Mechanical Stimuli in Prediction of Trabecular Bone Adaptation; Numerical Comparison

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Adaptation is the process by which bone responses to changes in loading environment and modulates its properties and organization to meet the mechanical demands. Trabecular bone, the spongy component of many bones, undergoes significant adaptation when subjected to external forces. It was found that intensive mechanical stimulation results in thicker and mechanically stronger bones and bone morphology with individual elements of this bone tissue, *trabeculae*, aligned along the loading direction [1]. In contrast, a lack of mechanostimulation induces a bone-mass reduction, thinning of trabeculae, and deterioration of mechanical properties [2]. Load-induced adaptation is implemented through resorption of old and fractured bone and formation of a new bone material. These processes are hypothesized to be driven by mechanical stimuli of bone-matrix deformation sensed by bone mechanosensory cells [3]. The exact nature of mechanical stimuli triggering bone resorption and formation activities in response to external loads is currently unknown.

This study aims to compare different mechanical stimuli on their ability to trigger load-induced adaptation in trabecular bone. To achieve this, developed 3D unit cells of trabecular lattice are developed with bone marrow in its intertrabecular space, reconstructed from two sets of high-resolution peripheral computed tomography (HR-pQCT) scans. The first set includes baseline scans of distal tibia of a human participant, the second one comprised scans of the same participant after a six-months-long high-impact exercise. The finite-element method is implemented for the baseline model loaded in compression, tension, and shear to calculate the magnitudes of several mechanical stimuli that are widely considered as candidates to trigger the bone adaptation. A user-material subroutine is developed to relate the magnitude of each candidate to changes in mechanical properties and shape of trabeculae in the baseline model. The obtained adaptation results are qualitatively compared against the follow-up model.

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