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THE INFLUENCE OF CERVICAL DEGENERATE DISC PROPERTIES ON THE STRAIN DISTRIBUTION IN ADJACENT VERTEBRAE, A COMPUTATIONAL MODEL

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1 INTRODUCTION

Cervical diseases are increasing in the world and are the third most common disease, mainly causing pain discomfort to the patient and sometimes disc degeneration. The cervical spine is made up of several structures including the vertebrae, intervertebral discs (IVDs), nerve tissue, and ligaments. Each structure is made up of a unique biomaterial , the vertebrae are made of hard bone material, while IVDs are made of elastic soft tissues [1] loosening the mechanical properties and dimensions with degeneration. The main objective of this study is to build a computational model that allows the analysis of the deformations applied to adjacent vertebrae when the properties of the natural IVD change, namely the mechanical properties.

2 MATERIALS AND METHODS

The finite element model (FEM) was developed according to geometric characterization coming from [2], based on a CT scan of a cervical anatomy. The model includes the C5 and C6 cervical vertebrae and the intervertebral disc divided into two bodies nucleus and anulus (figure 1). The anteroposterior disc length is approximately 17 mm, the lateral distance is 18 mm and the thickness of the disc is 5.5 mm which, follow the measurements of a natural cervical disc for a normal adult [3].The model was developed using second order tetrahedral elements and was considered to be glued between bodies.

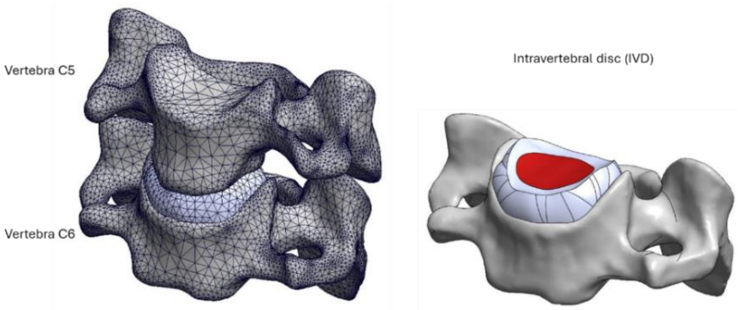

Figure 1 –Computational model of C5 and C6 cervical vertebra.

The model includes the anterior ligament with two springs and posterior ligaments through one spring, with stiffness presented in table 1. The boundary condition was the C6 fixed to the base and the load of 50N, equivalent to the head load, applied to C5, and a pre-load on the anterior and posterior ligaments of 20N each one.

Table 1 – Mechanical properties used in the simulations.

Component	Young Modulus	Poisson ratio
Vertebra cortical	10 GPa	0,3
Vertebra trabecular	100 MPa	0,4
Disc (nucleon)	1, 10 MPa	0,4
Disc (anulus)	55, 110 MPa	0,4
		Stiffness (N/mm)
Anterior ligaments	30 MPa	16
Posterior ligaments	25 MPa	25,4

Typically, the process of disc degeneration begins in the form of dehydration in the nucleus pulposus and uncovertebral joints. During the process, the fluid content in the nucleus region reduces and turns into a granular semi-solid. To simulate this in FEM, the mechanical properties of the tissues were implemented according to table, to approximate the degenerating process.

3 RESULTS

The results confirm that the stiffness of an IVD plays a fundamental role in altering the deformation of disc and adjacent vertebrae (figure 2) and may affect the development of spinal pathologies in the long term. The results also show that most of the load is carried by the posterior part of the vertebral body rather than the anterior part. The thickness of disc decreases from 9% up to 33.6% with degenerate disc properties.

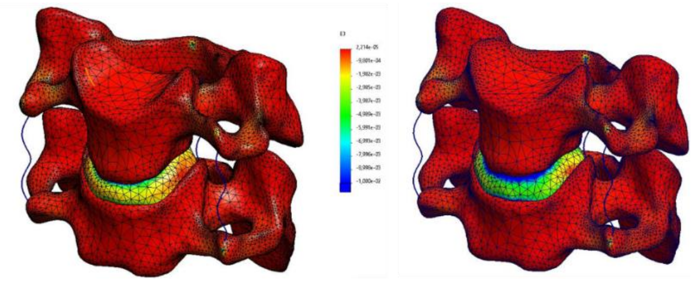

Figure 2 – Strain distribution in native model and degenerated.

4 CONCLUSIONS

Strain energy density and stress in vertebral cortex increased in areas adjacent to the degenerated disc. Specifically, the anterior region of the cortex responded with a greater increase in these responses. The increased strain energy density over time may induce the remodeling process according to Wolff's law, leading to the formation of osteophytes.

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