A69 Volumetric Histological Age Estimation Utilizing a Geographic Information Systems (GIS) -Based Analytical Approach

Suzanna Michener, MSc, Simon Fraser University, 8888 University Drive, Burnaby, BC V3Z 0E3, CANADA; Lynne S. Bell, PhD, Simon Fraser University, Dept of Criminology, 8888 University Drive, Burnaby, BC V5A 1S6, CANADA; Nadine Schuurman, PhD, Simon Fraser University, 8888 University Drive, Burnaby, BC V5A1S6, CANADA; and David Swanlund, BA, Simon Fraser University, 8888 University Drive, Burnaby, BC V5A1S6, CANADA*

After attending this presentation, attendees will appreciate the potential of using GIS software to visualize and analyze bone histological structures three-dimensionally.

This presentation will impact the forensic science community by introducing a new method of viewing and quantifying histological remodeling events that are used for age estimation.

If salient macroscopic elements are damaged or missing, adult human age can be estimated through histological examination of the remodeling events in cortical bone. Several techniques have been developed and refined but, to date, all analysis has focused on a single two-dimensional plane. Osteons are 3D structures; they are typically cylindrical in shape, round to ovoid in cross section, 200-250 micrometers (µm) in diameter, one to ten millimeters long, and oriented on average 11°-17° relative to the long-axis of the bone. They are also dynamic structures; they grow, age, and are resorbed. Utilizing the volume of osteons, or incorporating the stage of osteonal development into age estimation regression formulas, may minimize standard error estimates and improve age estimates when building the biological profile in forensic cases.

To date, the only way to view osteons in three dimensions is to use confocal microscopy, which provides a maximum z-axis depth of no more than 100µm, or to use micro-Computed Tomography (micro-CT) or synchrotron-assisted micro-CT, which is better suited for negative spaces, such as the pores or Haversian canals in bone tissue. The current study employed a GIS-based analytical approach to digitally map remodeling events on three serial cross-sections, thereby providing a 3D perspective of bone remodeling. The use of GIS techniques for bone histological analysis is novel, but researchers have previously utilized arcGIS® to manually delineate intracortical remodeling events as polygon feature classes across a single section of femoral midshaft. This study extends this approach in which osteonal systems are measured three-dimensionally, potentially allowing for a more realistic assessment of their features, but it necessitates several additional steps. First, vertical alignment grooves were cut into the cortex of an adult human femoral midshaft in order to maintain multi-planar spatial orientation. Three serial thin-sections of approximately 80µm were subsequently cut using a Leica® SP1600 microtome saw; they were separated by 300µm due to blade thickness, providing an overall height of approximately 840µm. Second, each sample was photographed under circularly polarized light and combined into a seamless image using free photo-stitching software. These entire cross-sections were then imported into arcGIS® v10.1 and aligned to overlay using the vertical grooves as georeferencing points, tying the layers to each other. Third, polygon features tracing the cement line were manually created to overlay each remodeling event.

To accommodate for the off-axis vertical path at which osteons may form, as well as the void created by the saw blade, buffers were produced in arcGIS® around the polygon features, allowing osteons found on multiple cross sections to be connected to each other. Once the osteons on the serial sections were identified as the same remodeling event, they were coded appropriately and excluded from other potential matches. Not all osteons could be followed through all three sections, and some osteons in one layer could potentially connect to multiple others in the next layer. In such cases, the relative size and shape of osteons were used to connect related osteons in different layers. Change detection algorithms to quantify differences in area and shape between remodeling events in the transverse sections provided a volumetric measurement of individual osteons based on the formula for a cylinder.

This study reinforces the value and utility of GIS-based analysis for identifying, comparing, and capturing patterns for histological mapping, as well as introduces the concept of volumetric osteonal measurement for histological age estimation.

Age Estimation, Skeletal Histology, Forensic Anthropology

*Presenting Author