New Insights into the Identification of Bone Fragments in Forensic Science

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Biogenic hydroxyapatite (HA) is a poorly crystalline material that has been studied extensively using a number of analytical methods [1,2]. With regards to bone's mechanical properties, many studies have examined architectural adaptions within bone and the effects of its variation [3]. There is also significant work on the effect of specific mineralization (amount bone mineral per bone matrix, irrespective of bone volume and void spaces) [4]. With regards to intra-individual and intra-bone element variability of physicochemical properties, several studies have measured between different sampling sites on the same skeletal element, and recently Gonçalves et al. [5], has studied both intra-bone and inter-bone differences, though only through the use of Fourier transform infrared spectroscopy (FTIR).

The work presented herein aims to correlate bone's physicochemical features with bone function. Skeletal elements are categorized by function as (a) mechanical – weight bearing (femur and humerus), (b) mechanical – protective (sternum), and (c) hematopoiesis/homeostasis (sacrum and pelvis). Weight bearing long bone adaptions depend on species, as quadrupeds' weight bearing is spread over both fore and hind limbs, dramatically different from bipeds. Thus, in a bovine individual both the fore limb (e.g. the humerus) and the hind limb (e.g. the femur) share weight nearly equally [6, p.254]. Protective skeletal elements possess a layer of cancellous bone enclosed by two plates of cortical bone (e.g. the ribs and the skull) [7]. These elements have evolved to protect vital organs from harm. For this reason, they are expected to be less stiff, as elasticity and transfer of load along the structure is needed for this protection. Maintenance of hematopoiesis (production of blood cells) and mineral homeostasis are provided by skeletal elements that act as an ion sink for both calcium and phosphates; one would expect they will have characteristics which allow rapid dissolution: higher strain within the material, such as that induced by higher rates of carbonate substitution [8], higher surface area, achieved with a high proportion of trabecular bone [7], and higher turnover rates, leading to younger average tissue age and higher levels of carbonate substitution [2].

A total of 30 samples, 6 repeated samples from each of five sites, were taken from a single bovine individual (sourced ethically from the Animal Health and Veterinary Laboratories Agency). X-ray diffraction (XRD) and FTIR were used to probe physicochemical differences within the bones. Principal component analysis (PCA) was performed on the raw diffraction signatures. Profile fitting with was used to determine the full width half maximum (FWHM) for calculation of coherence length, as well as lattice parameters. All FTIR spectra were analyzed by measuring the area and height of relevant absorption bands; peak fitting was used to determine A-type, B-type, and labile carbonate contributions.

PCA of the diffraction signatures clustered samples into weight bearing, protective, and homeostasis maintaining groups. Significant differences were observed for XRD and FTIR data between differing bone sites. These differences correlate with the function and physiology, namely the crystallite size in $\langle 00\ell \rangle$ with the expected mechanical load and carbonate substitution with proposed turnover rate. Differences across skeletal elements may lead to applications in both the fields of anthropology and medicine. There is potential for assessment of the relative function of bones in archaeological finds particularly when small fragments are found and little architectural context can be seen, as well as insight into the physicochemical properties needed for specific skeletal elements to function well when used in biomedicine.

[1] R.G. Handschin, W.B. Stern, *Bone* **16** (1995), 355S.
[2] E.P. Paschalis, et al, *Calcified Tissue International* **59** (1996), 480.
[3] J.D. Currey, *Bones: Structure and Mechanics* (2002), Princeton University Press.
[4] J.D. Currey, *Osteoporosis International* **14** (2003), 29.
[5] D. Gonçalves, et al, *American Journal of Physical Anthropology* **166** (2018), 296.
[6] D.W. Thompson, *On Growth and Form* (2014) Canto Classics.
[7] R.B. Martin, D.B. Burr, *Structure, Function, and Adaption of Compact Bone* (1989) New York: Raven Press.
[8] K. Venkateswarlu, et al, *Procedia Materials Science* **5** (2014), 212.