Universität Rostock

Traditio et Innovatio

Student Job

Numerical solution of the chemically stimulated hydrogels

Project description:

Articular cartilage is found at opposing bone surfaces and its damage can result in pain and loss of mobility for many patients. The treatment of cartilage defects poses a clinical challenge owing to the lack of intrinsic regenerative capacity of cartilage. Cartilage defects can be treated by introducing a hydrogel material seeded with chondrocytes to the defect site whose properties resemble to the native cartilage [1]. Hydrogels are three-dimensional polymeric networks filled with water and mimic tissue environments. They are considered optimal to deliver cells and engineer damaged tissues. Hydrogels possess the ability to form multifunctional cartilage grafts since they possess polymeric swellability when immersed in an aqueous phase. Appropriate external stimuli like mechanical, magnetic, pH and electrical are then applied in order to integrate and adapt the hydrogel material to the native tissue environment [2].

Lai et al. [3] first developed a multiphasic theory to depict the mechanical properties of articular cartilage which is essentially a kind of natural polyelectrolyte hydrogel. Later, Wallmersperger et al. [4] composed a comprehensive model based on the previous theories and added the Nernst-Planck and Poisson equations to study the behaviors of polyelectrolyte hydrogels under the effect of electrical and chemical stimuli. The numerical solution of the one-dimensional chemical stimulation case is already implemented using FEniCS. In the current project, the numerical solution for the chemically stimulated hydrogel for the steady state will be extended for the two-dimensional case.

References:

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[2] M. Mahinroosta, Z. J. Farsangi, A. Allahverdi, Z. Shakoori, “Hydrogels as intelligent materials: A brief review of synthesis, properties and applications”, Materials Today Chemistry, vol. 8, p. 42–55, 2018.

[3] W. M. Lai, J. S. Hou, and V. C. Mow, “A triphasic theory for the swelling and deformation behaviors of articular cartilage”, Journal of biomechanical engineering, vol. 113, no. 3, 245–258, 1991.

[4] Wallmersperger, T.; Kröplin, B.; Holdenried, J.; Gülch, R.W. A Coupled multi-field-formulation for ionic polymer gels in electric fields. Proc. SPIE 4329, Smart Struct. Mater, 2001, pp. 264–275.

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