Test Methodology of Characterizing the Behavior of Injectable Hydrogels: An In Vitro Model

J.L. Isaacs1, V.R. Binetti2, K.B. Kita3, G.W. Fussell4, M. Marcolongo5, A.M. Lowman6

1Widener University, Chester, Pennsylvania 19013; 2Drexel University, Philadelphia, Pennsylvania 19104; 3DePuy Synthes, West Chester, Pennsylvania, 19380; 4Rowan University, Glassboro, New Jersey 08028

Statement of Purpose: The development of synthetic models for the prediction of swelling and mechanical behavior is crucial for the development of new biomaterials due to an inability to test every candidate material in an in vitro model. Commonly phosphate-buffered saline (PBS) is used as a model swelling solution for candidate nucleus replacement materials in the intervertebral disc (IVD); this however does not take into account the gradient through the annulus fibrosus (AF). The aim of this study was to evaluate the swelling behavior and compressive moduli of polyvinyl alcohol/polyvinyl pyrrolidone/polyethylene glycol hydrogel system in synthetic osmotic and in vitro model systems.

Methods: Polyvinyl alcohol (PVA) was chemically stabilized with polyvinyl pyrrolidone (PVP) to form a solution in deionized water. Barium sulfate was added to the PVA/PVP solution as a slurry. Polyethylene glycol (PEG) was stirred into the solution to form a gel. Heat Distribution: Five human spinal segments were dissected and posterior elements removed. The nucleus was cored and removed by drilling through superior vertebral body and halfway through the disc. The nuclear material and bone plug were removed. The anterior column units (ACU) were placed in 1x PBS with protease inhibitor (PI) and placed in refrigerator overnight. Thermocouples were placed around the circumference of the annulus in three locations: posterior, anterior and lateral. Each region had three thermocouples placed at three different locations along the thickness of the annulus. The bone plug was replaced and the ACU was submerged in a 37°C heated water bath. The hydrogel was heated to 90°C and injected into the nuclear cavity. Time versus temperature graphs are compiled from thermocouple output data for annular wall and hydrogel thermocouples.

Results: Figure 3: Left - Axial of hydrogel relative to superior IVD position over 24 hours. Average and standard deviation of three time points within each 15 minute hold were plotted for each ACU. Right - Elastic modulus from 5th quasi loading cycle of hydrogel over 24 hours. Note time zero is the beginning of the mechanical test, but it is actually t=5.5 minutes since hydrogel injection. Results shown are representative curves for specific hydrogel tested.

Conclusions: A new method was designed that evaluates the swelling behavior and modulus of a hydrogel system in in vitro model systems.