

Abstract (300 words)

Three-dimensional X-Ray imaging of bone microdamage in bone tissue

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X-Ray CT imaging is a choice technique to analyze bone tissue at different scales. X-ray CT at the microscopic scale (μ CT) has become a standard technique for the three-dimensional (3D) investigation of bone micro-architecture. However, the three dimensional observation of bone micro-damage remains challenging due to the small size of the damage relative to the attainable spatial resolution.

Bone micro-damage occurs naturally in bone due to stress and strain imposed on the tissue, and is hypothesised to be the main trigger of bone repair. Different types of micro-cracks may develop; the most commonly observed being linear micro-cracks, appearing as planar defects with an opening on the order of a micrometer. The 3D imaging of micro-damage requires a technique able to penetrate bone tissue, to reach sub-micrometric spatial resolution, and to yield sufficient contrast. To achieve this, 3D Synchrotron Radiation (SR) μ CT is a good candidate.

In this presentation, we will review the use of SR- μ CT, in absorption and phase modes, to image micro cracks, and discuss the processing of such images to extract quantitative information. The 3D observation and quantification of bone micro-damage in native human trabecular bone and cortical was first demonstrated using SR- μ CT at a voxel size of 1.4 μ m. SR phase μ CT at higher spatial resolution was then used to image defects after applying different types of biomechanical constraints on the samples. In an ongoing study, we aim to study damage distribution after three-point bending test to failure, with two loading rates: quasi static (typical of walking) and dynamic (typical of falls).

Phase μ CT has the advantage to enhance the visibility of osteons at the price of a small loss of spatial resolution. We highlight the image processing chain performed to extract quantitative parameters on several features, including cracks, as well as the segmentation of different structures of interest pertinent to micro-damage, such as canals, osteons and lacunae. We present the first results of these analyses.