STRESSES IN MINERALIZED TISSUES

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Bone and tooth posses a remarkable combination of strength and fracture toughness, and the mechanisms underlying these properties remain incompletely understood and perhaps even misunderstood. Bone is a composite of carbonated apatite (cAp) nanoplatelets embedded in a matrix of collagen. Tooth consists of volumes of two phases, dentin forming the bulk of the structure and providing toughness and enamel covering the dentin and providing wear resistance. Dentin, a composite phase, has a composition similar to that of bone but with a different collagen organization; enamel consists almost totally of cAp.

The challenge in studying bone and tooth is observing the interactions of the two nanostructures without so altering their environment that the measurements no longer apply to the intact tissue. High energy synchrotron ($E > 60$ keV) wide angle and small angle x-ray scattering (WAXS and SAXS, respectively) use the constituents of these mineralized tissues as embedded strain gages and offer a powerful probe of these mineralized tissues' response to applied stresses. In the WAXS regime, changes in the nanoplatelet d-spacings are the basis of the deviatoric strain quantification for cAp. In the SAXS regime, changes in the collagen D-period (axial periodicity in collagen) underlie strain determination for the mineralized fibrils.

After briefly reviewing data acquisition and analysis methods, three studies are presented where the spatial distribution of strain is determined in bone or tooth. The first example describes maps of strain around a hole in bone as a function of applied stress. In the second example, strains in cAp across the dentin-enamel junction are mapped as a function of applied stress; understanding how the large mismatch in elastic constants is accommodated may provide important guidance for design of engineering coatings. The third example is measurement, as a function of applied displacement, of the distribution of strain across beams of bone in four point bending. The presentation concludes with description of a relatively new method of quantifying 3D strain distributions in bone, diffraction microComputed Tomography, and illustration of its application to trabecular bone.