EFFECTS OF ELECTROCHEMICAL PARAMETERS ON MECHANICAL BEHAVIOR OF INTERVERTEBRAL DISC BASED ON A TRIPHASIC FINITE ELEMENT MODEL

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INTRODUCTION

In general, intervertebral disc is basically formed from a fibrous network of structure proteins, abundant interstitial water, soluble electrolytes, and cells residing in the interstitial space. So it can be described as a charged, hydrated and permeable material which is comprised largely of collagen and elastic fibers embedded in a proteoglycan gel to form a solid matrix. During the last decades, several researches have been proposed the multiphasic computational models to study mechanics of the soft tissues. Based on a triphasic porous model, this paper investigates the swelling mechanism and effects of some electrochemical parameters for using in IVD tissue engineering researches.

METHODS

This triphasic finite element model considers a charged hydrated tissue engineered intervertebral disc as a mixture consisting of: a porous, permeable, charged solid phase; an incompressible fluid phase; and ion phase with two ion species, i.e., anion and cation. After derivation of the governmental equations, the standard Galerkin weighted residual method was used to form the finite element model. Then the implicit time integration schemes were applied to solve the nonlinear equations [1, 2]. The formulation accuracy and convergence for 1D case were examined with analytical solutions. Also this model was used to simulate the load displacement response as obtained by Drost et al. [3] which considered the compression of the canine annulus under chemical and mechanical loading. According to excellent agreements in results, it was shown that our finite element formulation is capable of solving the problems of intervertebral disc under different types of mechanical, electrical and physicochemical loading conditions.

Due to the coupling of mechanical and electrical effects, the measured hydraulic permeability of intervetebral disc also depends on the electrical current flow. So it is important to investigate the effect of electrochemical factors in a natural intervertebral disc to optimize the related design parameters in tissue engineering procedure. As we predicted, our infrastructure model is capable for this study. For example, a homogenous two dimensional version of this mathematical model, can analyze the effect of fixed charge density and water content on mechanical behavior in a simple sagittal slice of the disc.

RESULTS AND DISCUSSION

Creep tests were simulated for investigation of mentioned electrochemical effects on IVD mechanical response. In this compression creep problem, σ_0=10 KPa was applied to the 2-D intervertebral disc model. The effect of fixed charge density on creep deformation was investigated with five different amounts (FCD=0.1~ 0.3M) and plotted in Figure 1.

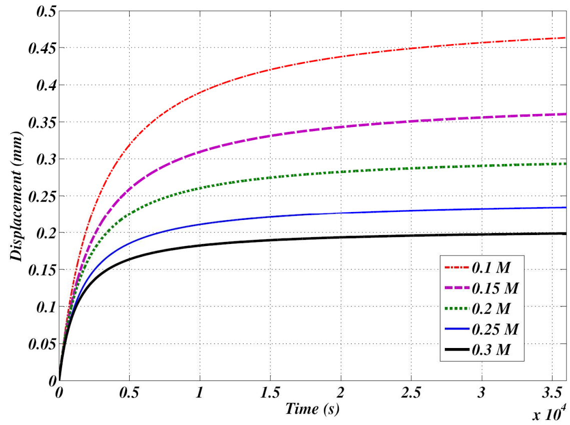

Figure 1: Effect of FCD on the creep behavior

In next step, the effect of water content coefficient on creep deformation was investigated with five different amounts (ζ_w= 0.7~ 0.9) and plotted in Figure 2.

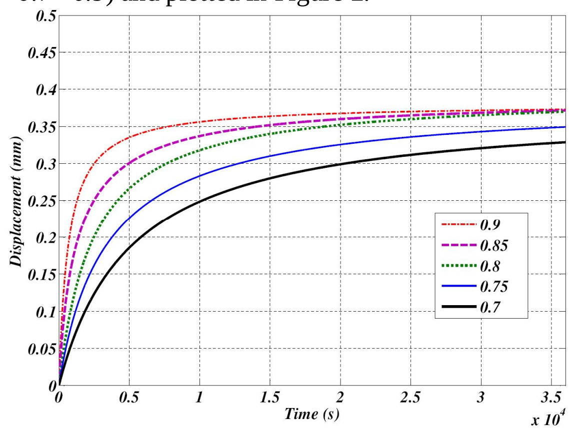

Figure 2: Effect of water content on the creep behavior

Figure 1 shows that the intervertebral disc tissue becomes stiffer with increasing the FCD and Figure 2 shows that changes in water content do not affect its stiffness. By the way, on the basis of this developed model and our experimental results, we try to gain a complete understanding of IVD mechanobiology for tissue engineering researches

REFERENCES

1. Haghpanahi M., et al., Proceedings of ESB 2007, Dublin, Ireland, 46-47, 2007.
2. Haghpanahi M., et al., Proceedings of BEBI 2008, Rhodes, Greece, 162-167, 2008.
3. Drost MR, et al., *J Biomech. Eng.* **117**:390-396, 1995.