8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

A MULTIBODY MODEL OF THE HUMAN CERVICAL SPINE FOR THE SIMULATION OF TRAUMATIC AND DEGENERATIVE DISORDERS

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Key Words: *Multibody Dynamics, Cervical Spine, Head and Neck, Traumatic Disorders, Degenerative Disorders.*

ABSTRACT

The human cervical spine and the atlanto-occipital articulation can suffer traumatic and degenerative disorders, like whiplash or rheumatoid arthritis (RA), for example. RA is a inflammatory autoimmune disorder that causes the immune system to attack the joints and affects 0,5-1% of the world population. Usually the spine is the last part to be affected and the atlanto-occipital joint the first part of the spine to be involved [1]. The upper cervical spinal cord may be compressed and neurological symptoms may appear. In these situations, sometimes, the therapeutic approach is chirurgic and it consists in the realignment of the injured anatomical structures which compress the spinal cord. In this way, it is necessary to fix the spine internally aiming the osteofusion of the C1 and C2 vertebrae or the C1 and occipital bone. Whiplash is a soft tissue injury, caused by excessive hyper extension or hyper flexion to the cervical, thoracic or lumbar spines. It is commonly related to the injuries in a motor vehicle accident, especially when the vehicle is hit in the rear, throwing the neck backwards. Specifically, it may include lesions to intervertebral joints, discs and ligaments, cervical muscles and nerve roots.

The main goal of this work was to develop a 3D biomechanical model of the cervical spine and occipital bone, using a multibody system dynamics approach, in order to predict the results of chirurgical interventions needed to fix pathologic situations. The model comprises the occipital bone, seven cervical vertebrae (atlas, axis and 5 similar cervical vertebrae), the first thoracic vertebra (fixed, used as origin of the global coordinate system), intervertebral discs, ligaments and muscles. In this model, briefly depicted in *fig. 1*, intervertebral discs were modelled as 6 degree-of-freedom bushing elements, restricted through spring-damper relationships. There are no discs between the atlas, axis and occiput. All the properties of the discs were collected from the literature [3]. The limits of motion between adjacent vertebrae are defined by the facet joints, as proposed by Lopik [3].

The lumbar, thoracic and cervical curves of the spine are produced by the differences in

the anterior and posterior thicknesses of the disc, when the trunk is erect. The cervical curve was also considered, according to values taken from literature for the size and angulation of the vertebral processes [4]. This will change the orientation of the facet joints and, therefore, will provoke curvatures on the spine.

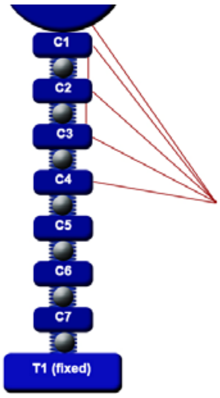

Figure 1. 2D simplified model of the human cervical spine and occipital bone. Only a few muscles and ligaments are represented.

The ligaments support the spine, contributing to its stability, and in this model they are represented as spring-damper elements [2,3]. Anatomic data from literature is used both for ligaments and muscles properties, as well as their attachment sites [3]. Muscles were included in the model using Hill-type muscle models [5].

The atlanto-axial articulation is different from the others between adjacent vertebrae, as well as the atlanto-occipital articulation. The first allows considerable axial rotation, as well as a small amount of flexion, extension and lateral flexion [3]. The second is, anatomically speaking, very complex. It is modelled as a concave-convex joint, allowing flexion and extension of the head, and preventing lateral and posterior/anterior sliding of the head [3].

Using this model the results of several situations can be predicted by removing, adding or joining rigid bodies: movement ranges and resulting forces and moments in the muscles, ligaments and articulations, as well as an estimation of the deformations in soft tissues such as the intervertebral discs.

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