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Growth mechanics in degradable hydrogel scaffolds

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ABSTRACT

Despite tremendous advances in the field of tissue engineering, a number of obstacles are still hindering its successful translation to the clinic. One of these challenges has been to design cell-laden scaffolds that can provide an appropriate environment for cells to successfully synthesize new tissue while providing a mechanical support that can resist physiological loads at the early stage of in situ implementation. A solution to this problem has been to balance tissue growth and scaffold degradation by creating new hydrogel systems that possess both hydrolytic and enzymatic degradation behaviors. Very little is known, however, about the complex behavior of these systems, emphasizing the need for a rigorous mathematical approach that can eventually assist and guide experimental advances. This presentation will introduce a mathematical and numerical formulation based on mixture theory, to describe the degradation, swelling, and transport of extracellular matrix (ECM) molecules released by cartilage cells (chondrocytes) within a hydrogel scaffold. The model particularly investigates the relative roles of hydrolytic and enzymatic degradations on ECM diffusion and their impacts on two important outcomes: the extent of ECM transport (and deposition) and the evolution of the scaffold's mechanical integrity. Numerical results based on finite element show that if properly tuned, enzymatic degradation differs from hydrolytic degradation, in that it can create a degradation front that is a key to maintain scaffold stiffness while allowing ECM deposition. These results, therefore, suggest a hydrogel design that could enable successful in situ cartilage tissue engineering.