NUMERICAL ANALYSIS OF THE EFFECTIVE MECHANICAL STIMULI IN AGAROSE CELL COSNTRUCTS

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Introduction

Osteoarthritis is a degenerative joint disease which provides progressive pain and disability. The limitations of current therapies and promising results obtained from tissue engineering research are the driving forces behind regenerative concepts for degenerated and traumatic joints [Schulz, 2007]. Loaded explants and cell cultures demonstrated that chondrocyte metabolism can be regulated via physiologic loading. However, the explicit ranges of mechanical stimuli that correspond to favourable metabolic response associated with extracellular matrix synthesis are elusive. The present study, compare with computational models, how different macro stimuli imposed at the 3D agarose constructs in development on a bioreactor environment changes the intrinsic mechanical parameters of the construct; as pore pressure, pressure on solid matrix and von Mises stress. These intrinsic mechanical parameters of the cellular construct matrix can be associated with the favourable metabolic outcomes like protein synthesis and NO production [Tsuang, 2008].

Methods

The 3D agarose constructs were simulated with finite element models, performed with the finite element software ABAQUS v.6.10 (Simulia Inc., RI, USA). The geometry of agarose constructs were modelled with 8mm in diameter and 6mm in thickness. The agarose, was modelled as a poro-elastic material with 20 node brick elements with linear pore pressure and quadratic displacement. Six loading patterns, combining three strain magnitudes (5%, 10% and 15%) with two frequencies (0.5, and 1Hz), were simulated. Boundary conditions of uniaxial compression were implemented on the top of the upper porous plate. Fluid influx and outflux from the lateral surface were free. For agarose, the Young's modulus considered was 133 kPa, the Poisson´s ratio 0.32, the hydraulic permeability $5x10^{-12}$ m4/Ns and the initial void ratio 4.0. The pore pressure was evaluated after the first 100 load cycles for each loading pattern.

Results

The pore pressure gradients at the central region of the agarose construct at the maximum compressive strain for each loading pattern are presented in figure 1.

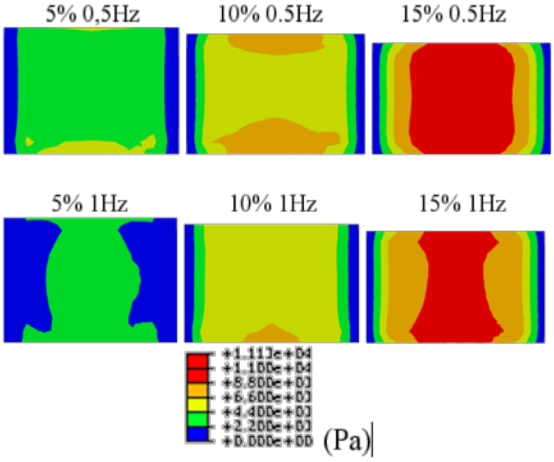

Figure 1: Pore pressure gradients in agarose construct.

Discussion

The macro stimuli parameters applied to the agarose construct changes the intrinsic mechanical parameters; as expected the pore pressure it less sensible to the changes of the frequency stimulus than the compressive strain stimulus.

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References

Schulz RM *et al*, Eur Biophys J 36: 359–368, 2007

Tsuang YH *et al*, Int J Artif Organs 31:439-449, 2008;