Short Communication
Volume 11:10, 2022

Journal of Spine

ISSN: 2165-7939 **Open Access**

Validation of a Functional Spinal Unit and the Creation of a Cervical Spine Finite Element Model

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Introduction

The cervical spine is a typical site of injury in the vertebral section, with serious wounds frequently connected with harm to the spinal string. There have been a number of studies done to learn more about these situations mechanisms and come up with ways to treat or even prevent them. Computational models are one of the best and most widely used methods because they have unique features like providing information on strains and stresses that would be hard to get otherwise. As a result, developing a brand-new finite element model of the human cervical spine that accurately reflects the majority of its components is the primary goal of this work, which aims to improve comprehension of the necks mechanics. Using the computer tomography scans of a woman who was 46 years old, the initial geometry of the cervical spine was determined. After that, the entire model was broken up and the C6–C7 segments of a functional spinal unit were simulated to start the validation process. *In vitro* tests evaluated the range of motion of various cervical segments in terms of flexion–extension, axial rotation and lateral bending and the reduced model was validated against experimental data.

Description

The cervical spine, which is viewed as the human neck, is the upper district of the vertebral segment and a typical physical issue site. Damage to the spinal cord is frequently linked to severe cervical injuries, which can result in permanent disabilities or, in the worst cases, even death. However, the majority of neck injuries do not pose a significant threat to life. Whiplash is one of the most common neck injuries; Whiplash-associated disorders (WAD) have been assigned to the plethora of clinical symptoms and complications. Sports injuries, physical abuse and other types of trauma, such as falls, can all cause whiplashes; It occurs most frequently in automobile collisions, particularly rear-end collisions. In North America and Western Europe, the annual incidence of whiplash is estimated to be around 300 cases per 100,000 people. About 40% of people who get whiplash end up with chronic headaches and neck pain. Therefore, in order to develop methods for treating or even preventing such injuries, it is necessary to study how the body reacts in such circumstances [1].

To collect data, there are three types of studies to choose from: computational models, *in vivo* studies and *in vitro* studies. Due to the risk of injury and legal and ethical considerations, *in vivo* testing has been reduced. Casuariums are required for *in vitro* studies; the deterioration of the samples caused by repeated use results in less precise results. Because they are able to provide information that cannot be easily obtained in other studies, such as internal stresses or strains, are simple to quickly simulate various situations and they can be used repeatedly for multiple experiments with uniform consistency, which lowers costs, computational models are more appealing. As a result, they are now the most commonly used strategy. Simple geometries were used in the initial computational models of the cervical spine; today, nonetheless, progresses in innovation have prompted the improvement of models that all the more precisely mimic the way of behaving of the cervical spine. The parametric and precise reconstruction approaches, respectively, have been utilized to generate the geometry over time. Despite the fact that they each have their advantages and disadvantages, both typically exhibit acceptable spinal behavior [2].

The complexity of the model geometry is reduced when parametric studies are used to generate it and the simulation of spinal behavior yields reasonable results. It speeds up computation, makes it easier to see what's going on and lets you change geometric dimensions if you need to. The fact that they do not accurately represent the actual geometry of the cervical spine is their primary drawback. A more bio-realistic model may be produced by utilizing medical images for geometry acquisition, such as computer tomography (CT) and magnetic resonance imaging (MRI). Programs that make it simple to manipulate medical, biomedical and related imaging have contributed to the rise of this strategy. Although it takes longer to acquire models and run computer simulations, it yields the most trustworthy results. The methodology of combining parametric and precise reconstruction has grown to be widely used. Also, different models have utilized the cross section meaning of nearby vertebrae to acquire the intervertebral circles. Six degenerative models representing mild, moderate and severe disc degeneration at the C5–C6 level were created by modifying the initial model [3].

The biomechanical response of cervical disc replacement with a self-designed prosthesis was accessed by validating the model developed to accurately represent the C2–C7 segment. To comprehend the previous approaches and, consequently, to comprehend how to approach the subject, a review of these studies is essential. These studies can also be applied in other areas, such as the design of implants, surgical planning and the prevention of cervical injuries. In addition, any necessary model modifications can be carried out easily. In order to begin the validation process, this work focuses on the creation of a new model of the human cervical spine by combining medical images with parametric studies to accurately represent the majority of its components, including the vertebrae, intervertebral discs, facet joints and various ligaments. By providing information that would otherwise be impossible to obtain, the finished model can contribute to a deeper comprehension of the kinematics of the cervical spine, with an emphasis on the mechanisms by which injuries occur. Additionally, more accurate simulations may be possible by combining the created model with a 3D head model [4].

The vertebrae were then divided into the cortical and cancellous types of bones. The spinous process, for instance and the posterior elements of the vertebrae were not considered distinct types of bones and were not modelled as such in this work. As the outer layers of the mesh on the vertebrae, the cortical bone was thought to have a thickness of about 0. 5 mm, which is the average thickness reported in the literature. The AF ground substance, the nucleus pulpous and the cartilaginous endplates were the three distinct types of materials that separated the intervertebral discs. It was concluded that the AF strands wouldn't be remembered for request to improve on the primary re-enactments of the cervical FEM. The endplates were displayed as the top and base layers of the intervertebral circle. The nucleus pulpous (40%)

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Date of submission: 01 October, 2022, Manuscript No. jsp-22-81468; **Editor assigned:** 03 October, 2022, PreQC No. P-81468; **Reviewed:** 10 October, 2022, QC No. Q-81468; **Revised:** 17 October, 2022, Manuscript No. R-81468; **Published:** 24October, 2022, DOI: 10.37421/2165-7939.2022.11.568

and AF grounds (60%) made up the remainder of the disc. The formulation of the facet joint was the next step. The superior and inferior articular cartilages were given contact integration properties to model these. The superior and inferior articular process surfaces—corresponding to the inferior and superior cartilages of each corresponding vertebra as well as anatomical descriptions from the literature served as the basis for the creation of the cartilage geometry [5].

Conclusion

With the exception of the facet cartilage, which was modelled using general purpose linear brick elements (C3D8) and the nucleus pulpous, which was modelled using hybrid reduced integration hexahedral elements (C3D8RH), the majority of the components were modelled using eight-node brick elements with reduced integration (C3D8R). The software can only represent incompressible materials using these elements, so the hybrid formulation was used in the first case because reduced integration elements performed poorly during contact and the general-purpose elements performed best when simulating.

Acknowledgement

None.

Conflict of Interest

None.

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How to cite this article: Wahhab, Abdel. "Validation of a Functional Spinal Unit and the Creation of a Cervical Spine Finite Element Model." J Spine 11 (2022): 568.