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A HISTOMORPHOMETRIC ANALYSIS OF INTACT, FRAGMENTARY, AND DRIFTING OSTEONS IN THE ADULT MID-SHAFT FEMUR

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Abstract

The relationship between mechanical loading and bone dynamics has been well studied through comparisons of cross-sectional shape and investigations of microstructural organization. Previous research suggests that topographical bone remodeling may coincide with the orientation of predicted bending forces in long bone diaphyses.

I utilized mid-shaft femur cross-sections (n=52) from a known-age cadaveric population to assess the amount of variability in intact (PI), fragmentary (PF), and drifting (PD) osteon population densities along the major (Imax) and minor (Imin) centroidal axes. Due to their unknown etiology, I placed particular emphasis on drifting osteons. Heterogeneous osteon distributions across assessment locations (ImaxAnt, ImaxPost, IminLat, and IminMed) reflect a relationship between bone geometry and remodeling activity. It was hypothesized that regions of interest (ROIs) centered along the Imin axis would exhibit more extensive bone remodeling in order to accommodate greater mechanical loadings. Age and sex effects were also considered, given that these factors are known to influence the rates and characteristics of bone remodeling.

Contrary to expectations, analysis of variance (ANOVA) conducted on mean variable data revealed no significant differences between assessment locations for the PF and PD variables. For PI, the Imin assessment locations were more variable and exhibited greater mean values than the Imax assessment locations. Significant differences were observed among four pair-wise location comparisons: ImaxAnt vs. IminLat, ImaxAnt vs IminMed, ImaxPost vs IminLat, and ImaxPost vs IminMed. Thus, in terms of bending stresses/strains, as inferred through cross-sectional geometric analysis, intact osteons appear to be the most relevant microstructural adaptation for deducing mechanically driven bone turnover. New intact osteons not only remove damaged tissue, but also promote toughness by increasing cement line and lamellar interfaces. Fragmentary and drifting osteons more strongly reflect other biological relationships, such as that between remodeling and age-related change, or between remodeling and metabolic demands.

ANOVAs executed on derived variables, osteon population density (OPD) and percent drifting osteons (%Dr.On.), yielded insignificant results, masking the assessment location effect of the PI variable. These data advise the use of constituent OPD variables when assessing both regional variability and inferring load history in the mid-shaft human femur.

Intact population densities did not significantly correlate with age in females, and only PIImax significantly correlated with age in males. The remaining histological variables demonstrated the same age-related patterns in both sexes. With advancing age, PF and OPD increased, whereas PD and %Dr.On. decreased. In agreement with Crowder

and Domínguez (2012), age-related turnover events are best expressed in terms of fragments, and constituent OPD variables should be considered in histological methods for age-at-death estimation. In females, fragmentary osteon population densities are higher and probably reflect both physiological and dimorphic differences between the sexes. Although stochastic remodeling or mechanical factors cannot be ruled out by this research, other studies provide strong evidence for the metabolic causation of drifting osteons. In this view, high frequencies of drift in younger individuals are at least partially related to the need for mineral ions during growth and reproduction.