Fully Coupled FEM Modeling of the Swelling Behavior of Human Intervertebral Disc in Response to a Change in Chemical Environment

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Abstract

The swelling behavior of human intervertebral disc strongly influenced by chemical change in surrounding environment such as concentration of the mobile ions and the pH of the bio-fluid. This change in geometry of the intervertebral disc can be described by various responsible physical phenomena via sets of partial differential equations. These equations are: Nernst-Plank for chemical species transport via chemical and electrical potential, Poisson's for the balance of fixed charges inside the vertebral disc, and mechanical field for balance of osmotic pressure and resulting expansion of the disc. Thus, swelling of IVD is governed by various physical phenomena, among which three main physical phenomena 1) chemical and electric potential based transport 2) electrical charge balance, and 3) swelling due to concentration difference within IVD relative to surrounding fluid. This paper describes the fully coupled solution via combing all three equations in moving mesh domain using COMSOL Multiphysics®. The effects of several important physical conditions, such as concentration of mobile ions, and pH change in surrounding bio-fluid on the distributions of the concentrations of ionic species, electrical charge balance, and the expansion of the vertebral disc are investigated.