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# DEVELOPMENT OF A BIOMIMETIC FINITE ELEMENT MODEL TO STUDY THE INTERVERTEBRAL DISC DISEASES AND REGENERATION

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Biomechanics, Finite Element Method, Human Spine, Intervertebral Discs, Disc Degeneration.

## INTRODUCTION

The study and numerical simulation of the Intervertebral Discs (IVD) are the paramount issue of this work. Its major expected achievements are to develop of a biomimetic strategy for the IVD regeneration, through the updating of a spine-oriented Finite Element (FE) solver. The motivation for this work comes from the fact that degeneration of the IVDs is one of the main problems of the spine, with a particular emphasis on the low back pain. For many years, a considerable amount of studies developed significant efforts to found the causes and possible solutions for such issue, given that spine problems are a major cause of disability on western societies. In fact, DDD (also known as spondylosis) is one of the largest health problems faced worldwide when judged by lost work time and associated costs (Shankar et al. 2009).

## THE INTERVERTEBRAL DISCS

The general anatomy of the human spine is well described in the literature. The IVDs are fibro-cartilaginous cushions serving as a shock absorbing system of the spine, which protect the vertebrae (VB), brain, and other structures, providing both flexibility and load support. They are composed by three major components: the nucleus pulposus (NP), the annulus fibrosus (AF) and the cartilaginous endplate (CEP), which are all functionally and anatomically interdependent (Jongeneelen 2006, Raj 2008).

The development of a biomimetic FE model of the IVD, in both healthy and degenerated states, is the fundamental objective of this work. Therefore, as the anatomical properties are already described, the definition of the biomechanical parameters of both states is essential. Some authors have demonstrated that the IVD presents hiper-visco-poro-elastic behavior, so this is the direction where most of the FE-based works devoted to the IVD are heading. Argoubi and Shirazi-Adl (1996) took one of the first steps on analyzing the poroelastic creep behavior of the IVD through FE modeling (Argoubi and Shirazi-Adl, 1996). Schmidt and co-workers (2010) created a L1-L5 FE model to study the relation between time of the day and loading of the spine, by measuring the fluid pressure. They simulated (and validated) 48 hours of loading-loading compression cycles, accounting on the tendency of the disc to swell due to the osmotic pressure. The results showed that the permeability of the IVD tissues and the resting periods play a major role on the mechanical behavior of the spine: these tissues present greater resistance to fluid outflow than inflow, and the consideration of this fact is essential to the equilibrium in the unloading and recovering phases (Schmidt et al. 2010). Schroeder and co-workers (2010) created and L4-L5 FE model to study the internal biomechanical characteristics of the IVD, based on an accurate description of both biophysical parameters and biochemical constitution. Fluid exchanges were also considered. This team was able to analyze the behavior of the IVD from an inside point of view, which was impossible to be directly performed, as the IVD are hardly accessible for in vivo studies (Schroeder et al. 2010).

## FINITE ELEMENT ANALYSIS

A good FE mesh is essential to perform accurate numerical simulations and so to properly describe the behavior of the IVD. Smit (1996) created a FE 3D model of half of a human L3-L4 motion segment (Smit, 1996). This model was adapted and transformed in a full motion segment model (fig. 1), and then served as basis

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for the development of an improved full VB-IVD-VB FE model (fig. 2).

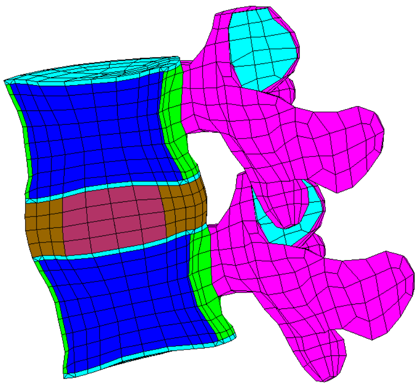

Figure 1: 3D FE model adapted from Smit (1996)

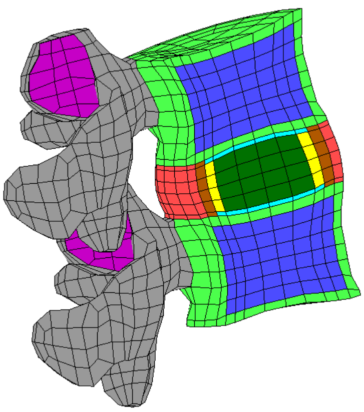

Figure 2: Improved 3D FE model

It must be highlighted that these models are being shown through an antero-posterior cut, but the represented meshes include the full components of the correspondent motion segment: cancellous and trabecular bone of the VB, facets, facet cartilage layers and NP, AF and CEP of the IVD . The major anatomical differences between the two models are the inclusion of the vertebral endplate between the trabecular bone of the VB and the IVD, the splitting of the AF in three layers and a new configuration of the CEP. All the modifications were done using specifically developed FORTRAN subroutines. This so-called "improved IVD model" allows the present work to become more close to the most up-to-date publications in this field. Using a home-developed FE solver, this model is subjected to numerical simulations. At the current point, is possible to apply hiper-visco-elastic parameters, and the next step is the poroelastic modeling of the IVD.

## CONCLUSIONS

Regarding that this is an on-going work, no major conclusions may be yet drawn. However, preliminary numerical testing with the current FE model showed satisfactory reproductibility of literature data. Such fact means that the FE model and the home-developed FE solver are heading on the aimed direction.

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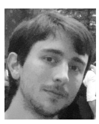

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