A30 Utilizing Osteon Volume for Histological Age-at-Death Estimation

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Learning Overview: After attending this presentation, attendees will appreciate the utility of incorporating Geographic Information Systems (GIS) technology to visualize and analyze the spatial distribution of histological structures, as well as to quantify and measure the size and type of these structures in bone in three dimensions.

Impact on the Forensic Science Community: This presentation will impact the forensic science community by improving collective understanding of both osteonal volumetric calculations and how such information can be used to improve human age estimation.

Histological examination of remodeling events in cortical bone has been used to estimate adult age at death if appropriate macroscopic elements are damaged or absent. There are several approaches that have examined different skeletal elements, variable histological variables, and diverse regions of interest. What is common to all these methods is that a single transverse section is utilized, thus viewed in two dimensions. Osteons and associated bony remodeling events are 3D, dynamic structures. Osteonal shape may be round to elliptical in cross section and 200–250 microns in diameter; cylindrical in shape and one to ten millimeters in length; and oriented at 11–17 degrees off the longitudinal z-axis. None of these known 3D features have been incorporated into histological age estimation methods. Incorporating osteonal features, such as volume, into age regression equations, may improve the accuracy and replicability of age estimation formulae.

The current study employed a GIS-based analytical approach to digitally map, quantify, and connect remodeling events on three serial cross-sections, providing a 3D, volumetric perspective of bone remodeling. To develop the method, vertical alignment grooves were cut into the cortex of an adult human femoral midshaft to maintain multi-planar spatial orientation. Three serial thin-sections of approximately 70 microns were subsequently cut; they were separated by 300 microns due to blade thickness, resulting in an overall z-axis dimension of approximately 800 microns. Each cross-section was photographed in its entirety under circularly polarized light and composited using panorama-stitching software. Using georeferencing tools, the three cross-sections were aligned as overlays in arcGIS® v10.2. Intact and fragmentary osteons were manually outlined using polygon feature classes; these histological units were then connected across the cross-sections utilizing buffer and join processes. The centroid was identified for each cross-section, permitting the overlay of a quadrant and octant system. This allowed comparison of histological variables between quadrants both within and between cross-sections.

One thousand osteons were outlined using polygon feature class layers for each cross-section and a random sample of 30 connecting osteons were selected from eight octants (anterior, medial, posterior, lateral, anteromedial, posteromedial, anterolateral, and anteromedial) for comparative analyses. The area of the osteons was compared between quadrants and across layers using Analysis of Variance (ANOVA) statistical tests. Osteonal area was found to be smaller in the anterior portion of the femoral cross-section, likely due to faster remodeling from increased strain. Osteon area was also compared within quadrants between cross-sections. There were statistically significant ($p<0.05$) differences within the same quadrant of different transverse sectional layers. These results suggest that osteon area may not be a reliable indicator for histological analyses, as the average area of osteons differs between layers a mere 300 microns apart. Utilizing truncated cone geometric functions, the volume of the 240 connected osteons was interpolated and compared between quadrants. Osteon volume was significantly different between the anterior and posterior portions of the transverse section; however, there were no significant differences in osteon volume between quadrants of the same portions. That is, anterior, anterolateral, and anteromedial did not differ from each other, and nor did the posterior, posterolateral, and posteromedial quadrants differ from each other. These results indicate that region of interest may matter less when utilizing volumetric interpolations for histological variables. Volumetric calculations may be more robust and consistent across serial transverse sections and, if incorporated into age-at-death estimation equations, may serve to improve the accuracy and reproducibility of such approaches.

Age Estimation, Skeletal Histology, Geographic Information Systems