INTRODUCTION: A bone's strain (or stress) history is thought to be reflected in its internal cortical structure and external shape (1,2). Many of the morphological features resulting from these strain histories are evident in the bone's microstructure. These features allow bone to control the forces and moments placed on the bone by the attached muscles and other tissues. In this study, we examine the relationship between the mechanical history of the bone and its internal structure. This relationship is expressed in the form of a statistical model that relates the bone's microstructure to its mechanical behavior.

EVIDENCE OF POTENTIAL STRAIN-MODE-SPECIFIC DIFFERENCES IN CORTICAL BONE MICROSTRUCTURE IN A TENSION/COMPRESION SYSTEM

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MATERIALS AND METHODS: Ten skeletal mature male mule deer (Cervus elaphus hemionus hemionus) calvariae were each sectioned transversely at 40, 50 and 70 percent of length (L). Each section was embedded in polyethylene methylacrylate and the degree of porosity in the polished and prepared sections for imaging was measured by the backscattered electron (BSE) mode in a JEOL scanning electron microscope. A total of 160 images, representing almost 650 square millimeters of cortical bone, were recorded on Polaroid 52 film and saved for analysis. The cortical and cancellous cortices of each section were subdivided into three regions: subperiosteal (P), middle (M), and endosteal (E) (Fig 1). The subperiosteal region was defined as being immediately adjacent to the periosteal surface, without including any circumferential lamellae. The middle region was defined as half-way between the periosteum and the border of the endosteal canal. The endosteal region was defined as being adjacent to the endosteal canal. Only 50% and two 100% images were taken in each region. Care was taken to avoid any overlying of the 50% images. The 100% images were taken within the bounds of the 50% images. The images were analyzed for the number of osteons, fractional area occupied by secondary (cortical) bone, and percent of area. Comparisons between shear stress in the different regions were made using an ANOVA design and the level of significance was set at p<0.01. Since there is a transverse cortical strain magnitude gradient, comparisons were also made between the P, M and E regions within each cortex.

RESULTS: Results are shown in Table 1. There were more osteons in the compression cortex (38±15/mm²) than in the tension cortex (34±10/mm²) (p<0.01). There were also more interstitial bone in the compression cortex (Cranial 1.3±0.4 mm²/image vs Caudal 0.88±0.3 mm²/image) (p<0.01). Osteons in the cancellous cortex were oval and irregularly shaped than those in the compression cortex. Backscattered electron (BSE) greylevel showing lower mineral content indicated that the osteons in the tension cortex were younger. The porosity of the cancellous cortex (8.5±5.9%) was greater than the porosity of the cranial (compression) cortex (4.7±2.0%) (p<0.01). Comparisons between the three regions (Fig. 1B) within the respective cortices showed no differences between the subperiosteal region and the middle region in terms of porosity and all osteon parameters examined (Table 1). However, in the endosteal regions (Fig. 1B) of both strain environments, there were fewer osteons. The osteons were also larger than in either the middle or subperiosteal regions. The porosity of the medullary regions (8.9±6.9%) was greater when compared to both subperiosteal (5.2±2.1%) and middle regions (5.3±2.7%) (p<0.01) in both strain environments. Comparisons between the three regions along the length of the bone in both strain environments showed no differences in any of the parameters examined in this study.

DISCUSSION: Julius Wolff (5) suggested that tension and compression loading are important in directing bone adaptation.