Biomechanical modeling of soft tissues in the context of intervertebral disc degeneration

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https://www.irphe.fr/~biomeca/index.html

Back pain affects most of us during life and is often related to intervertebral disc (IVD) disorders like scoliosis or disc degeneration. The latter is difficult to diagnose because there is no obvious signature in medical imaging for the early stages of degeneration. To provide an answer to this problem, our research team led for several years numerical and experimental studies to understand the link between mechanical stresses and degeneration with the aim to propose a reliable tool to assess the disc functionality and viability.

IVD degeneration could be induced by a reduced effectiveness of the cellular nutrient mechanisms. A biomechanical model has been therefore developed [1] to analyze the nutrient diffusion into the IVD when this latter is subjected to various dynamic loads and electro-chemical effects. This model allowed i) to predict the ability of the cell material to receive nutrients and ii) to evaluate the impact of parameters such porosity, elastic modulus and ionic contents on the concentration levels of nutrients and the pH level within the disc.

The objective of this numerical approach is to predict the long term ability of the nutrient processes to maintain cell material conditions close to homeostasis\(^1\) state for a given set of mechanical stresses including normal and abnormal 3D loading.

The IVD exhibit a complex and singular anatomy free from vascularization, very rich in water, heterogeneous and with a high content in collagen fiber in their peripheral part the *annulus fibrosis*. These fibers strongly contribute to the tissue’s mechanical properties, stress resistance but also fluid exchanges between disc and the outer tissues. These last mechanisms are not completely understand in details particularly concerning the fiber network permeability behavior under stresses which plays probably an important role in the global hydric content disc regulation. The study of these phenomena will be at the center of the study proposed during this thesis.

The MSc internship will be done at the IRPHE laboratory, located at Marseille, close to the Ecole Centrale Marseille campus. IRPHE is a public laboratory specialized in nonlinear mechanics, physics and biophysics. The present study belongs to the IRPHE’s project “Mechanics and Complexity” which is part of the LABEX (“Laboratoires d’Excellence”) national program of “investment for the future”.

**Research subject, work plan:**
The student work will be more precisely dedicated to the improvement of the numerical multi physic finite element model of the IVD. Several points need to be improved: taking into account i)

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\(^1\) Homeostasis : normal activity
collagen fiber network permeability ii) nutrient transport feedback effect on the disc mechanical properties iii) long term effects of the mechanics/biology coupling on the disc sustainability. The student will participate also to in vitro experiments with X ray micro-tomography measurements.

The candidate should have good knowledge of continuum mechanics, fluid mechanics. Skills in numerical modeling and biomedical engineering will be appreciated.

References:


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