

Probing the micro-mechanical behavior of bone via 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. The fracture propensity of bone has been linked to both bone fracture strength and loading spectra, so it is important to quantify mechanical input to bone and identify “weak-link” microstructures or changes in global parameters characterizing microarchitecture. Numerous investigators have quantified this mechanical input *in vivo* with strain gages attached to cortical bone. 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, in which mechano-transduction must translate the forces applied to the whole bone to instructions at the cellular level directing adaptation of the bone.

In light of these issues, we have recently applied wide- and small-angle x-ray scattering techniques to study the micro-mechanical response of bone on different length scales. High-energy x-rays (80 keV) and a transmission geometry are used for bulk sampling through transverse cross-sections of hydrated bones under *in situ* compressive loading. The aggregate macroscopic response is determined using strain gages and a load cell. Simultaneously, wide-angle scattering is used to quantify texture, domain size and internal strains and stresses in the apatite mineral phase, while small-angle x-ray scattering is used to determine the collagen response along the longitudinal axis. Combined, these data provide unique information about load transfer between the constituent phases of bone. In addition to *in situ* loading, effects of hydration on internal strain are presented.