Mixture theory for multiphase flow: application to bone interstitial fluid

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Introduction

Interstitial fluid mechanical behavior in bone has received little attention by itself. Fluid flow phenomena occur at a smaller scale than pores. Physical phenomena that do not influence macroscopic flow could be of interest at the microscopic scale for their interaction with cells membrane. Thus, physical phenomena need to be described at the fluid scale to account for physical interactions that could be ignored at the macroscale.

Methods

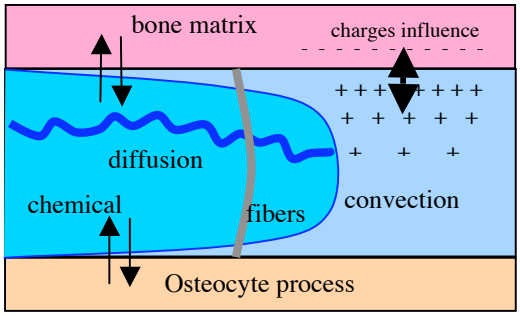
To account for the multiphasic nature of interstitial fluid, it is modeled as a mixture of fluids with the mixture theory. Noting that electrostatic phenomena can occur in bone, ionic phases are considered to model interaction between charges. Furthermore, as compressibility plays a significant role in bone fluid flow within bone porous matrix, fluid phases are considered to be compressible. The entropy inequality is used to derive thermodynamics restrictions on constitutive equations for the constituents and the mixture. Supplementary consequences of equilibrium state of the mixture are developed. Finally, obtained equations are customized to model interstitial fluid flow. Consequences of neglecting certain phenomena are discussed.

Results

Equations for fluid behavior as a mixture and each of its constituents are obtained. They show that physical phenomena such as electro-osmosis and diffusion could intervene while convection drives the flow when hydraulic pressure gradients occur.

Discussion

This new model allows one to include interaction between phases within interstitial fluid. Estimation of different physical phenomena leads to a better understanding of what could influence fluid flow through bone tissue. Some experimental data on composition of bone fluid and its variations and also on chemical exchanges are needed to precise boundary conditions to solve the equations set.



Physical phenomena influencing fluid flow within the lacuno-canalicular porosity