New Insights into the Mineralization Process of Bone

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Bone is a composite material of mineral platelets with a thickness of a few nanometers, embedded in a fibrous collagen matrix. Although this important system has been extensively studied for almost a century, many aspects of the bone superstructure, of the correlations between the mineral crystals and the collagen matrix, and of the mineralization process remain unclear.

The presented synchrotron small-angle x-ray scattering (SAXS) study investigates intramuscular herring bone as a model system for bone with well-defined orientation (no plywood structure) and composition (no cartilage). When the SAXS experiment scans along the length of the fish bone, it allows to study the effects of the continuously varying degree of mineralization present in these fish bones. Furthermore, these fish bones have fleshy ends of yet unmineralized but ready-to-be-mineralized collagen which are of particular interest.

SAXS from bone can be divided into three parts: (i) equidistant meridional reflections with a period around 65 nm; (ii) diffuse butterfly-shaped equatorial scattering for mineralized samples; (iii) usually very weak or absent equatorial arcs or row lines crossing the equator at spacings between 1 and 10 nm.

The equidistant meridional reflections (i) are always found in various types of collagen but their information content is limited due to the effective density projection onto the fiber axis. Thus, they cannot provide any information about the lateral packing of the collagen molecules, about the arrangements of holes in the cross-section, possible microfibrillar substructures etc.

The diffuseness of the butterfly patterns (ii) indicates that the arrangement of the mineral crystals cannot be highly ordered. Nevertheless, under certain assumptions, a quantitative analysis in terms of disordered stacks of platelets is possible and reveals thickness distributions for both the mineral platelets and intermediate organic layers.

Equatorial arcs or row lines (iii) are very often not observed at all, indicating a lack of lateral packing order at the probed length scales, e.g. induced through a perturbation of the collagen matrix by the embedded mineral crystals. However, the unmineralized fleshy ends of these fish bones do show a rich set of equatorial arcs/row lines, with spacings significantly different from those known for rat tail tendon, that allow various interesting conclusions, to be discussed in this presentation.