4	18.0 ± 0.2
Porosity (pores/mm^2)	13 ± 0	13 ± 1	11 ± 4	8 ± 0	9 ± 2	12 ± 5	9 ± 5	6 ± 0
Collagen fiber orientation (% L, % I, % T)	97 ± 2 3 ± 2 0 ± 0	97 ± 1 3 ± 1 0 ± 0	79 ± 3 17 ± 1 4 ± 3	97 ± 2 2 ± 1 1 ± 1	97 ± 1 3 ± 1 0 ± 0	83 ± 3 16 ± 2 1 ± 2	55 ± 5 26 ± 6 20 ± 1	93 ± 2 5 ± 2 1 ± 1