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ASSESSMENT OF THE TENSION CONDITION THAT OCCURS WHEN THE BODY IS IMMOBILIZED IN A BOSTON-TYPE PLASTIC CORSET

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Abstract
The paper aims to make a theoretical study - using the finite element method, on the local elastic stresses and deformations that appear in the sagital plane under the use of a Boston corset made of polypropylene.The studies prove the fact that the elastic stress state appearing in the xOy plane in the case of the flexion motion is higher whit 18% than the elastic stress state appearing in the same plane in the case of the extension movement and the higher elastic displacements are recorded in the flexion motion. The occurrence of local deformities at the level of the fractured vertebrae may lead to the wrong splicing of the vertebrae, which causes changes in the geometry of the spine.

Keywords:Spine, Boston orthosis, vertebrae, finite element.

Introduction

Polypropylene or polypropene($(CH_4=CH\text{-}CH_3)_n$is a thermoplastic polymer obtained by the polymerization of the propylene monomer ($CH_2=CH\text{-}CH_3$), [1]. Due to its thermoplastic properties, polypropylene is used successfully in various sectors of activity such as automotive, electronics, aeronautics, machine building, chemical industry, in medicine for the construction of various prostheses, external orthotics, etc, [2].

One of the oldest methods used to stabilize the spine in the case of a fractured fracture is to fix the body in an outer fixator called the Boston orthosis or corset - made of plastic. In the case of plastic orthotics, there are situations where fusion of bone fragments of the traumatized vertebrae is accomplished imperfectly, altering the biomechanical behavior of the spine, [3, 4].

The underlying causes of imperfect fusion of traumatized vertebrae are due to the rotation or long-distance movement of bone fragments of the vertebrae component during flexion or sagittal extension [5, 6, 7]. The paper aims to make a theoretical study - using the finite element method, on the local elastic stresses and deformations that appear in the sagital plane under the use of a Boston corset made of polypropylene.

Materials and method

Finite element method

The state of tension, deformation and local displacements in the spine as immobilizing the bodyin a Boston orthosis and executing the flexion and extension movements in the sagittal

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plane - were determined by using a two-dimensional model of the spine and ANSYS Multiphysics Finite Analysis Program (ANSYS Inc., Canonsburg, PA) [8-10]. The model of the ligament spine contains vertebrae, vertebrae with upper and lower end plates and a number of ligaments: anterior longitudinal, longitudinal posterior, flavum ligament, interspin ligament and supraspinal ligament.

From the literature and the Ansys database, the properties of the materials used in simulation [10-15], respectivley Young's Modulus (E) and Poisson ratio, were taken as foolows: Cortical bone: E_l= 12000MPa, ν_1 = 0.3, Cancellous bone: E_2=200MPa, ν_2 = 0.3; Posterior bony elements: E_3=3500MPa, ν_3 = 0.25; Annulus: E_4=8.4MPa, ν_4 = 0.45, Nucleus: E_5=1.0MPa, ν_5 = 0.49; Anterior longitudinal ligament (ALL) – E_6=11.4MPa, ν_6 = 0.4; Posterior longitudinal ligament (PLL) – E_7=9.12MPa, ν_7 = 0.4; Ligamentum flavum (LF) – E_8=5.7MPa, ν_8 = 0.4; Interspinous ligament (ISL) – E_9=4.6MPa, ν_9 = 0.4; Supraspinous ligament (SSL) – E_{10}=8.5MPa, ν_{11} = 0.4, Body I – E_{11}=9000MPa, ν_{11} = 0.3; Body II – E_{12}=2000MPa, ν_{12} = 0.3.

In the considered model, the chest box and the abdominal box were not represented, which is why these bodies were attributed to specific mechanical properties. For meshing the model elements, the two-dimensional solid elements, respectively Plane 183, Plane 82 and Plane 93 were used, [16].

The model has undergone, in the upper zone, stretching forces to allow flexion or extension of the body. The model was also validated for flexion and extension movements using in vitro data published by various researchers [17-22] and detailed in detail by Zader et al. [23] and a high degree of compliance.

The following simulation plan was adopted to establish the range of motion-ROM as well as the stress state of deformation occurring at the level of the fractured vertebra T11 in the anterior longitudinal ligament

Table 1. Simulation program

Model	Movement type	Force, (N)
Boston-Type Plastic Corset	Flexion	300 500 700
	Extension	300 500 700

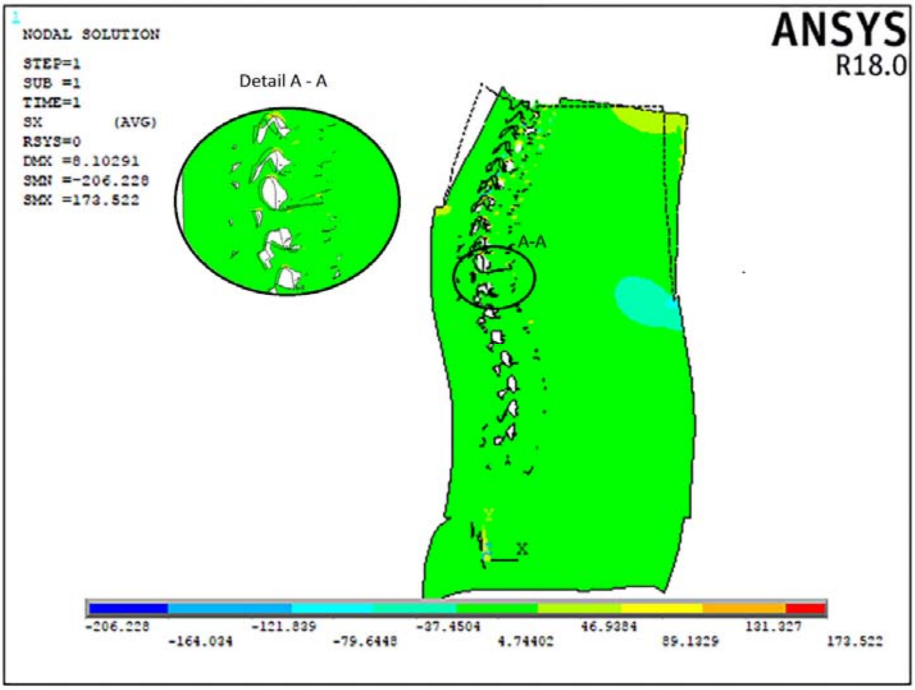
In the considered model the relative average elastic deformation degree of the bones from the bone fragments adjacent to ALL longitudinal ligaments was determined.

The forces required to achieve the extension and flexion were applied to the body at an angle of inclination of 60 degrees against the negative direction of the Oy axis.

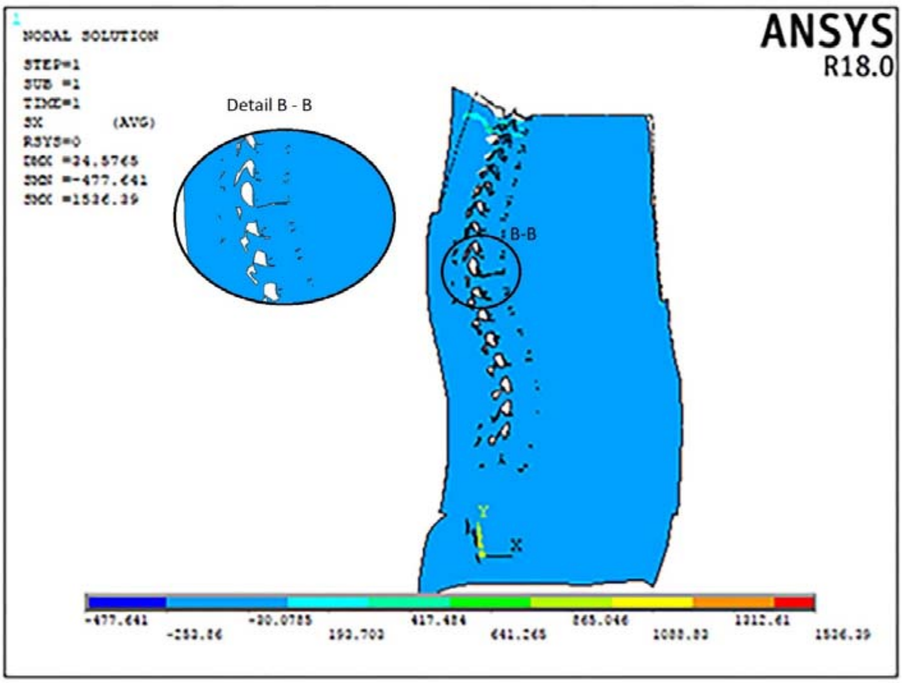
Results and discussions

The theoretical investigations made by this study focus on the T11 vertebral fractured fractured fracture pattern because this type of fracture has the highest incidence of car accident occurrence.

In Figure 1a-b is shown the total variation of stresses inside the body in the xOy plane, provided the 700N force flexion movement and the 400N force action extension movement are performed. In detail, the stress variation in the vertebra T11 is presented

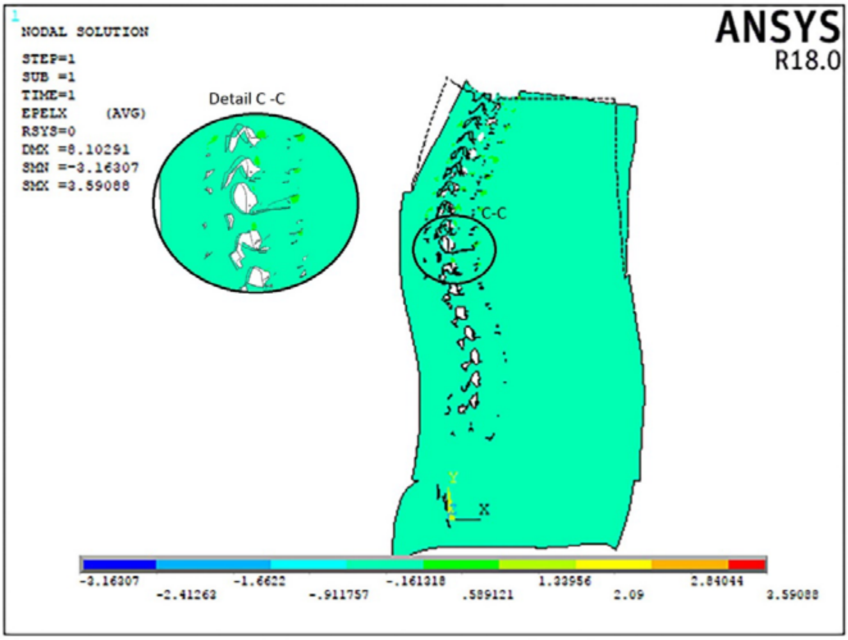


a)

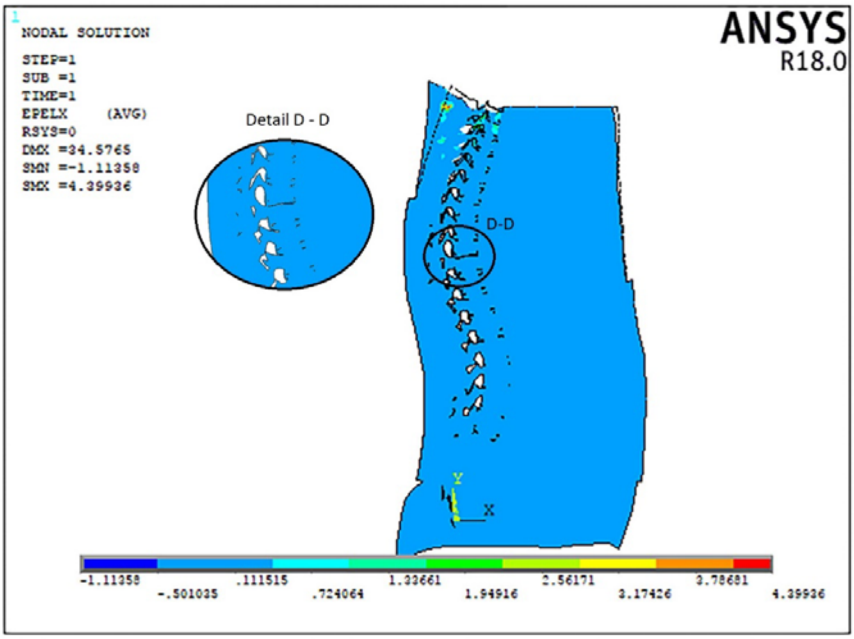


b)

Fig. 1. Variation of elastic tension in the body - in the xOy plane, provided the body is immobilized in a Boston orthosis, and the execution - in the sagittal plane, of a movement of: a) flexion with the force of 700N; b) extension with the force of 700N.



a)



b)

Fig. 2. The elastic deformation in the fractured area T11, provided the body is immobilized in a Boston orthosis, and the execution - in sagittal plane of a movements of: a) flexion with the force of 700N; b) extension with the force of 700N.

By analyzing Fig. 1 a and c it is observed that in the plane of movement (xOy), higher tensions at the level of the fractured vertebra T11 occur in the case of the flexion movement. Because the state of mechanical tension inside the human body is the one that acts directly on body pain receptors, we can say that in the case of the extension movement of an immobilized body in the Boston-type orthesis, plastics, there are more pains in executing the flexion movement , rather than the extension move.

It can be noticed that with the use of one Boston orthosis - 5 mm thick, the greater local elastic deformations occur at the fractured fragments, provided the body performs a flexion movement – see figure 2a and b. The appearance of local deformities at the level of the fractured vertebrae can lead to the wrong splicing of the vertebrae, which causes changes in the geometry of the vertebral column.

It is noted that the size of the extension angle, in the case of stabilizing fracture with the Boston orthosis in PP, is greater by about 62% compared to the flexion angle obtained under the same conditions.

Conclusions

Immobilization in orthesis is a common method of treatment for toraco-lumbar fractures at vertebral T11 level. By analyzing the finite elements of the flexion movement, respectively the extension of the body, provided it is immobilized in the Boston orthosis of the polypropylene, and the existence of a burst fracture it is observed that:

- The elastic stress state appearing in the xOy plane in the case of the flexion motion is higher than the elastic stress state appearing in the same plane in the case of the extension movement;
- Larger elastic tensions in the fractured area occur in the flexion movement;
- For the same value of the extension or flexion force, the higher elastic displacements are recorded in the flexion motion. The occurrence of local deformities at the level of the fractured vertebrae may lead to the wrong splicing of the vertebrae, which causes changes in the geometry of the spine - see Figure 2.

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