Simulations of bone functional adaptation can improve our understanding of age-related bone loss and be used in design of tissue-engineered devices. Recently developed simulation models incorporate traditional optimization algorithms to account for the anisotropic nature of trabecular bone, thus providing an algorithm that simulates bone functional adaptation at the tissue level and incorporates biological aspects of bone remodeling. The algorithm is then incorporated into a hierarchical model in order to determine apparent density distribution at the continuum level. This technique makes use of finite element analysis, cellular automaton (CA) paradigm, control, and structural optimization techniques.

A hierarchical functional adaptation model has been developed in this investigation. A continuum-level model evaluates the global stress/strain field. Tissue-level sub-models use the global field values to define local load conditions. Cellular automata in the sub-models apply a control rule to drive an averaged strain energy density to a target value. The convergent results are returned to the global model. Preliminary results show the application of this technique to quantify apparent density distribution in a two-dimensional femoral head and to simulate the formation of trabecular structure in a three-dimensional model is promising.

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