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FE MODELS PREDICT MICRODAMAGE IN NORMAL AND OSTEOPOROTIC TRABECULAR BONE DURING COMPRESSION

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Computed tomography can be adapted to evaluate both macroscopic and microscopic structure of bone. Specifically, Micro-CT has gained popularity over the years within the field of bone research for its ability to provide three-dimensional (3D) reconstructions of small cancellous bone specimens which later can be used as input to high-resolution finite element analysis for mechanical characterization.

Micro-CT scans of a bovine trabecular bone were performed and, from the images acquired, a 3D reconstruction of a cubic specimen was achieved. Furthermore, a first-stage thinned and sequentially a second-stage thinned model were technically produced by altering the BV/TV of the original bone specimen. The original physical specimen had BV/TV=40% and the simulated osteoporotic models had BV/TV=34% and BV/TV=21% respectively. A voxel-based Finite Element (FE) model was built from the segmented micro-CT datasets by direct conversion of voxels into tetrahedral elements, which resulted in high-resolution FE meshes (594,984 for BV/TV=40%, 581,609 for BV/TV=34% and 451,707 for BV/TV=21%). Our aim was to observe the accumulation of tissue microdamage for these three models by calculating the elements that passed the yielding point and to examine the deformation mode of the structure during apparent compression.

The trabecular bone tissue was modeled as an elastoplastic material. To replicate mechanical experiments, all the nodes at the lower surface of the specimen were fully constrained and the nodes at the upper surface were imposed a uniaxial compressive displacement of 0.05 mm (apparent strain of 1%) for the elastic analysis and afterwards at 0.1 mm displacement (2% apparent strain) for the elastoplastic analysis.

To provide indications about the tissue microdamage accumulation, the number of elements that yielded (either maximum principal strain>0.6% or minimum principal strain<-1.0%) were calculated. Results showed that for all models, at the very low strains there is a number of elements that passed the yielding point but the tissue microdamage did not lead immediately to micro-fracture. Thereafter, micro-damage was developed rapidly, and the yielded elements appeared to be distributed throughout the whole structure for all models. Finally, the number of elements that had a tensile predominance (max principal stress>min principal stress) have grown by lowering the BV/TV, indicating that more trabeculae seem to deform in a bending mode.

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