Bone hierarchical structure through 3D X-ray imaging techniques

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Bone is an anisotropic hierarchical composite material that is special amongst biominerals in that it contains living cells called osteocytes that acts as sensors of damage. The multi-length-scale structures of bone remain far from understood. We have harnessed recent developments in X-ray imaging including high throughput synchrotron sub-µm tomography [1-5], X-ray nanotomography and X-ray multimodal imaging to shed new light on bone structure and mechanics.

Nanotomography reveals the osteocyte cellular network. We found that the network contains junctions, seen as voids in the bone matrix, where connections between several cells cross. Their presence raises questions about current models of stress sensing in bone.

The 'standard' tomographies do not probe the bone biomineral properties, merely the density of it. However, many open questions in bone science relate to the bone biomineral. This includes for instance the question of whether bone mineral has the constant crystallographic properties across a bone piece or if the nanoscale structure depends on the spatiotemporal conditions present when the bone was made. To address this problem we have used diffraction scattering computed tomography (DSCT [6]) and fluorescence tomography with a 400 nm X-ray beam. DSCT combines diffraction and scattering with tomography and allows reconstructing diffractograms from inside a specimen. We use the measurements to show that bone biomineral properties vary across a human osteon indicating that the crystallographic properties of the bone biomineral are determined by the conditions at the time of synthesis.

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