

# Degree of Bone Mineralization in the Ultra Distal Radius as a Function of Type and Location

+Wagner, D W; Lindsey, D P; Beaupre, G S

Bone & Joint Center of Excellence, VA Palo Alto Health Care System, Palo Alto, CA 94304

dwwagner@va51.stanford.edu

## INTRODUCTION:

The degree of mineralization of bone (DMB) is a metric that has been used to non-destructively quantify the distribution of mineral density using micro-computed tomography (microCT). Small increases in the average DMB value have been shown to correlate with substantial increases in experimentally derived bone fracture strength [1]. However, the role of mineral heterogeneity remains ambiguous as both increases and decreases in heterogeneity have been associated with reduced fracture strength [1]. One potential reason may be attributed to a lack of understanding related to the customary mineral heterogeneity of typical cortical and trabecular bone tissue. Although the peripheral radius site has received increased attention with the introduction of micro-level imaging technology for clinical use, the DMB has not been well studied for the distal radius. The purpose of this study is to quantify the DMB distributions of the distal radius and identify trends related to proximal/distal location and trabecular/cortical bone sub-regions.

## METHODS:

Ten excised left radii from adult donors were scanned with a Scanco vivaCT 40 microCT scanner. The radii were excised from fresh frozen cadavers from 7 men and 3 women (age range from 64 to 88 years). The distal section of each radius was scanned from the most proximal subchondral point through a distance of 24 mm proximally along the longitudinal axis. Each scan was performed using the following settings: 55kVp, 145  $\mu$ A, 1000 ms integration time, 19  $\mu$ m voxel size; a 1200 mg-HA/cm<sup>3</sup> beam hardening correction algorithm was also applied. A semi-automated contouring algorithm [2] was applied to identify the cortical and trabecular regions of each axial slice. Bone tissue was segmented using a constant threshold and a peeling procedure [3] of two voxels was applied to reduce partial volume effects. Three volumes of interest (VOI), each 9 mm in length along the longitudinal axis, defined as the most distal (MD), middle (MI), and most proximal (MP) were analyzed (Figure 1).

The microCT derived voxel-based linear attenuation values were converted to an equivalent hydroxyapatite density (i.e. mgHA/cm<sup>3</sup>) using the manufacturer supplied calibration curve. The DMB values for each voxel were extracted for each VOI/contour combination and grouped in bins of 6.0538 mgHA/cm<sup>3</sup> to construct the DMB distribution. Parameters of the DMB distribution including, mean density, peak density, and full width at half max (FWHM) were analyzed.

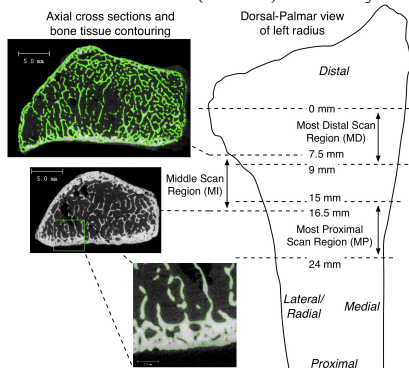


Figure 1. Graphical depiction of the volumes of interest and example contours of the bone tissue.

## RESULTS:

The DMB distributions for the cortical contoured region of a single representative specimen are depicted in Figure 2. The mean density for the cortical contoured region increased for all specimens as the analyzed VOI moved proximally. The average difference in mean density between the MD and MP VOIs for all specimens was 77 mgHA/cm<sup>3</sup>, or 9% when normalized to each specimen's MD mean. The average difference between the MD and MP VOIs for the tissue in the trabecular region only was 16 mgHA/cm<sup>3</sup>, or 2% of the MD means. The peak densities of the cortical contoured region showed a similar relationship as the mean densities, with a normalized difference of 12% between the MD and MP volumes. The mean density of the cortical region was

higher than the trabecular region for the same VOIs for all specimens with an average difference of 63, 92, and 124 mgHA/cm<sup>3</sup> for the MD, MI, and MP volumes, respectively.

The full width at half max (FWHM) metric did not demonstrate any consistent trends between the cortical and trabecular regions or between the proximal/distal locations of the analyzed volume. On average, the FWHM of the cortical region was higher than the corresponding trabecular region by  $12 \pm 19$  mgHA/cm<sup>3</sup>.

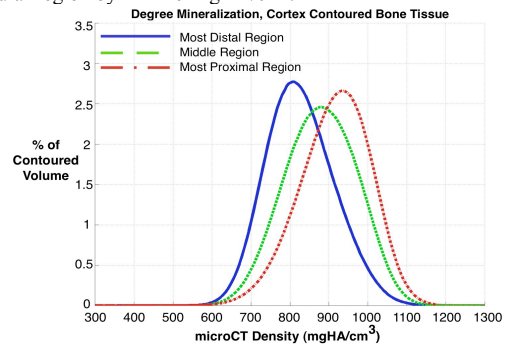


Figure 2. Degree mineralization of bone for the cortical contoured region of one representative specimen.

## DISCUSSION:

The purpose of this study was to evaluate the DMB for different locations and contoured regions of the distal radius. The data showed a larger average and peak mineralization for cortical bone than cancellous bone in all analyzed volumes. This differs from data presented by Boivin and Meunier [4], who showed a slight increase in the peak DMB for cancellous versus cortical bone for iliac bone samples using contact micro-radiography. In contrast, Mulder et al. [5] observed a higher DMB in developing corpus (develops into cortical bone) versus condyle (develops into trabecular bone) bone from pig mandible specimens measured with microCT, which agree with the findings presented here. The mean and peak densities of trabecular bone were consistent across the analyzed regions. This is in agreement with data presented by Roschger et al. [6], who observed less than a one percent standard deviation (normalized to the mean) of the mean calcium content for 5 different trabecular regions of the same transiliac specimen measured using quantitative backscattered electron imaging. In contrast, the mean and peak densities of cortical bone increased as the VOI moved proximally for all subjects analyzed here. One potential explanation may be attributed to the narrowing of the cortical bone region as the VOI moves longitudinally in the proximal to distal direction. In the narrow cortical regions (e.g., the radial aspect in the most distal axial cross section shown in Figure 1) trabecular tissue may be included as an artifact of the contouring algorithm and confounding the comparison of cortical bone mineral density as a function of proximal/distal location.

This study did not analyze mineralization distribution skewness or kurtosis metrics, which may also contribute to shifts in the observed mean and peak mineralization. The mineralization heterogeneity (as defined by FWHM) was not substantially different across the VOI and contoured regions suggesting that although mean and peak mineralization may be dependent on the analyzed region, the heterogeneity is not.

## SIGNIFICANCE:

Understanding the functional behavior of the bone mineralization distribution is critical to the future development of metrics for identifying when normal bone homeostasis is interrupted and subsequently that a patient may benefit from a pharmacological or lifestyle intervention to reduce the risks associated with osteoporosis.

## REFERENCES:

[1] Marcus, Osteoporosis vol. 1, 2008; [2] Buie et al., Bone, 41:505-15, 2007; [3] Fajardo et al., Bone, 44:176-184, 2009; [4] Boivin et al. Calcif Tissue Int, 70:503-11, 2002; [5] Mulder et al. Anat Embryol (Berl), 211:71-8, 2006; [6] Roschger et al., Bone, 23:319-26, 1998.

## ACKNOWLEDGEMENTS:

Supported by the Dept of Veterans Affairs, Rehab R&D (Proj. A6816R).