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Influence of Vertebral Compression Fractures on the Deformation in Thoracolumbar Spine

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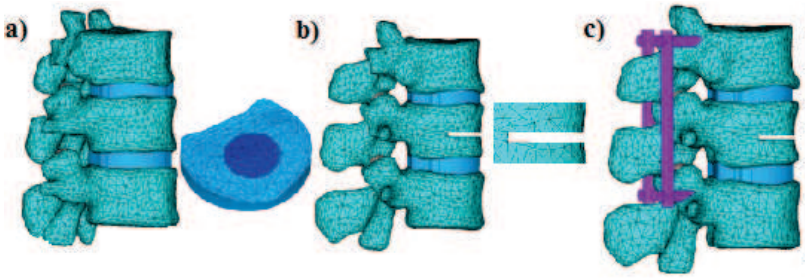
Abstract: The aim of this study is to create a numerical model of the thoracolumbar spine. The model was built on the basis of diagnostic computed tomography. The simulations were performed on a physiological model, with a vertebral compression fracture and model with transpedicular fixation system. The knowledge about the mechanical properties obtained from numerical simulations would allow explain influence of vertebral compression fracture on the deformation thoracolumbar spine and the biomechanical aspects in the treatment of spine injury.

Introduction

Spine, as the main organ of movement, is subjected to variable loads and overloads often lead to injuries and mechanical damage. Treatment of the damaged spine segment is a very complicated process, consisting mainly from a complex construction and the occurrence of multiple connections of joints and ligaments. It is usually based on the use of technical aids to improve the stability in the form of implants. Thoracic and lumbar spine differ from each other both in movements as well as in structure. This affects the complicated structure of the transition between them, thereby increasing the instability of the connection [1,2].

Material and methods

The numerical model of the thoracolumbar spine was built on the basis of diagnostic CT. The motion segment (Th11-Th12-L1) was developed in several stages using programs such as: Mimics, MeshLab, AutoMesher and Ansys. The physiological model was constructed with solid elements (more than 2 million tetrahedral 10-nodes elements), divided into several structures with different tissues; the isotropic material properties are shown in the Fig.1. Numerical simulations were performed for three cases: physiological condition , condition with a vertebral compression fracture and model with transpedicular fixation system. The vertebral compression fracture in the motion segment was simulated as a fissure of thickness 2mm comprising two-thirds of the volume L1 vertebra. The analysis was carried out under the influence of axial compression force equal to 600N for each case.



Component name	E [MPa]	υ [-]
Cortical bone	12 000	0,3
Cancellous bone	100	0,2
Annulus fibrosus	8,4	0,4
Nucleus pulposus	1	0,499
Articular cartilage	33	0,3
Titanium alloy Ti-6Al-4V (stabilization)	110 000	0,36

Fig. 1: The numerical model of the spine segment: a) physiological, b) with a vertebral compression fracture, c) with transpedicular fixation system and their material properties [3,4]

Results

Analysis was performed to show the impact of stabilization on the state of displacement of the damaged segment of the thoracolumbar spine. The computed displacements for all three cases considered models are shown in the chart (Fig.2). It can be concluded that the transpedicular fixation system increases stiffness of the spine motion segment and prevents the excessive deformation caused by the compressive load. Considering the distribution of computed displacements (right hand side of Fig. 2) the differences between the physiological model and the model with transpedicular fixation system is easily distinguishable. Additionally, it can be seen that the fracture in front of the vertebral body (L1) contributes to the compression mechanism connected with the bending.

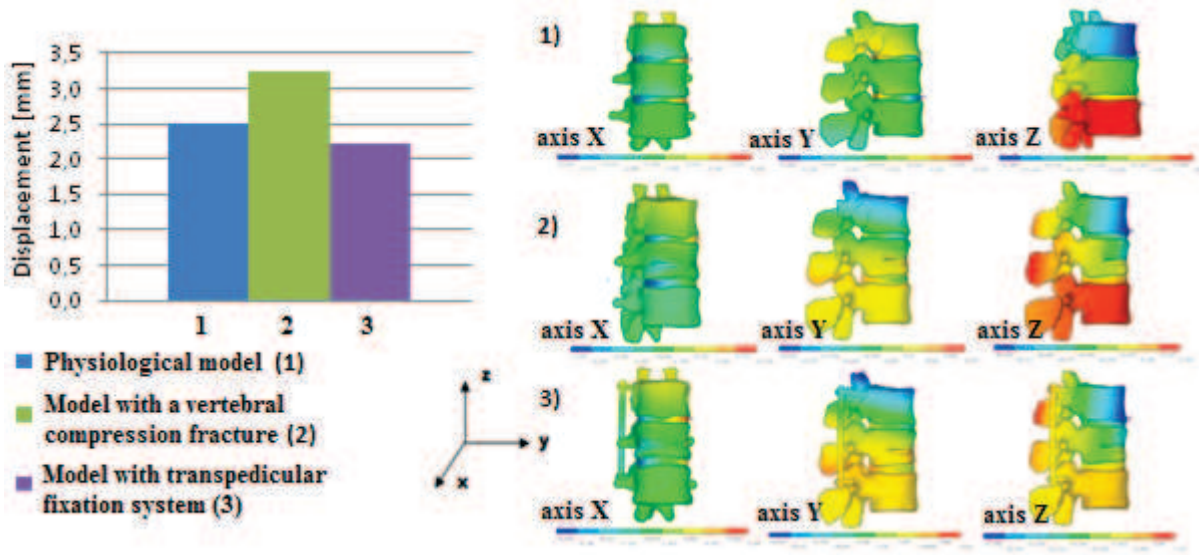


Fig. 2: Complete displacement case considered models under the influence of the loading force equal to 600N

Summary

The analysis showed that the transpedicular stabilization of vertebral fracture in the thoracolumbar segment does not provide enough stability in case of compressive load, causing bending of the motion segment. This could justify the fact that the two-segment spine stabilization is not able to completely prevent displacement of the region damaged vertebra. Therefore, in clinical practice thoracolumbar spine fractures are often stabilized in four segments constructs [4]. It should be also noted that the transpedicular stabilization of thoracolumbar segment with the vertebral fracture gives the opportunity to improve the stability and stiffness of the case.

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