Local Variations of Fabric Anisotropy in the Human Calcaneus
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INTRODUCTION: The human calcaneus is the preferred skeletal site for assessment of changes in bone mass using quantitative ultrasound (QUS) – a non invasive, radiation-free and inexpensive approach [1-3]. In recent studies, QUS has shown the ability to quantify mass density with accuracy and repeatability similar to BMD from DEXA. While these approaches can measure global changes in mass density, they do not distinguish microarchitectural changes during bone loss [4-7]. Importantly, ultrasound waves are sensitive to changes in bone microarchitecture [8-11], but such ability has not been exploited in measurements at the calcaneus since ultrasound interrogation at this skeletal site is often performed in the medio-lateral direction only.

The aim of this study was to investigate the local variation of bone microarchitecture (fabric) and the degree of anisotropy at four anatomical locations within the human calcaneus. Significant differences among local regions may indicate the need for the use of anisotropic models of wave propagation when assessing directional changes in bone microarchitecture with ultrasound.

METHODS: Sample Preparation. Sixteen human calcanei were obtained from the National Disease Research Interchange. Donors were female with age ranging from 60 to 80 years old. Whole bone samples were formaldehyde fixed for 48h and cleaned free of soft tissue prior to microCT scanning. MicroCT Image Acquisition. Images acquisition was performed using a SkyScan 1172 micro-CT scanner (Skyscan, Belgium) with isotropic voxelsize of 13.47 μm (80kVe, 125μA, field of view 54mm, 11h scan duration). The sample was contained in a holder filled with PBS to prevent dehydration and/or shrinkage of the sample during the scan. Image Processing. Approximately 4000 images (cross sections) were reconstructed using NRecon software (V1.6.1.1, SkyScan) and compensated for misalignment, ring artifacts and beam hardening. Image Analysis. Cross sections were then imported into CTAn (Ver. 3.0 skyScan, Belgium), an image processing software for segmentation of bone and marrow compartments. A single global threshold value was used to obtain the 3D volume for the trabecular bone and marrow spacing. Microarchitectural characterization. The regions of interest were selected in CT-analyzer software (SkyScan™) using a circle with a diameter of 7mm in each specific anatomical region (top, bottom, medial, or lateral). A second circle at the same anatomical area, but at a depth of 25mm from the first one was selected. By dynamic interpolation, four volume of interest were created for each sample. The Mean Intercept Length (MIL) was measured on each image and described as an ellipsoid [12]. The software was used to calculate the MIL by setting parallel equidistant lines through a 3D image volume and described as an ellipsoid [12]. The software was used to calculate the MIL by setting parallel equidistant lines through a 3D image volume and described as an ellipsoid [12]. The software was used to calculate the MIL by setting parallel equidistant lines through a 3D image volume and described as an ellipsoid [12]. The software was used to calculate the MIL by setting parallel equidistant lines through a 3D image volume and described as an ellipsoid [12]. The software was used to calculate the MIL by setting parallel equidistant lines through a 3D image volume and described as an ellipsoid [12]. The software was used to calculate the MIL by setting parallel equidistant lines through a 3D image volume and described as an ellipsoid [12].

DISCUSSION: This result indicates that a) there exist local differences in the density of the samples, and, b) the microarchitecture in the analyzed regions is anisotropic with a preferred alignment along the posterior-anterior direction. These differences in local microarchitecture suggest that the use of a homogeneous/equivalent medium approximation for the analysis of wave propagation may not be always valid. The use of anisotropic wave propagation poroelastic models [14] may be necessary to better characterize the wave propagation in osteoporotic bone at the calcaneal bone, the preferred skeletal site for QUS assessment test.


ACKNOWLEDGEMENTS: This work was financially supported by grants from the NIH/NIA (AG34198) and the NSF/MRI (CBET 0723027)