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Micromechanically based poroelastic modeling of fluid flow in Haversian bone.

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Abstract
To explore the hypothesis that load-induced fluid flow in bone is a mechano-transduction mechanism in bone adaptation, unit cell micro-mechanical techniques are used to relate the microstructure of Haversian cortical bone to its effective poroelastic properties. Computational poroelastic models are then applied to compute in vitro Haversian fluid flows in a prismatic specimen of cortical bone during harmonic bending excitations over the frequency range of 10(0) to 10(6) Hz. At each frequency considered, the steady state harmonic response of the poroelastic bone specimen is computed using complex frequency-domain finite element analysis. At the higher frequencies considered, the breakdown of Poisueille flow in Haversian canals is modeled by introduction of a complex fluid viscosity. Peak bone fluid pressures are found to increase linearly with loading frequency in proportion to peak bone stress up to frequencies of approximately 10 kHz. Haversian fluid shear stresses are found to increase linearly with excitation frequency and loading magnitude up until the breakdown of Poisueille flow. Tan delta values associated with the energy dissipated by load-induced fluid flow are also compared with values measured experimentally in a concurrent broadband spectral analysis of bone. The computational models indicate that fluid shear stresses and fluid pressures in the Haversian system could, under physiologically realistic loading, easily reach the level of a few Pascals, which have been shown in other works to elicit cell responses in vitro.

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