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APPLICATIONS COMPUTER EQUIPMENT AT OPTICAL-MECHANICAL MEASUREMENTS OF BIOMECHANICAL CHARACTERISTICS OF CADAVEROUS LUMBAR SPINES

UŽITÍ VÝPOČETNÍ TECHNIKY PŘI OPTICKO-MECHANICKÉM MĚŘENÍ BIOMECHANICKÝCH VLASTNOSTÍ KADAVERÓZNÍ LIDSKÉ PÁTEŘE

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Special equipment was realized for measurement of biomechanical characteristics of samples of lower part of the spine that means the lumbar part L1-L5. During straining and measurement of the rigidity of the sample as a whole it is also necessary to observe the movement of individual parts of the sample. This movement is followed with the help of round targets connected to the appropriate vertebra to be observed. The detectional targets are lit with a lamp, in some cases with a laser, and are watched by two CCD cameras. An optical signal is brought into a computer and evaluated by the fast Fourier transformation method. The period and direction of interference fringes determine the size and the direction of the shift.

Key words: Fourier Transformation, Lumbar spine, Interbody fusion, Translaminar fixation, Stiffness of samples.

1. INTRODUCTION

The goal of this work is to evaluate the degree of stability of various surgical fixation methods by biomechanical analysis of the human lumbar spine [1], [2], [3], [4], [5]. This measuring was carried out on cadaverous samples of the lumbar spine using precisely defined mechanical loads on the spinal samples, including pressure, flexibility, torsion and combinations thereof and was done prior to the development and manufacture of original mechanical electrical equipment for the measurement of deformed samples of the spine.

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2. EXPERIMENTAL METHODS OF MEASUREMENT

Fusion constructs were evaluated in several cadaveric specimens sequentially loaded in axial compression, torsion, flexion, extension, lateral bending.

1. ***Axial compression*** is defined as the ratio of axial force (load) F and axial change of the length l of the specimen

$$S_c = \frac{F}{\Delta l}; \qquad [S_c] = \frac{\text{N}}{\text{mm}} \,. \tag{1}$$

2. ***Axial torsion*** can be expressed as the ratio of axial torque moment Fr and the angle of rotation φ

$$S_t = \frac{Fr}{\varphi}; \qquad [S_t] = \frac{\text{Nm}}{\text{rad}}$$

or (2)

$$S_t = \frac{Fr}{d}; \qquad [S_t] = \frac{\text{Nm}}{\text{mm}}$$

where φ is replaced with the shift d of the constant arm r.

3. ***Flexion*** and ***extension*** and ***lateral bending*** tests are evaluated as the ratio of bending moment Fl and the angle α of flexion (extension, bending)

$$S_f = \frac{Fl}{\alpha}; \qquad [S_f] = \frac{\text{Nm}}{\text{rad}}$$

or (3)

$$S_f = \frac{Fl}{d}; \qquad [S_f] = \frac{\text{Nm}}{\text{mm}}$$

where also the angle α is replaced with the shift d of the arm l.

3. MEASURING DEVICE FOR BIOMECHANICAL STUDY OF LUMBAR SPINE

Measurement of biomechanical characteristics of samples of the lumbar part of the spine was carried out on special equipment especially constructed for this purpose (Fig. 1). A sample of spine sections L1 to L5 was provided with two fixed aluminum jigs, which with the help of screws are securely attached in both axial and radial directions with L1 and L2, respectively L5 and L4 (Fig. 2). This mechanically secured sample was then placed into the already mentioned measuring device and with the help of additional mechanical parts it was securely joined to those parts of the equipment, which are adapted to individual types of straining of the sample.

Measurement of the parameters of a sample while being strained under pressure in the axis of the spine is carried out with a massive screw (ascension 2 mm) through a strength measuring device ($0 < F \leq 1000$N). When the defined turning of the screw (in our case an addition to the axial length of the screw $\Delta l = 0.4$ mm) a change in the axial strength ΔF occurs on the spinal sample, which is expressed as a change in tension measured by the strength measuring device ΔU in mV. The strength measuring device is tested before each experiment and therefore changes in tension ΔU, can be categorized as additional straining strength ΔF.

Measurement of the rotating moment of strength during torsion straining is made possible by the free movement of the axis of rotation around the axis of the spinal specimen, which is brought forth by the pressure of the rotation of a massive screw (the same degree of ascension – 2mm, but by steps of $\Delta l = 1$ mm), which affect the shoulder with a constant distance of d = 80 mm, through the strength measuring device to an extent of $0 < F \leq 200$ N. The change in strength ΔF, respectively the change in the moment of strength ΔM is the same as in the preceding example and determined by a change in tension in the torsion straining of the sample, if this sample is strained at the same time by an axial strength of 80 N. The study of mechanical characteristics of a strained sample, which correspond to flexion, extension and to movement to the left or right is made possible by bending of the upper part of the sample (of the fixed upper aluminum cylinder) with a free axis once again under a load of constant strength 80 N. At a distance of d = 100 mm from the axis of rotation of the massive joint, which affects the strength of $\Delta 1 = 1$ mm through the strength measuring equipment to an extent of $0 < F \leq 400$ N, a change in the strength of ΔF, respectively the moment of strength M, which again is equal to the characterized change in tension of strength measuring equipment U in mV.

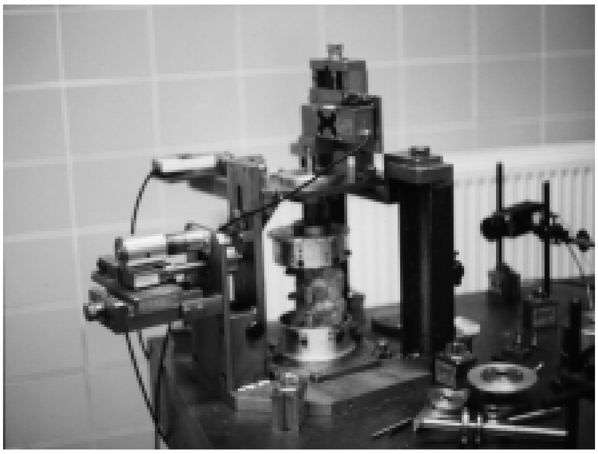

Fig. 1. The mechanical device that enables measurement of compression, torsion and bending of the sample

Fig. 2. A sample of cadaveric lumbar spine prepared for experiment

During straining and measurement of the rigidity of the sample as a whole it is also necessary to keep an eye on the movement of individual parts of the sample, that is parts L2, L3 and L4. Their behavior is of interest especially with a point of view to the application of various types of destabilizing and fixation methods. This movement is followed with the help of round targets connected to the appropriate vertebra to be observed. The sample, respectively the detectional targets are lit with a lamp, in some cases with a laser, and are watched from two mutually slanted directions by two CCD cameras. An optical signal is brought in through analog-digital units into a computer and evaluated by the fast Fourier transformation method in such a way that the appropriate area frequency of interfering bands (density of bands), respectively the period of the bands and their reverse value determine the size of the shift of the target and the tendency of interferential bands to go in the direction of the shifted target [6], [7]. For bigger changes of positions of the vertebras it is suitable to evaluate the changes of the positions of the centers of round targets. It is realized by the comparative method of the greating of the area of the targets (Fig. 3).

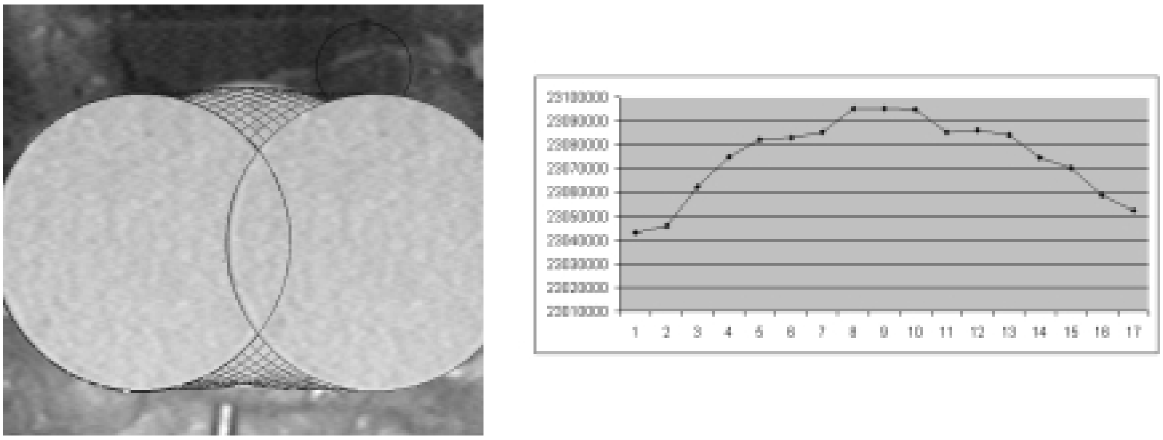

Fig. 3. Evaluation coordinate X

The direction and size of the shift of individual targets, respectively vertebrae L2, L3 and L4, when various destabilizing and fixation methods are introduced, provide information about the size of the deformation of the individual elements of the sample as dependent on the size of the destabilization, respectively in the case of fixation methods, the size and direction of the deformation of individual components of the sample, which are characterized by Fourier(s pictures as seen on the targets, should be close to the picture detected in the case of an intact spine (Fig. 4).

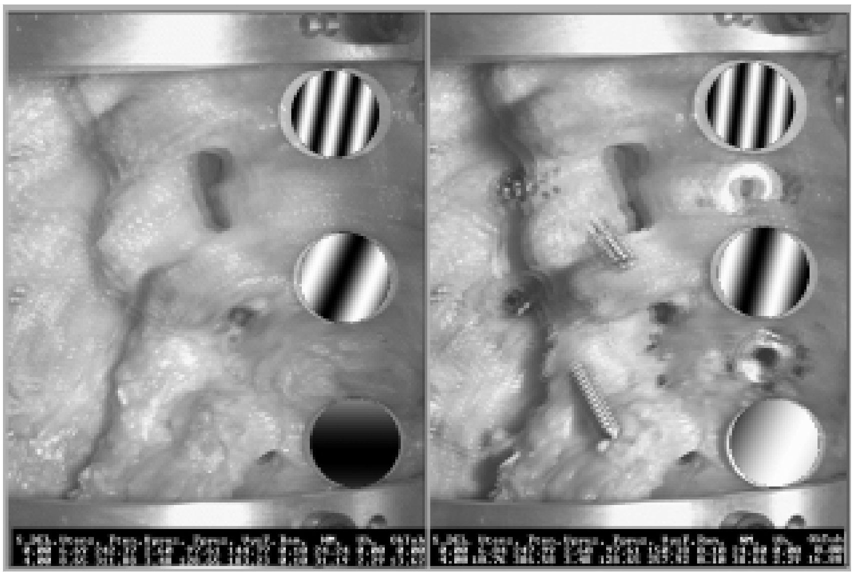

Fig. 4. Comparison of the movement of vertebras before (intact) and
after the best application of fixation methods (screws and cages) by the same load of the sample

4. RESULTS

Results for three samples are clearly marked in graphs (Fig. 5) for each tested characteristic. Results depicted in the graphics are related to an intact spinal sample (1.00, that means 100 percent) and are therefore normative. Because of the statistically low number of samples, we did not carry out a statistical analysis.

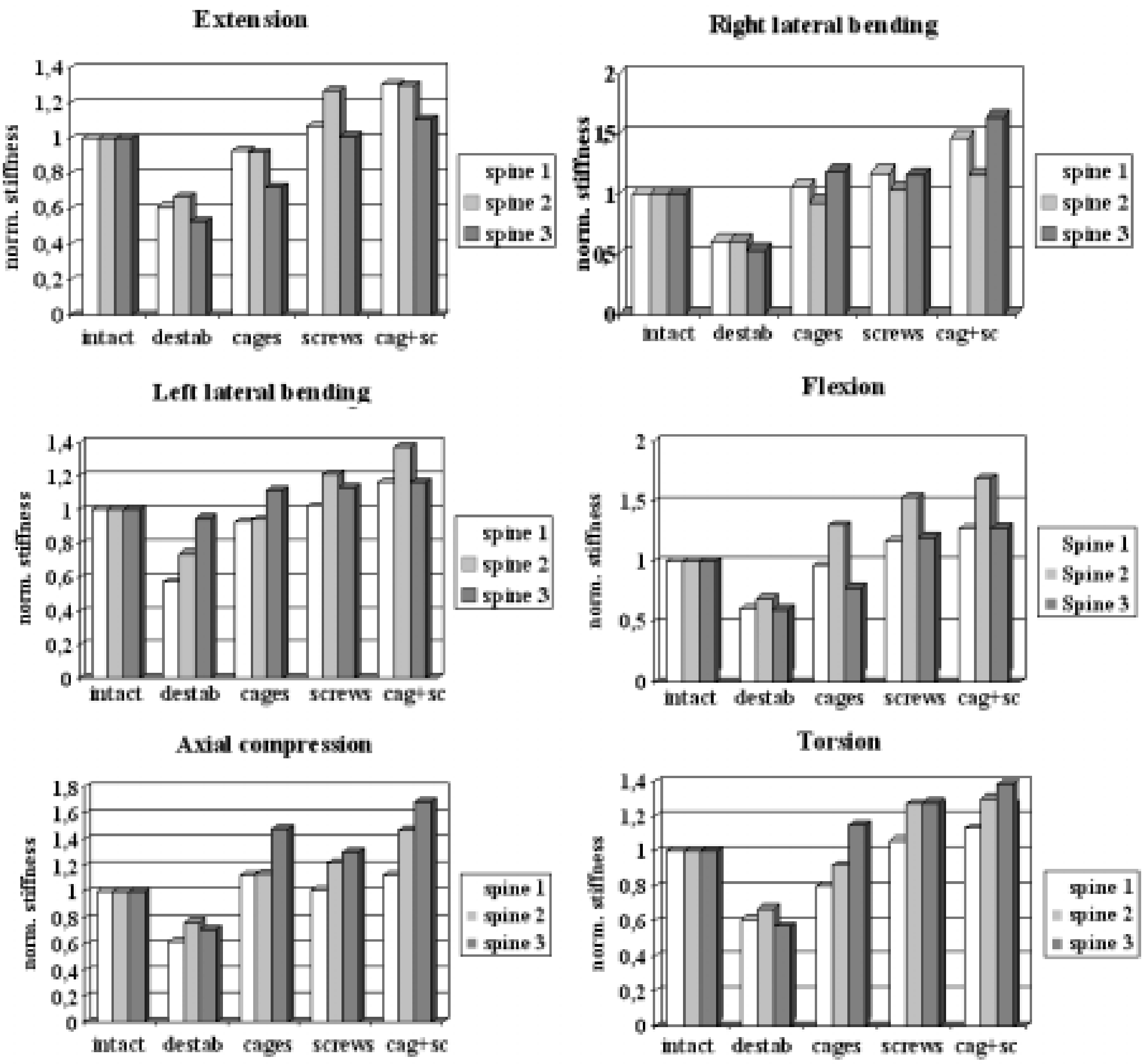

Fig. 5. Graphical evaluation of biomechanical measurements for three samples of cadaveric lumbar spines

5. CONCLUSION

This method enable the intact monitoring of studied samples. It seems that the use of the optical-computerized method by the help of 2D Fourier transformation could be suitable for evaluation of biomechanical characteristics of lumbar spine samples. We hope the results of measurement of the samples can help the specialists in neuro-surgery for determining how methods of lumbar fixation can maximize rigidity and promote development of body fusion.

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