H8 Mapping Spatial Patterns in Cortical Bone Histology From the Femoral Midshaft Using Geographic Information Systems Software

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After attending this presentation, attendees will be better able to conceptualize the spatial variation and distribution in skeletal remodeling events across the entire cortex of the femoral midshaft.

This presentation will impact the forensic science community by demonstrating the use of Geographic Information Systems (GIS) software as a new method for the analysis of bone microstructure that may better inform sampling procedures employed for the estimation of age-at-death through histological means.

When constructing a biological profile of unknown human skeletal remains, forensic anthropologists must estimate the age-at-death of the decedent. As a complement to traditional macroscopic methods employed, or when the necessary macroscopic elements are absent, age estimation can be conducted through a histological examination of remodeling events in cortical bone. During the last half century, the femoral midshaft has been the most commonly employed skeletal site for obtaining histological age estimates; however, different methods employ various sampling locations that differ in size, number, and location for the collection of histological data across the cortex. Building upon recent work that has demonstrated the utility of GIS software for the study of human bone microstructure, this pilot study employed GIS software to examine patterns in the spatial distribution of histological remodeling events across the entirety of the femoral midshaft.[1]

Ten femoral midshaft samples from modern cadaveric donors (five male, five female) were photographed under polarized light and micrographs were compiled into seamless cross-sectional images; samples ranged in age from 30-76 years at time of death, with a mean age of 54.5 years. Images were imported into ArcGIS™ (v. 10.1), where polygon features were created to overlay the cortical area and point features were created to mark all intact and fragmentary osteons, as well as resorption spaces. A total of 66,491 remodeling events were manually notated and density maps were generated to visualize the clustering of remodeling events across the cortex. Density maps revealed a striking qualitative pattern, with the highest density of remodeling events in the lateral/anterolateral cortex across both sexes and all ages.

To quantitatively analyze this pattern, cortical areas were digitally divided into quadrants to delineate standard anterior, medial, posterior, and lateral quadrants, as well as offset anterolateral, anteromedial, posteromedial, and posterolateral quadrants. The total number of remodeling events contained within the area of each quadrant was used to determine Osteon Population Density (OPD; remodeling events/mm^2). One-way Analysis Of Variance (ANOVA) tests demonstrated a significant difference in OPD values for both the standard quadrant system ($F=5.752$, $p<0.01$) and the offset quadrant system ($F=6.031$, $p<0.01$). A statistically significant positive correlation coefficient was found between OPD and age-at-death ($p<0.05$) for all standard and offset quadrants with the sole exception of the posterior quadrant, which was not statistically significant.

Remodeling events were further investigated for their distribution across the depth of the femoral cortex. Measurements were taken to digitally divide the cortex into periosteal, middle, and endosteal cortical thirds. A one-way ANOVA test yielded no significant difference between OPD values for the periosteal, middle, and endosteal thirds ($F=2.726$, $p>0.05$). However, correlation between OPD and age differed greatly across the depth of the cortex: the periosteal third yielded the highest correlation ($r=0.911$, $p<0.001$); the middle third was also significant ($r=0.729$, $p<0.05$); and the endosteal third did not significantly correlate ($r=0.600$, $p>0.05$). A significant correlation was also found between OPD and age for the entire femoral cortex ($r=0.854$, $p<0.01$).

This pilot study demonstrates the utility and potential of using GIS software for mapping spatial patterns of histological remodeling in human cortical bone. Continued research is underway to further refine which sampling location (or combination of sampling locations) across the cortex will yield the best age-at-death estimates, with specific focus on determining when different cortical regions become saturated with remodeling events and reach the OPD asymptote. Elucidating these patterns will be of great use to forensic anthropologists who use histological methods for estimation of age-at-death from human skeletal remains.

References:

1. Rose DC, Agnew AM, Gocha TP, Stout SD, Field JS. The use of geographic information systems software for the spatial analysis of bone microstructure. Am J Phys Anthropol 148:648-54.

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