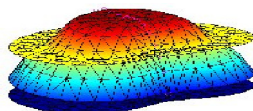


## Update 68

### PORO-ELASTIC AND CHEMICAL ELECTRIC MODEL OF HEALTHY AND DEGENERATED INTERVERTEBRAL DISCS

Evidence suggests that substantial biologic remodelling occurs in the intervertebral disc in response to mechanical stimuli, which may contribute to the health or degenerative state of the intervertebral disc. (1)



**Fig 1.** Demonstrates the model prediction of the hydraulic pressurization of the healthy intervertebral disc slice at equilibrium. (1)

Furthermore, degenerative changes to the intervertebral disc result in significant losses of water content and proteoglycans, particularly in the central nucleus pulposus. The loss of fixed charges (associated with the proteoglycans) influence mechanical and electrical fields within the disc. The objectives of a recent study (2) were to apply a poroelastic and chemical electric (PEACE) finite element model to a 2-D slice of intervertebral disc and investigate the influence of fixed charge density (FCD) and applied electrical potential on fluid transport, pressurization, and streaming potential.

The PEACE finite element model was written using MATLAB software based on the models of Gu et al 1993, and Simon et al 1996. Geometry was taken as a thin horizontal slice of disc (5 mm thick) with idealized horizontal plane dimensions characteristic of a human lumbar disc. Boundary conditions included impermeable, insulated, frictionless, and rigid top and bottom surfaces so that there was no vertical flow. This could represent the conditions at the mid-elevation of a disc. The mechano-electrochemical material coefficients were taken from the literature. Values for healthy and degenerated fixed charge density distributions were taken from experimentally determined values for 26 year old and 74 year old discs from Urban & Holm 1986. The healthy distribution had values for FCD approximately 0.15M at the edge of the disc and approximately 0.3 M at the centre of the disc. The u-w solution was obtained for: 1) a swelling & compression test where the disc was equilibrated in 0.2M NaCl followed by a step compressive stress of 0.2 MPa; and 2) an applied electrical potential on the boundaries where point A was set to 0 mV and point B was set to twice the natural potential (i.e., -10.75 and -6.3 mV for healthy and degenerated discs, respectively).

**Figure 1** demonstrates the model prediction of the hydraulic pressurization of the healthy intervertebral disc slice at equilibrium. Significant alterations in the load carrying mechanism from healthy to degenerated discs were determined with the healthy disc carries most of the loading through fluid stress (pressurization). The degenerated disc, on the other hand, carries significantly more stresses in the solid matrix which could predispose the increased matrix damage. Alterations in the disc fixed charge density from healthy to degenerated will affect load carrying mechanisms, fluid content, and electrical potential response.

These differences have implications for disc failure, disc nutrition, modulation of cellular activities, and tissue remodelling.

Information on the mechanisms that govern cell responses to mechanical stimuli in the intervertebral disc is just emerging. Studies must address determination of the factors that control micromechanical stimuli, but also mechanisms by which mechanics may interact with genetic factors to regulate expression and remodelling of extracellular matrix molecules and cytokines in degenerating tissue. (1)

(Note: Poro-elastic finite element model including strain-dependent permeability and osmotic pressure is the most popular analytical tool currently available that can be used to understand how cyclic loading affects the biomechanical characteristics of a degenerated lumbar disc. It has been suggested that a complete understanding of the behaviour of the intervertebral disc will require the use of a combination of analytical models, in addition to in vitro and in vivo experimental methods.) (3)

#### **References:**

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