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Modeling deformation-induced fluid flow in cortical bone's canalicular-lacunar system.

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Abstract
To explore the potential role that load-induced fluid flow plays as a mechano-transduction mechanism in bone adaptation, a lacunar-canalicular scale bone poroelasticity model is developed and implemented. The model uses micromechanics to homogenize the pericanalicular bone matrix, a system of straight circular cylinders in the bone matrix through which bone fluids can flow, as a locally anisotropic poroelastic medium. In this work, a simplified two-dimensional model of a periodic array of lacunae and their surrounding systems of canaliculi is used to quantify local fluid flow characteristics in the vicinity of a single lacuna. When the cortical bone model is loaded, microscale stress, and strain concentrations occur in the vicinity of individual lacunae and give rise to microscale spatial variations in the pore fluid pressure field. Furthermore, loading of the bone matrix containing canaliculi generates fluid pressures in the contained fluids. Consequently, loading of cortical bone induces fluid flow in the canaliculi and exchange of fluid between canaliculi and lacunae. For realistic bone morphology parameters, and a range of loading frequencies, fluid pressures and fluid-solid drag forces in the canalicular bone are computed and the associated energy dissipation in the models compared to that measured in physical in vitro experiments on human cortical bone. The proposed model indicates that deformation-induced fluid pressures in the lacunar-canalicular system have relaxation times on the order of milliseconds as opposed to the much shorter times (hundredths of milliseconds) associated with deformation-induced pressures in the Haversian system.

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