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A finite difference model of load-induced fluid displacements within bone under mechanical loading.

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Abstract
Load-induced fluid flow in the lacunocanalicular network, induced by the mechanical loading of bone, is believed to play an important role in bone modelling, remodelling and adaptation processes. There are strong indications that this fluid flow is responsible for the mechanotransduction from external mechanical loads to the cells responsible for bone apposition or removal. Since direct flow measurements (especially in compact bone, in vivo and in situ) are not yet possible, theoretical modelling offers an alternative approach to determine the fluid flow velocities, displacements and effects of interstitial fluid flow. In this model, the fluid displacements in a middiaphyseal slab of a rat tibia under a cyclic four-point-bending load were calculated by applying Biot's theory of poroelasticity. The resulting differential equations were solved numerically for the fluid displacement vectors using the finite difference method. Thereby, the cross section located in the middle between the two inner points of force application was chosen for examination, such that the problem, although formulated in three dimensions, reduced itself to an essentially planar form. The maximal fluid displacements for the vector components in the cross sectional plane were found in the proximity of the neutral axis of bending. The direction of the displacement vectors was from the lateral aspect, which was in compression in the examined loading situation, towards the medial aspect in tension. In a parameter study it was found that the fluid displacement pattern and the distribution of fluid displacements remained constant for all the examined parameters, while the magnitude was influenced by the model parameters Young's modulus, Poisson's ratio and porosity. This study represents a further step in the examination of load-induced fluid displacements in loaded bone using theoretical models, aiming to understand the relationship between mechanical loading and bone modelling, remodelling and functional adaptation.

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