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# ANALYSIS OF THE INTERVERTEBRAL DISCS USING A FINITE ELEMENT AND MULTIBODY DYNAMICS APPROACH

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## ABSTRACT

The vertebral column (figure 1) is responsible not only for a wide range of movements, including lateral flexion, left and right rotation and flexion of the torso, but it also encloses and protects the spinal cord, supports the head, and serves as a point of attachment for the ribs and the muscles of the back. The human spine consists of 33 to 35 vertebrae divided in five regions: cervical (7), thoracic (12), lumbar (5), sacrum (5 fused vertebrae) and the coccyx (4 to 6 fused vertebrae) [1].

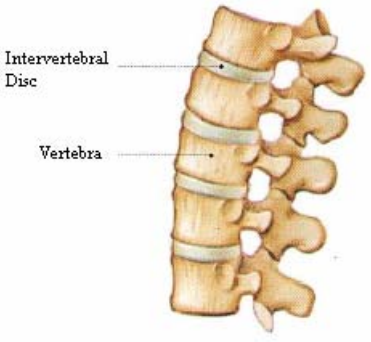


**Figure 1:** Vertebral Column.

Between adjacent vertebrae (from C2 to the sacrum) there is a deformable segment, the intervertebral disc, with a convex shape that adapts and connects to their articular surfaces. The discs form strong joints, permit various movements of the vertebral column, and absorb vertical shock. In each disc it is possible to identify two distinct areas: a peripheral area, consisting of *quasi* concentric lamellae of fibrocartilage; and a soft, pulpy, highly elastic central area. Fibre's orientation of each lamella depends on the direction of undergoing stress, which is applied in the vertical or horizontal direction according to the type of movement, flexion of the torso or rotation, respectively; so the fibre's orientation is an intermediate direction (oblique).

Intersomatic fusion is a clinical procedure used to treat some lesions of the vertebrae associated with tumours, degenerative pathology or trauma, like disk herniation. This procedure consists of the complete removal of one or more intervertebral discs and their replacement by a bone graft, which provides a substrate for reconstruction of the vertebral column by bone fusion of the adjacent vertebrae [2]. Until bone fusion occurs internal fixation plates are used to ensure the connection between the corresponding vertebrae.

The results of this surgery are excellent, neurologically speaking; however, afterwards,

there are some registered cases of patients with lesions on the intervertebral discs, adjacent to the fused region. As a consequence, there is an incidence of 17% (study with an observation period of more than two years) of symptomatic cases [3], and in some cases it is necessary a new surgical procedure. In fact, intervertebral fusion eliminates the articulation in the region where it occurs, changing the conditions of stress applied in the adjacent intervertebral discs, associated with a mobility limitation [4].

The objective of this work is to confront the stress applied in the intervertebral discs before and after the intersomatic fusion, as well as the mobility limitation introduced in the vertebral column.

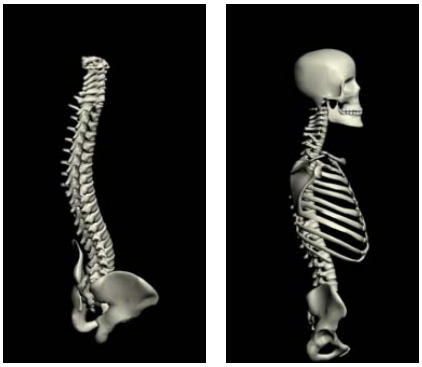

**Figure 2:** Model used for visualization.

In order to achieve these goals a biomechanical model simulating the structure of the spine is developed (figure 2). The model has a hybrid structure in which the vertebrae and associated components are modelled as rigid bodies and springs (ligaments, tendons) using a multibody dynamics approach and the intervertebral discs (amphiarthrosis) are comprehensively described by a finite element mesh (figure 3) [5]. The multibody part of the model thoroughly describes the kinematics and dynamics of the vertebrae and ligaments and prescribes these to the FEM model of the disks that, by its turn, calculates their deformation, stresses and reactions on the vertebrae facets, returning these values again to the MDS part. With this model it is possible to simulate the movements of the vertebral column and compare the forces and moments acting on the intervertebral discs at each time step, before and after a surgical procedure. The results exemplifying the functionality of the simulation model are exposed in the work's discussion.

**Figure 3:** Mesh of a given vertebra.

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