THEORETICAL AND EXPERIMENTAL STUDY OF ARTICULAR CARTILAGE GROWTH

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One promising strategy for repairing articular cartilage defects is the growth of tissue engineered constructs *in vitro* which are then surgically implanted into defects *in vivo*. Quantitative models of cartilage growth may be used to guide tissue engineering experiments in order to fabricate constructs with specific biomechanical and geometrical properties required for a successful clinical outcome. In this paper, we present our ongoing efforts to develop theoretical and experimental protocols for modeling the biomechanics of cartilage growth.

Cartilage growth models (CGMs), based a continuum mechanics approach, have been proposed that model the tissue as a mixture of a fluid and an *arbitrary* number of growing elastic materials [1-2]. The motivation for developing such a complex theory was that many tissue constituents appear to play a role in growth (e.g., proteoglycans (PGs), collagens (COLs), growth factors, etc.), but the relative importance of their functional roles is unknown. Since the PG and COL constituents are thought to be predominantly responsible for the tissue's compressive and tensile properties, respectively, current CGMs describe the solid matrix as a mixture of growing PG and COL elastic materials [3]. Due to the nonhomogeneous biomechanical properties that are expected to develop during *in vitro* growth, a cartilage growth finite element model (CGFEM) has been developed [4]. The CGFEM uses the user-defined material and poroelastic capabilities of ABAQUS to define a daily tissue stimulus, which is then used to solve an equilibrium growth boundary-value problem using a custom element growth routine (MATLAB). Results obtained for a dynamic compression protocol reveal that the CGFEM is capable of predicting the growth of a nonhomogeneous material that mimics the biomechanical properties of native adult cartilage.

Concurrently, *in vitro* growth protocols are being developed that can be used to rigorously test several model assumptions and, consequently, develop more accurate CGMs. Analyses using biomechanical experiments with bovine cartilage explants harvested at the fetal, newborn, and adult stages of *in vivo* growth suggest that the COL remodels to produce a stiffer COL network, consistent with measures of COL crosslink density [3]. Analyses using *in vitro* growth experiments with newborn bovine cartilage explants pre-treated with chondroitinase ABC (which depleted PGs by up to 90%) [5] identify limitations in the current CGM; those results suggest the need for identifying, and including in the model, additional constituents that regulate COL mechanical properties.

References

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