

## Re-Swelling Degenerate Intervertebral Discs by Percutaneous Injection: an *In-Vitro* Investigation

S. Olsen, Á. Higgins Ní Chinnéide, W.-R. Fritz, S. J. Ferguson

MEM Research Center – Institute for Surgical Technology and Biomechanics, University of Bern, Bern, Switzerland

**INTRODUCTION:** Healthy intervertebral discs (IVD) are swollen structures that support substantial static and dynamic loads through hydrostatic pressurization of the fluid-filled nucleus pulposus (NP). During the diurnal loading cycle, the disc is compressed and the fluid within it seeps out. The NP contains a high concentration of proteoglycans (PG), which effect a high osmotic potential, drawing water back into the disc during rest. Although the exact mechanism of disc degeneration remains unclear, it is widely known that degenerate discs generally contain less PG and hence less fluid [1]. Restoration of the natural swelling capacity of the disc would appear to be a critical requirement for the effective treatment of damaged or degenerate discs. The concept of artificially increasing the osmotic potential of PG-extracted intervertebral discs by direct injection of a biocompatible, osmotically active gel was investigated in this project as a means to recover their mechanical function.

**METHODS:** Porcine coccygeal discs were isolated with endplates intact. An apparatus was designed to measure the temporal changes in the swelling force of the discs. The discs were placed in a bath of 2M NaCl solution, and loaded to 4 N by a porous platen to which a load cell was connected. When the disc had reached equilibrium, the 2M solution was replaced by 0.15M NaCl. The transient (osmotic) swelling force was captured by the load cell and the maximum value recorded. The samples were then immersed in 4M GuHCl for six days to extract the PGs from the nucleus and were tested again. A viscous gel of high molecular weight polysaccharide alginate (1.5% alginate) was then injected into the NP, and tested again. The effectiveness of PG extraction comparing extracted (n=7) to control (n=10) discs was determined using the Alcian blue dye test [2]. The effects of mechanical damage (cutting and piercing the annulus) were also investigated using the same testing method.

**RESULTS:** The swelling force of cut discs (n=8) increased by 15% ( $\pm 27$ ), while that of the pierced discs (n=3) decreased by 11% ( $\pm 52$ ). The PG content of the discs decreased by an average of 40% after PG extraction (Fig. 1(a)).

The intrinsic swelling force exerted by discs following PG extraction decreased, on average, by almost 85%. Injection of the alginate recovered 10% of the original swelling force (Fig. 4(b)).

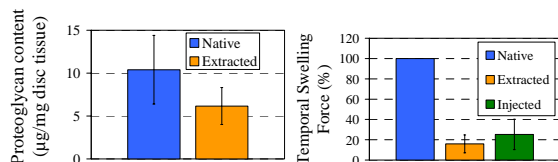


Fig. 1 (a) Proteoglycan content (left)  
(b) Swelling pressure (n=10) (right)

**DISCUSSION & CONCLUSIONS:** It was shown that the bulk swelling response of the disc can be reproducibly measured *in-vitro*. Loss of PG content had a disproportionate influence on whole disc swelling. A sensitivity study performed using a numerical model of the experiment showed that nucleus diameter has the greatest influence on swelling force, followed by swelling pressure and then annulus stiffness. Cutting the annulus had the effect of increasing the swelling force if more than  $\frac{3}{4}$  of the annulus was sectioned. Annular piercing was found to reduce the total swelling force, and therefore could have negative implications if employed in potential therapy. Injection of alginate partially restored the intrinsic swelling behaviour of the ‘degenerated’ disc, but only a very limited amount of gel could be introduced into the dense tissue matrix. Additional stimulation designed to produce new disc matrix material is likely required for complete functional repair. Alginate could possibly be seeded with autologous NP cells for biological, minimally-invasive disc repair [3].

**REFERENCES:** <sup>1</sup> J.P. Urban & J.F. McMillan (1988) *Spine* **13**:179-87 <sup>2</sup> S. Bjornsson (1993) *Anal Biochem* **210**:282-91 <sup>3</sup> H. Mizuno (2004) *Spine* **29**:1290-7

**ACKNOWLEDGEMENTS:** The authors would like to thank L. Ettinger for the GuHCl and alginate preparation and testing of the proteoglycan content.