Analysis of spine's transpedicular stabilizer

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INTRODUCTION

The spine is performing three very fundamental functions: supporting (for braincase and shoulder and pelvis girdle), protecting (for core and roots of a spinal nerve) and motor activity (insertion place of head and neck, trunk and limbs muscles). The spine the main movement organ, which is submitted of variable and complex static and dynamic loads. Correct distribution of load ensures the proper formation of anatomical characteristic in osteo–muscular system and the correct functioning of spine. The majority of pathological changes are observed in the lumbar part of spine. In this part of spine, maximum loading forces influencing the vertebras and intervertebral discs, are observed. It's connected with the presence of human's centre of gravity located at this level [1–5].
Pathological changes and injuries of spine after communication accident or extreme sports are realized with the use of spine stabilizers. From the beginning of 80's the wide use of transpedicular screw systems is observed. The transpedicular stabilization system of spine enables treatment of thoracic, thoracic – lumbar and lumbar segment of spine by posterior surgical approach. Geometric features of stabilizers' elements match individual anthropometric features of patients. Implants which are used can immobilize the sick part of spine and let achieve the stable adhesion [1, 4 – 9].
More often, in order to verify the numerical analysis, the experimental analysis were carried out. They are showed the correct mechanical properties of metallic biomaterials and geometrical features of implants.

MATERIAL AND METHOD

The results of numerical and experimental analysis of the patented transpedicular spine stabilizer [6] (made of stainless steel Cr-Ni-Mo) implanted on the lumbar part of spine by posteriori surgical approach was analyzed in the work. The transpedicular system consists of transpedicular screws, clamp element, nut, contact arm and supporting rod – Fig. 1a). Stabilization of two vertebras of lumbar part of spine (L3 – L4) was analyzed in the work. The scope of the analysis included determination of relative displacements of transpedicular screws against supporting rod.
In order to carry out numerical analysis, it was necessary to work out geometrical models of lumbar spine and transpedicular stabilizer were worked out, it was necessary to carried out of analysis. Geomatrical model of lumbar spine was prepared on the basis of data obtained from computer tomography of a real spine.
Finite element mesh was generated for the geometrical models – Fig. 1b). Meshing was realized with the use of SOLID95 element.
In order of carry out the calculations it was necessary to evaluate and estabilish initial and boundary conditions which imitate phenomena in real system with appropriate accuracy – Fig. 1c). The following assumptions were estabilished: the L5 vertebra part of lumbar spine was immobilized (all degrees of freedom of surface nodes were taken away). It enabled displacements at last cervical vertebrae, blocking possible rotation; the L2 spine vertebra was loaded with forces F: 700 N, 1000 N, 1300 N, 1600 N on whole surface; in the L3 and L4 vertebra the spine stabilizer was implanted according to the operating technique.
The muscle system of spine was omitted in settlement of boundary conditions. In the effect all the loads and displacements of the parts of spine were carried by stabilizer – vertebras – intervertebral discs system.

The mechanical properties for analysis were as follows [10, 11]: for Cr-Ni-Mo steel – E = $2 \cdot 10^5$ MPa, υ = 0.33, for vertebras – E = $1,15 \cdot 10^4$ MPa, υ = 0.30, for intervertebral discs – E = 110 MPa, υ = 0.40.

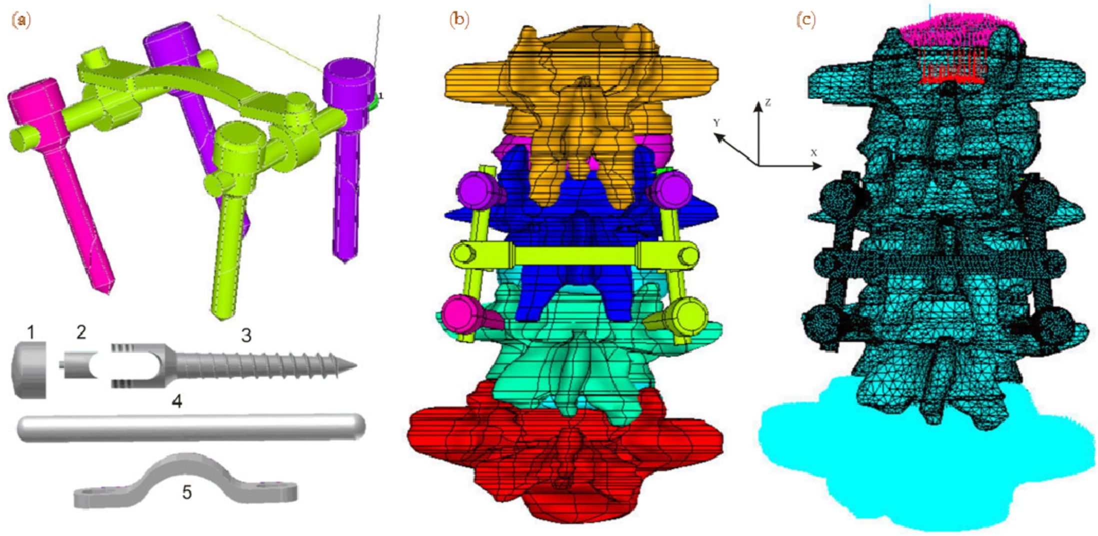

Figure 1: Numerical analysis system:
a) transpedicular spine stabilizer: 1 – nut, 2 – clamp element, 3 – transpedicular screw, 4 – supporting rod, 5 – contact arm;
b) geometrical model of analyzed system; c) meshed model with the boundary conditions

Transpedicular stabilizer made of stainless steel Cr-Ni-Mo was implanted on lumbar part of pig's spine according to the operating technique in experimental analysis. The analysis was performed with the use of testing machine MTS Insight with the use of videoextensometer. Model was loaded by uniaxial compression with forces 50 N − 1600 N – Fig. 2. Analyzed model was blackening by spray, for better measurement conditions. It allowed to determine reference markers – Fig. 3. A torque equal to 10 Nm was applied for nuts and screws. It was the most often torque use by spondylosurgeons.

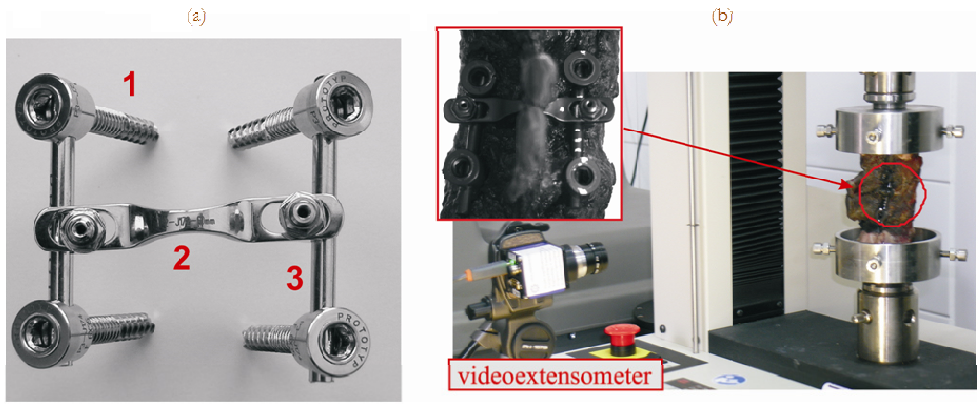

Figure 2: Experimental analysis sytem: a) transpedicular spine stabilizer: 1 – transpedicular screw, 2 – contact arm, 3 – supporting rod, b) analyzed system with the use of videoextensometer.

RESULTS

The analysis showed that the maximum values of relative displacements for the maximum force of 1600 N were equal to 0.20 mm. These displacements were localized along OZ axis. While the maximum values of relative displacements along OX axis were equal to 0.11 mm – Fig. 3.
The relative displacements of screw 1 and 2 with regard to the supporting rod along OZ axis were comparable. While the relative displacements for these screws analyzed determinate along OX axis were insignificantly different.

The analysis showed that the maximum values of relative displacements for the force of 1600 N were equal to 0.17 mm. These displacements were localized along OX axis. While the maximum values of relative displacements along OX axis were equal to 0.14 mm – Fig. 3.

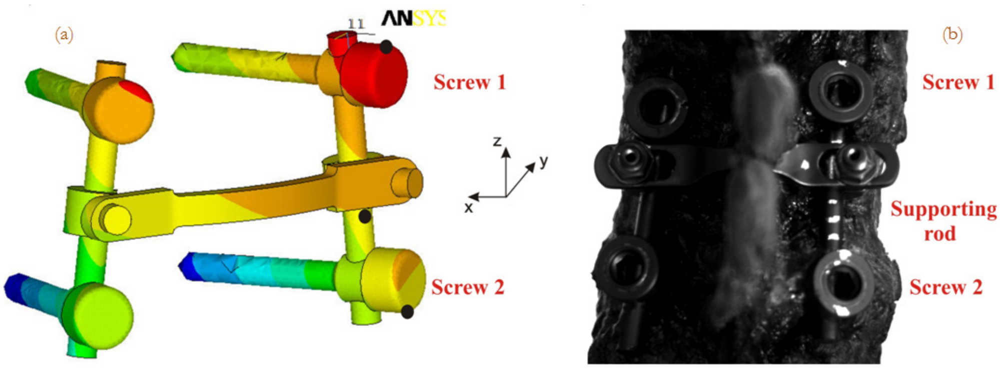

Figure 3: Determination of stabilizer elements with the reference markers:
a) numerical analysis, b) experimental analysis.

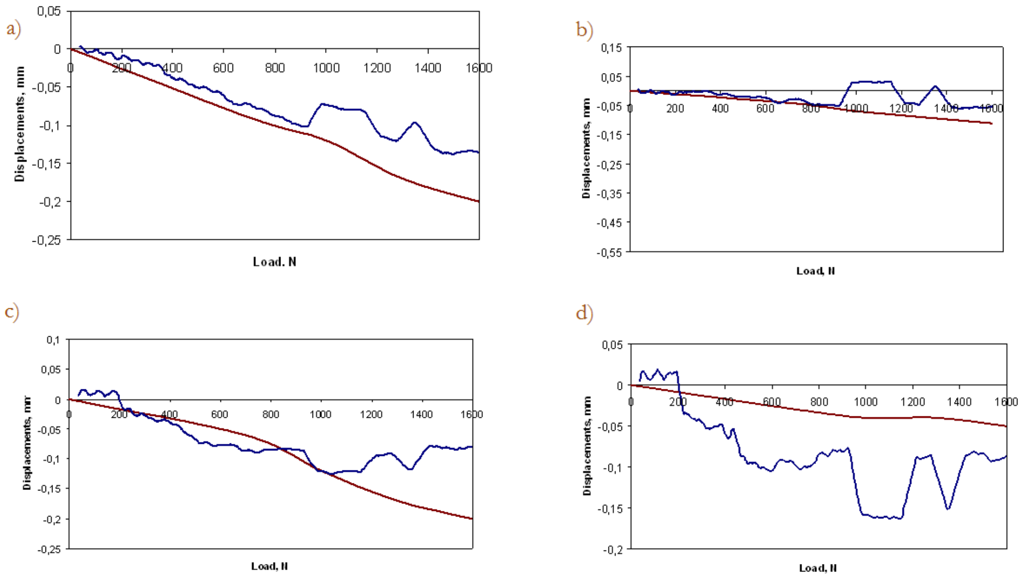

Figure 3: Distribution of relative displacements of: a) screw 1 with regard to the supporting rod along OZ axis, b) screw 1 with regard to the supporting rod along OX axis, c) screw 2 with regard to the supporting rod along OZ axis, d) screw 2 with regard to the supporting rod along OX axis, —— numerical analysis, —— experimental analysis.

CONCLUSIONS

Numerical and experimental analysis were carried out in order to compare the values of relative displacements of transpedicular screw with regard to the supporting rod.

The values of relative displacements obtained in numerical and experimental analysis are comparable along OX as well as OZ axis, and they didn't exceed the value of 1 mm, that proves stability and stiffness of the analyzed system. The calculation of displacements showed that the proposed type of stabilizer enables correct stabilization of spine. The results of numerical analysis as well as experimental analysis showed the correct selection of mechanical properties of metallic biomaterial and geometric features of implant's elements which were used to made the proposed type of transpedicular stabilizer.

Favourable results of numerical and experimental analysis are very valuable information source both for design engineers as well as for spondylosurgeons.

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