Universität Rostock

Traditio et Innovatio

Master Thesis

Simulation of electrically stimulated hydrogels for cartilage tissue engineering

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].

In this model, the sample consisting of hydrogel embedded with chondrocytes is immersed into a bathing solution subject to an externally applied electric field. The multiphasic model is used to solve this problem which consists of the Nernst-Planck equation for the ionic diffusion and convection, the Poisson equation for the electric potential and the mechanical equilibrium equations for the deformation. In the current project, the mechanical equilibrium equations will be coupled to the already solved Nernst-Planck and Poisson equations using multi-effect coupling electric-stimulus (MECe) model of Li *et al.* [3]. This multi-physics problem will then be solved using the open source software FEniCS with Python interface. Numerical results will be presented for the response of the electrical stimuli for both the buffer and hydrogel domains and compared with published literature results.

References:

[1] M. A. Brady, S. D. Waldman, and C. R. Ethier, “The application of multiple biophysical cues to engineer functional neo-cartilage for treatment of osteoarthritis (Part I: Cellular response)”, Tissue Engineering Part B: Reviews, vol. 21, no. 1, pp. 1–19, 2015.

[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] H. Li, Z. Yuan, K. Y. Lam, H. P. Lee, J. Chen, J. Hanes, and J. Fu, “Model development and numerical simulation of electric-stimulus-responsive hydrogels subject to an externally applied electric field”, Biosensors and Bioelectronics, vol. 19, no. 9, 1097-1107, 2004.

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