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BIOMECHANICAL TESTING OF SPINAL SEGMENT FIXED BY ARCOFIX SYSTEM

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Abstract: *The aim of this study was to compare the mechanical properties of the spinal segment in the intact state, destabilized (injury) state and the state after fixation by implant ArcoFix. The problem was solved by using the experimental modelling ZWICK testing machine. The study was based on in vitro biomechanical testing. Ten test samples were prepared for the experiment. Mechanical properties were described by the value of force couple needed to twist the specimen during the applied tensile force. Statistical analysis of measured results confirmed the hypothesis of different behavior of the states of intact, injured and fixed samples. Analysis did not confirm different mechanical behavior of intact and fixated specimens when comparing by the couple moment.*

Keywords: ArcoFix, Spine stabilization, Lateral stabilization, Biomechanics.

1. Introduction

The reconstruction of the anterior column of the thoracolumbar spine has become more common in the last few years. ArcoFix is an implant and instrument system for the anterior stabilization of the thoracolumbar spine. It can be used in combination with a bone graft or a vertebral body (ArcoFix, Technigue Guide).

Testing criteria for spinal implants and similar biomechanical studies have been described by Kocis (2010), Wilke (1998), Panjabi (1982, 1992), Manohar (2003), Janů (2011), Urbanová (2010). The aim of this study was to compare the mechanical properties of the spinal segment in the intact state, destabilized (injury) state and the state after fixation by implant ArcoFix.

2. Methods

Test specimens were taken from domestic pig. A total of 10 specimens were prepared for the purposes of the experiment. For the purposes of mechanical tests, spinal segment had to be modified so that it could be tightened into jaws of a testing machine. As the specimens are of organic origin, it was not possible to use fixtures designed for tests of technical materials. Both ends of the specimen were fixed in duracryl blocks that were tightened through plates with clamping pins into jaws of a standard testing machine using six-jaw lathe chucks. The specimen tightened into jaws of a testing machine is demonstrated in Fig. 1.

The Zwick testing machine with basic equipment made it possible to subject specimens to tension or torsion load, or the combination of both. Our Institute has rich experience with this combination of loads used for experimental modelling of spinal elements. Tension load selected for this experiment is rather unusual, as it almost does not occur during normal movements of a human body. However, tension load is suitable for the purpose of the experiment, as it exposes the specimen to mechanical states that can be considered as more adverse as compared with pressure load.

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The tests were performed for intact (physiological state, Fig. 2a), injury (state of instability, Fig. 2b) and fixed (stabilization by the implant, Fig. 2c) specimen. In each state, the specimen was subjected to tension load of a prescribed force and, subsequently, twisted by a given angle. Load values were defined based on the experience with measurements of similar nature. Force load was 200 N. Torsion load had a deformation character, i.e. control variable was twisting angle and measured variable was the moment. The amplitude of load alternating cycle was 3 deg. The value of amplitude was established based on the initial tests with regard to maximum allowed torque of 20 Nm (as limited by the sensor).

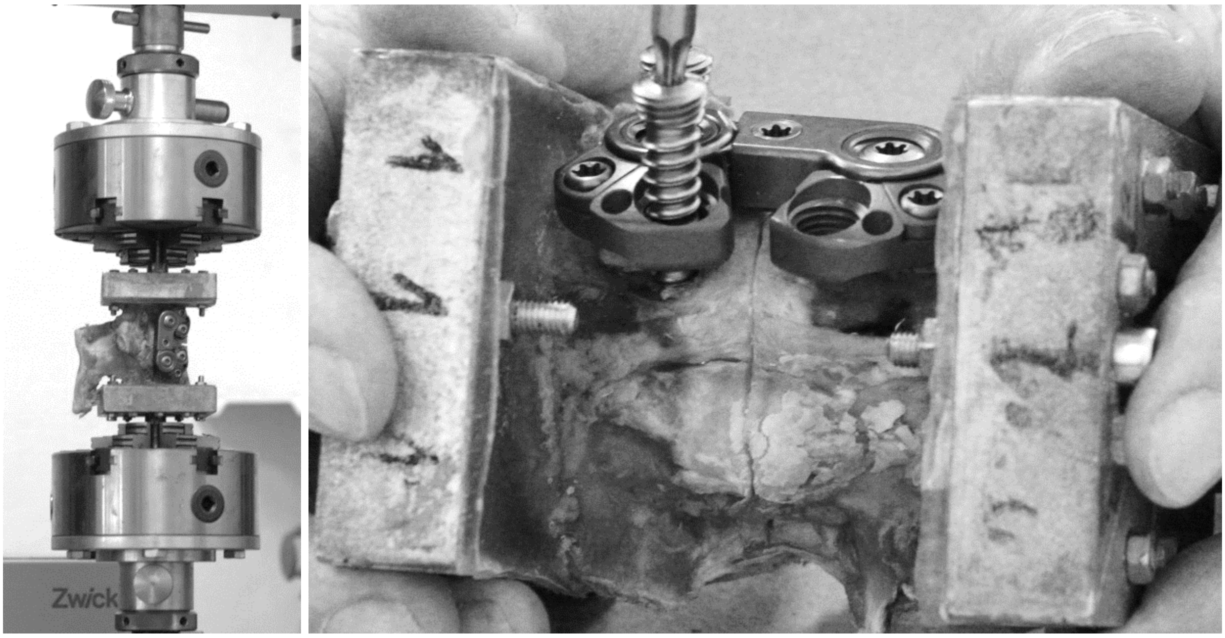

Fig. 1: The specimen tightened in jaws of a testing machine.

a) Intact specimen *b) Injury specimen* *c) Fixed specimen (ArcoFix)*

Fig. 2: Statuses of the specimen.

3. Results

During measurements, values of a couple necessary to twist the specimens were evaluated. An example of the behavior of moment in dependence on twisting angle for specimen 4 is demonstrated in Fig. 3.

The behavior of the specimens under rotation (both sides) can be seen in Fig. 4 which shows the mean value and standard deviation of torque needed for twisting the specimens of +3 and -3 degrees.

The measured maximum moments divided to three classes according to the specimen state are summarized in Fig. 5. It has to be decided whether the differences between classes are statistically significant or, in other words, whether the impairment of specimens and the application of fixators affect the moment necessary to twist the specimens. The paired t-test was used to evaluate the differences.

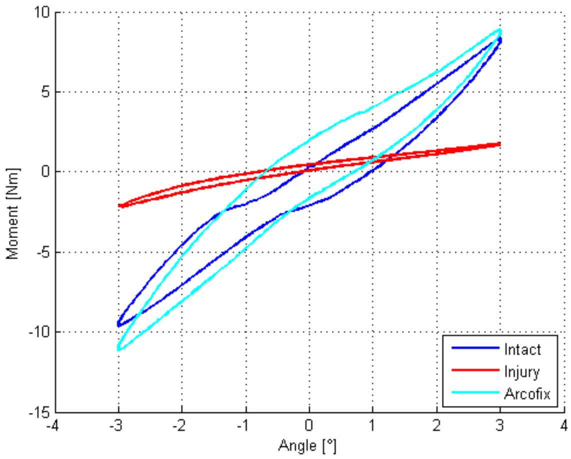

Fig. 3: Dependence of couple moment on twisting angle for specimen 4.

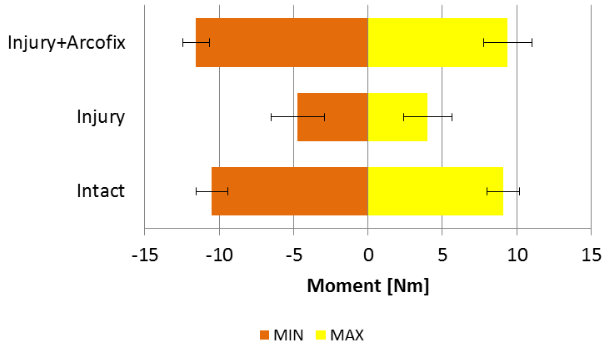

Fig. 4: The values of the moments for right and left rotation. Mean ± standard deviation.

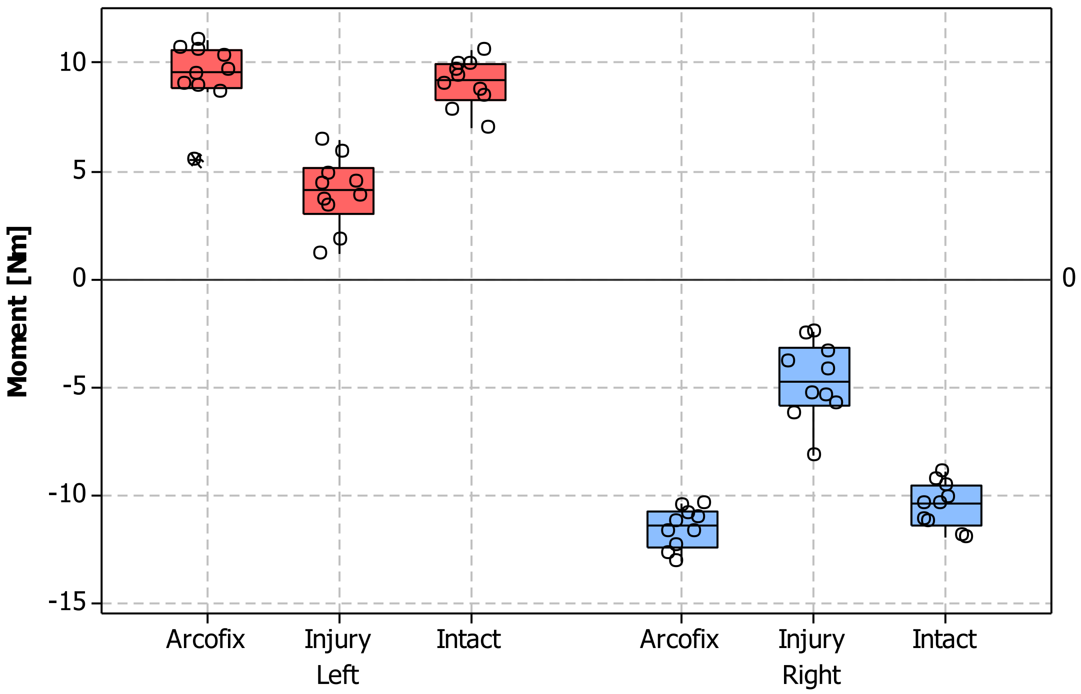

Fig. 5: Boxplot of maximum values of moment. Circle symbols – individual values.

The calculated p-values are summarized in Tab. 1. The test of normality at the significance level of 5% rejected the hypothesis that the data come from a normal distribution. The equality of the standard deviations and variances between two populations was determined using Bartlett's Test (p-value = 0.264).

Statistically significant difference was found between the state of the sample Intact and Injury and between the Injury and ArcoFix, both comparisons in positive and in negative twisting angle. The torque magnitude decreases for the damaged sample to about 45% of the value of the state ArcoFix and Intact. The different behaviour of specimens was also confirmed in state Intact and ArcoFix for positive and negative twisting angle. This indicates an asymmetric behaviour of the sample when rotation occurs. Statistically insignificant difference was found between the state Intact and ArcoFix. Implant therefore returns the stability of the injured sample to physiological state.

Tab. 1: P-values of paired t-test.

p-value		Left			Right		
		Intact	Injury	ArcoFix	Intact	Injury	ArcoFix
Left	Intact	X	< 0.0005	0.404	0.004	< 0.0005	< 0.0005
	Injury	< 0.0005	X	< 0.0005	< 0.0005	0.118	< 0.0005
	ArcoFix	0.404	< 0.0005	X	0.078	< 0.0005	< 0.0005
Right	Intact	0.004	< 0.0005	0.078	X	< 0.0005	0.008
	Injury	< 0.0005	0.118	< 0.0005	< 0.0005	X	< 0.0005
	ArcoFix	< 0.0005	< 0.0005	< 0.0005	0.008	< 0.0005	X

4. Conclusions

Statistical analysis of measured results confirmed the hypothesis of different behaviour of the states of intact, injured and fixed samples. Analysis did not confirm different mechanical behaviour of intact and fixated specimens when comparing by the moment. Behaviour of the fixed segment by ArcoFix implant is close to physiological state. The experimentally determined data were statistically processed using MINITAB 15 software.

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