

Mechanical Engineering & Mechanics Department

Ph.D. Defense

Finite Element Analysis and Materials Characterization of Changes Due to Aging and Degeneration of the Human Intervertebral Disc

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Place: MEM Seminar Room (162 Curtis)

Intervertebral disc (IVD) degeneration occurs with aging, and may be a major cause of back pain. Alterations in the major biochemical constituents of the IVD have been shown to coincide with aging and disc degeneration, and can subsequently alter the discs' ability to support load. A significant biochemical change that takes place in disc degeneration is the loss of proteoglycans (PGs) in the central region of the disc, the nucleus pulposus (NP). PGs work to resist mechanical forces in the NP and, through hydration of the molecules, provide a hydrostatic pressure to the outer layers of the disc, the annulus fibrosus (AF).

Poroelastic theory with incorporated osmotic swelling, first created for the simulation of articular cartilage, is applied to a finite element model of a human IVD throughout a daily loading cycle. The model was validated against experimental studies of axial displacement, radial bulge, and volume of fluid lost. The incorporation of osmotic swelling allows for the study of the effect of PGs on the mechanics of the IVD.

In this study, the IVD finite element model is created and validated, and the response of the model to a diurnal loading cycle is investigated. Various degrees of degeneration are examined, as well as the intervention techniques of a hydrogel NP replacement implant and the restoration of the PG content in the IVD for the restoration of degenerated discs. The implantation of a NP hydrogel replacement decreases the stresses in the AF, and the restoration of the PG content reduces the stresses in both the NP and AF, which may lead to deceleration or halting of the degenerative process.

In order to develop a more reliable and possibly diagnostic tool for the determination of IVD biomolecular components, Fourier transform infrared (FTIR) spectroscopy is investigated for the analysis of IVD tissue. The overall results of the study suggest FTIR as a dependable method for quantifying disc degeneration.

The model developed here provides a novel tool for the investigation of IVD tissue mechanics through the diurnal cycle. The incorporation of poroelastic components allows for the investigation of key biomolecular changes that as demonstrated have a marked effect on IVD mechanics. An accurate determination of biomolecular changes in the IVD will allow for a more physiologically relevant model to be developed and allow for possible detection of earlier interventional time points.