

Biomechanics Studies at APS Using High-Energy X-Rays

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Bone is a highly-adaptive, particulate-reinforced composite which, through a complex hierarchical structure, achieves excellent mechanical performance. The composite preserves, to a large degree, the desirable properties of the individual components: high toughness of the bone matrix, collagen fibrils stabilized by water, and high stiffness of the reinforcing phase, nano-sized crystallites of carbonated apatite. Mechanical properties and fracture susceptibility differ between healthy bone and bone with impaired functionality (as in osteoporosis), and reliable discrimination between the two remains a challenge, not only in the clinic but also in basic research employing in animal models.

The fracture propensity of bone has been linked to both bone fracture strength and loading spectra [1], so it is important to quantify mechanical input to bone and identify “weak-link” microstructures or changes in global parameters characterizing microarchitecture. Numerous investigators [2] have quantified this mechanical input *in vivo* with strain gages attached to cortical bone, typically at mid-diaphyses where installation can be done with minimal disruption to muscles and tendons. With attached strain gages, however, the mechanical response of volumes beneath the bone’s surface can only be inferred indirectly. This limitation hinders understanding of effects such as bone remodeling and inter-phase effects.

Here we present recent results obtained with wide-and small-angle x-ray scattering of cortical bone under *in situ* loading. High-energy x-rays ($E > 60$ keV) and a transmission geometry are used at the Advanced Photon Source to provide true bulk sampling across $\sim 2 \times 4$ mm² cross-sections of animal tissue. Wide-angle scattering is used to quantify texture, particle size and internal strains in the apatite mineral phase. Small angle x-ray scattering was used to infer the collagen spacing along the longitudinal axis, and in turn provide information about load transfer between the constituent phases. Future directions in this area are discussed.

References:

1. AA Biewener, *Calcif Tiss Int* **53** [Suppl 1] (1993) S58-S74.
2. SP Fritton, CT Rubin, Ch. 8 in S.C. Cowin (ed) *Bone Mechanics Handbook*, 2nd Ed. (Boca Raton: CRC Press, 2001) 8-1 to 8-41.