Introduction

The finite element method (FEM) is a numerical modeling method that is widely used in scientific research of the complex systems biomechanics. FEM provides an opportunity for researchers to repeat the analysis of the system at change of the model parameters. Newly developed mathematical models by the FEM need to be confirmed the adequacy of the obtained results and often for this purpose the finite-element models are compared with the experimental (physical) models. Then, it is possible to carry out research of models with modified parameters, for example in using the materials with different properties, a variety of surgical fixing systems and treatment methods.

The objectives of this study – to built the mathematical biomechanical models of the explosive ThXII vertebra fracture and compare their results with those of experimental (physical) models.

Materials and Methods

Animal (pig) experimental model of normal ThIX-LV vertebral segment and the models of the ThXII vertebra injuries developed by laboratory of biomechanics SI «Sytenko Institute of Spine and Joint Pathology of National Ukrainian Academy of Medical Sciences» were taken as a basis data. Four mathematical models corresponding to the experimental models were created: 1st model – normal ThIX-LV vertebrae; 2nd model –50 % destruction of the ThXII vertebral body including its posterior part; 3rd model –a total destruction of the ThXII vertebral body and the adjacent intervertebral disks; 4th model – a total destruction of the ThXII vertebral body and the adjacent intervertebral disks and posterior supporting complex (arc and partly joints).

Load tests were carried out on all models in the form of a vertical axial load which changed stepwise from 0 to 500 N. The offset value of vertebral segments in the fracture zone (kyphotic deformity) was recorded at each loading step. Geometric models were built in the program SolidWorks, finite element calculations were performed in the program ANSYS.

All mathematical models were rigidly fixed on the underside of the LV vertebral body, and the upper surface of the ThIX vertebral body was subjected to a vertical load, which changed stepwise from 50 to 300 N (loading step was 50 N). Obtained data were statistically processed by t-test for paired samples and correlation analysis.

Results

The mean values of loading offset are different between mathematical and experimental (physical) models of explosive thoracolumbar spine fracture. The offset values in the 1st and 2nd models (normal and with 50% destruction of the vertebra) are greater at the experiment (1.68 – 1.63 and 3.19 – 2.68 mm, respectively) than at the
mathematical modeling (0.66 - 0.35 and 1.75 - 0.93 mm, respectively). However, the difference between the mean values of loading offset in 3rd and 4th model (with the total destruction of the vertebrae and the adjacent disks, and additional destruction of the posterior supporting complex) is decreased significantly (experiment – 5.52 - 2.55 and 7.83 - 1.78 mm; mathematical modeling – 4.90 - 2.62 and 6.65 - 3.55 mm, respectively).

The obtained data of the correlation analysis showed that both experimental and mathematical models reproduce the offset processes of the samples with high statistical significance (p<0.01). The obtained data of the T-test for paired samples revealed no statistically significant differences between the experimental and mathematical models.

Conclusions

It was found that the mathematical models in normal and 50 % destruction of the vertebral body (1st and 2nd models) shows fairly close coincidence with the results of experimental models namely up to 30 % if efforts are not more than 150 N, and up to 70 % at a load 200 N. Nonlinear behavior of the experimental models clearly expressed at loads of more than 200 N in contrast to mathematical models. The significant difference the results of mathematical and experimental modeling because of the nonlinear behavior of the experimental model found in case of total destruction of the ThXII vertebral body and the adjacent disks, as well as additional destruction of the posterior supporting complex (3rd and 4th models). In general, the comparative analysis of the behavior of experimental and mathematical models showed the same process directionality, but without a complete coincidence of the obtained data. This means that the mathematical model calculations can show inadequate results at a load of more than 200 N.