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Research paper

# Local strain and damage mapping in single trabeculae during three-point bending tests

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ABSTRACT

The use of bone mineral density as a surrogate to diagnose bone fracture risk in individuals is of limited value. However, there is growing evidence that information on trabecular microarchitecture can improve the assessment of fracture risk. One current strategy is to exploit finite element analysis (FEA) applied to 3D image data of several mm-sized trabecular bone structures obtained from non-invasive imaging modalities for the prediction of apparent mechanical properties. However, there is a lack of FE damage models, based on solid experimental facts, which are needed to validate such approaches and to provide criteria marking elastic–plastic deformation transitions as well as microdamage initiation and accumulation. In this communication, we present a strategy that could elegantly lead to future damage models for FEA: direct measurements of local strains involved in microdamage initiation and plastic deformation in single trabeculae. We use digital image correlation to link stress whitening in bone, reported to be correlated to microdamage, to quantitative local strain values. Our results show that the whitening zones, i.e. damage formation, in the presented loading case of a three-point bending test correlate best with areas of elevated tensile strains oriented parallel to the long axis of the samples. The average local strains along this axis were determined to be (1.6±0.9)% at whitening onset and (12±4)% just prior to failure. Overall, our data suggest that damage initiation in trabecular bone is asymmetric in tension and compression, with failure originating and propagating over a large range of tensile strains.



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