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Biomodelling and craniocervical numerical analysis under the effect of frontal loading on the skull

Abstract

This research work presents the craniocervical mechanical behavior from the biomodelling of the skull, cervical C1-C5, intervertebral disc and spinal cord, therefore, visualize their behavior under the effect of frontal load on the skull. The material implemented for the skull and cervical C1-C5 is cortical and trabecular bone, then, for the intervertebral disc fibrous ring and nucleus pulposus were implemented, finally, for the spinal cord consists only of a material which is nervous tissue. To simulate this biological system is very difficult. However, the Finite Element Method (FEM) allows solving cases that were practically impossible, since mathematical models of the calculation of the real system can be made, easier and cheaper, in addition, improvements can be made iteratively, likewise, through simulation represent it as in reality it would be appreciated.

Keywords: finite element method, nervous tissue, biomodelling

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Introduction

Currently, computers have provided the effective means to solve problems that were practically impossible to solve through sophisticated graphics packages that allow modeling and assimilating the results.[1] Also, with the great technological advance it is easier to study the mechanical behavior of biological systems.[2] For the biomodelling of anatomical structures. First for the skull and cervical, cortical, and trabecular bone, then, the spinal cord and the intervertebral disc of the tomography are observed, then the construction of a solid is passed for analysis with the Finite Element Method and the interpretation of the results obtained. For the construction of the complex set. The patient undergoes a tomographic study, generating images in DICOM format.[3] The files are then processed in the Scan IP program (Figure 1).[4] Each image is displayed in a grayscale, which allows to identify each anatomical structure and to fill the areas of each structure with different colors. It will then be transformed into an STL format (Figure 2). Once generated, it is imported into the ANSYS WORKBENCH software, and the corresponding numerical analysis will be performed.

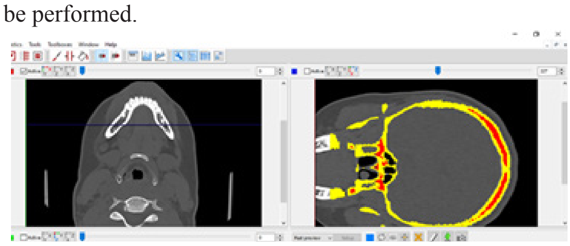

Figure 1 Area delimitation in cortical and trabecular bone.

Figure 2 Image in STL format.

Methodology

The craniocervical numerical analysis is obtained as follows:

A. Definition of the type of analysis.

B. Define the geometry type.

C. Finite element type selection for discretizing generation.

D. Set the edge conditions for the foreign agent application.

E. Model solution.

F. Obtaining results.

When the discretization of the biological system is established, it is automatically generated by the program by the irregularities of the surface of the anatomical structures (Figure 3). To solve this type of analysis, the frontal impact of a boxer in a real situation is established.[5]

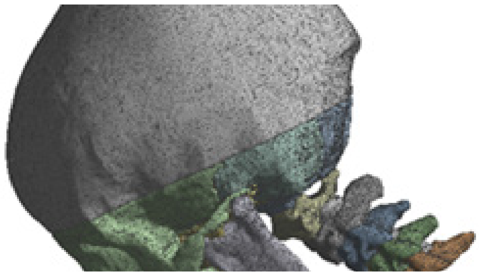

Figure 3 Discretizing the model.

Where a load of 0.229808 MPa is considered in the front of the skull, it is implemented in the form of pressure, since the contact begins on a surface of 10 cm and from there all the impact energy expands throughout the joint complex.[6] Based on the characteristics of a boxer in Mexico is 82 kg. For the calculation of the external agent applied was made based on Newton's second Law, where the biomechanical variables throw 22 m/s^2 of acceleration in a straight blow of a boxer.[7] Once the force is obtained, the pressure calculation is carried out with the area implemented in the skull.

Force with Newton's second law.[8]

$a = F / m$--- ---------------------------------- (1)

$F = (82\ kg)\ (22\ m/s^2) = 1\ 804\ kg\ m/s^2$.

Pressure is calculated.

$P = F / A$------------------------------------- (2)

$P = 1\ 804\ N / 0.00785\ m^2 = 0.2298089171\ MPa$ (Figure 3)

The boundary conditions for this analysis are established at the bottom of the cervical C5 in which all degrees of freedom are restricted on the X, Y and Z axes (Figure 4). It is important to mention that it is a dynamic study since an impact on the skull is analyzed. The application of the load for impact analysis is placed on the front of the skull, since it is the part, most hit by a boxer and allows better visualization of the most critical points after impact (Figure 5).[9] The model solution allows to visualize the values and displacement, of maximum and minimum tensions, showing the most critical points during the impact of the skull (Figure 6). The same way and in the cervical in conjunction with intervertebral discs and spinal cord (Figure 7) after impact.

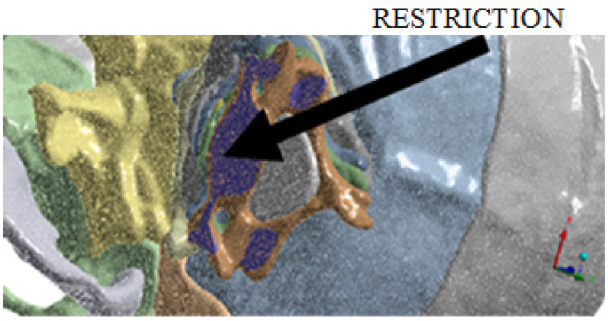

Figure 4 Application of boundary conditions.

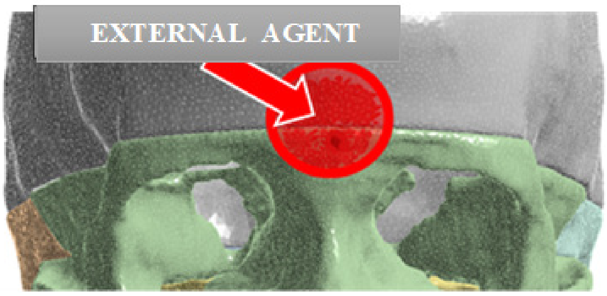

Figure 5 Load applied to the model.

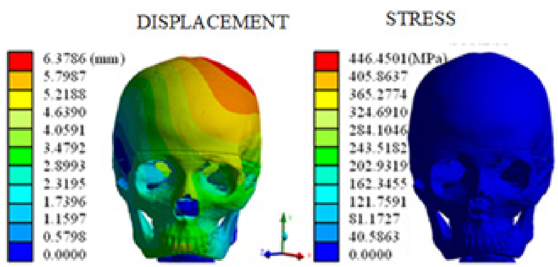

Figure 6 Displacement and stress Von Misses Craniocervical.

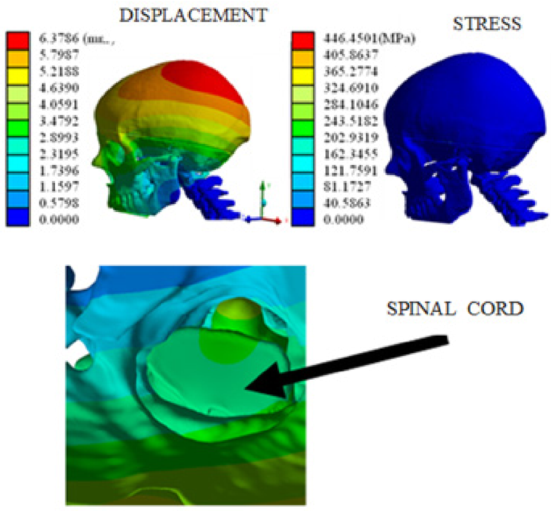

Figure 7 Displacement and stress Von Misses Craniocervical.

Discussion

Craniocervical modeling and analysis is a very useful tool because it not only works to understand the behavior of the joint complex, but in the medical area to understand concussions and avoid future conditions in cervical and intervertebral discs.

Conclusion

With the methodology presented in this work it is possible to carry out the construction of a craniocervical model from a computerized axial tomography, in this way a series of virtual objects that share characteristics are like those of real bones. On the other hand, with this type of work it is possible to visualize the real behavior of the skull, cervical C1-C5, intervertebral disc and spinal cord when a boxer is hit in a real situation in the front. Obtaining results of total displacement of 6.3786 mm and using the theory of failure to of Von Mises it is possible to visualize in the joint complex with a value of 446,450 MPa. This in turn indicates that bone being a ductile material has linearity, continuity, homogeneity, and isotropy.

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Conflicts of interest

The authors declare that there is no conflict of interest.

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