Photoelastic analyses of vertebrae models under influence of pedicle screw types USS1 of 5mm and 6mm

Dayana Pousa Paiva de Siqueira, dayana_pps@yahoo.com.br
Antônio Carlos Shimano, ashimano@fmrp.usp.br
Department of Biomechanics, Medicine and Rehabilitation of the Locomotor Apparatus, Faculty of Medicine of Ribeirão Preto, University of São Paulo, Av Bandeirantes, 3900. 14090-900 Ribeirao Preto, SP, Brazil

Sarah Faker Fakouri, sarahfakouri@yahoo.com.br
Department of Biomechanics, Medicine and Rehabilitation of the Locomotor Apparatus, Faculty of Medicine of Ribeirão Preto, University of São Paulo, Av Bandeirantes, 3900. 14090-900 Ribeirao Preto, SP, Brazil

Helton Aparecido Defino, hadefin@fmrp.usp.br
Department of Biomechanics, Medicine and Rehabilitation of the Locomotor Apparatus, Faculty of Medicine of Ribeirão Preto, University of São Paulo, Av Bandeirantes, 3900. 14090-900 Ribeirao Preto, SP, Brazil

Cleudmar Amaral de Araújo, cleudmar@mecanica.ufu.br
Faculty of Mechanical Engineering, Federal University of Uberlândia, 2160. João Naves de Ávila Av., Uberlândia-MG

Abstract: *This study aimed to analyze the behavior of the internal stress of vertebrae models confectioned with epoxi resin (photoelastic flexible material) with pedicle type USS1 of 5mm and 6mm under influence of screw pullout. A model of lumbar vertebrae (L5) made by photoelastic material with the pedicle screw type USS1 was used to evaluate the internal stress around the screw ,using a plain polaroscope transmission. Eighteen points located around the screw were analyzed. The results showed that the screw of 5mm presented an average value for inferior internal stress to the one of 6mm. However, it did not verify significant difference between the 5mm and 6mm screws (p=0,99). The comparison of each point between the screws did not present significant difference. We verified that the internal stress it holds was similar between the screws gradually in accordance with increasing the external diameters. Then, the internal stress are raised mostly on irregular areas and the medial face of the distal portion of the screw.*

Keywords: *Pullout of screw. Photoelasticity. USS1*

1. INTRODUCTION

The low back and thoracic region are two of the most common places injured in the spine (HARRINGTON, 1962).

The use of the screw as a fixation element for the vertebrae spine is not a recent idea, and the its first publication dates 1944, when King used it to fix the sided articulations of the low back sacrum.

The posterior fixation of the transpedicular screw has been widely used for dealing the unstableness of the lumbar vertebrae caused by trauma, degenerated conditions, congenital imperfections, neoplasia and extensive laminectomies (ASHMAN, *et al*. 1989; DICKMAN, *et al.*, 1994; KRAG, *et al.*, 1988 e MATSUZAKI, *et al.*, 1990).

The surgery for placing implants in the pedicles of vertebrae is done beyond the posterior area. The point of introduction of the screw presents variations, according to the recommendation of different authors (MAGERL, 1984; ROY-CAMILLE, *et al*., 1986; LUQUE, 1986; WEINSTEIN, *et al*., 1988). Most of the times, it is advisable to use the intersection point of the line that passes by the middle of the transversal process and other line that tangencies laterally the superior joint face (MAGERL, 1984; WEINSTEIN *et al.*, 1988).

The photoelasticity is an experimental technique to analyze stress and deformations, and it is especially useful for structures or models that present complex geometry. In this case, it is advisable to do the experimental analyses, because the analytical methodologies, purely mathematical are often harder to execute and less viable (MAHLER; PEYTON, 1955).

The technique of photoelasticity was discovered in the beginning of the century, and besides that, it has been used nowadays for analyzing the intensity of stress in components, in the teaching area of Engineering and Biomechanic (ALVAREZ e STROHAECKER, 1998).

The greatest advantage of this method is the possibility to visualize, quantify and register the internal stress of bodies via photographic means. Otherwise, when using other analytical methods, it is necessary to create graphics, schemes for distribution and strength built over numerical data (CAMPOS Jr., 1983).

This study aims to analyze the internal stress of models of vertebrae made with epoxi resin (photoelastic flexible material) under influence of screw pullout to pedicle type USS1 of 5mm and 6mm,.

2. MATERIALS AND METHODS

Models simulating a lumbar vertebrae L5 with plain geometric aspect were confeccionated with epoxi photoelastic flexible resin were used in this experiment. Pedicular screws with external diameter of 5 and 6 mm were placed in the vertebrae pedicle (Figure 1).

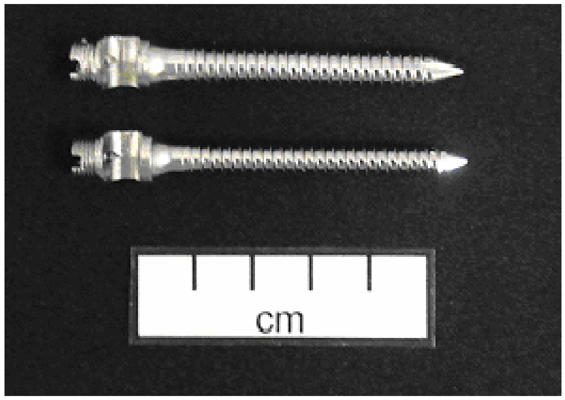

Figure 1 - Pedicular screw with external diameter of 5 and 6 mm.

The screw orientation in this area was convergent for the medium-sagital plan permitting the triangulation of the fixation system, what allowed greater stability. Figure 2.

Figure 2 - Screw orientation inside the vertebrae.

Negative moulds were confecioned in order to make the models (vertebrae) using photoelastic resin with the USS1 screw inserted in their pedicles.

With the mould correctly positioned, the manipulation of the photoelastic flexible resin (Polipox® - SP) was done using a proportion of 2:1 that was put inside the mould with the screw placed in the pedicle.

For the analyses of the study, 4 moulds were confectioned in silicone. In addition to them, another 8 models in photoelastic resin were made and divided into two groups:

Group 1 – 4 vertebrae in photoelastic resin with pedicular screw of 5mm.

Group 2 – 4 vertebrae in photoelastic resin with pedicular screw of 6mm.

The system to pull out the screw was adapted to the polaroscope of the Laboratory of Mechanical Projects of the Faculty of Mechanical Engineering of the Federal University of Uberlândia, where the photoelastic analyses were done.

After the placement of the polaroscope, the traction of the screw was performed, using a cargo of 8 N, generating enough stress (fringe order 3) for the analyses of the photoelastic vertebrae.

Eighteen points around each type of screw were analyzed, considering that they were set 1mm distant from the external diameter of the screw. All the points studied were the same for the screws of 5mm and 6mm. The figure 3 (A and B) shows the scheme of placement of the points around the screw inside the vertebrae.

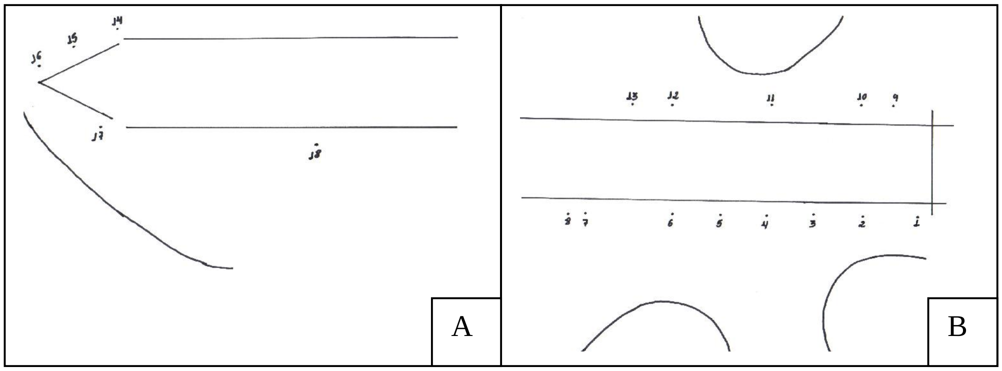

Figure 3 - A and B. Scheme of placement of the points around the screw inside the vertebrae.

The qualitative analysis was done by observing the behavior of the fringe images generated by the photoelastic material (Figure 4) and , to obtain the quantitative data, a reading was done, by observing the order of the fringe (N) and the stress were calculated for each point, using the Tardy[5] compensation method.

The data obtained were submitted to the multifatorial variation analysis (ANOVA). For the post hoc comparisons we used the method Bonferroni, with significance level of $p \leq 0{,}05$.

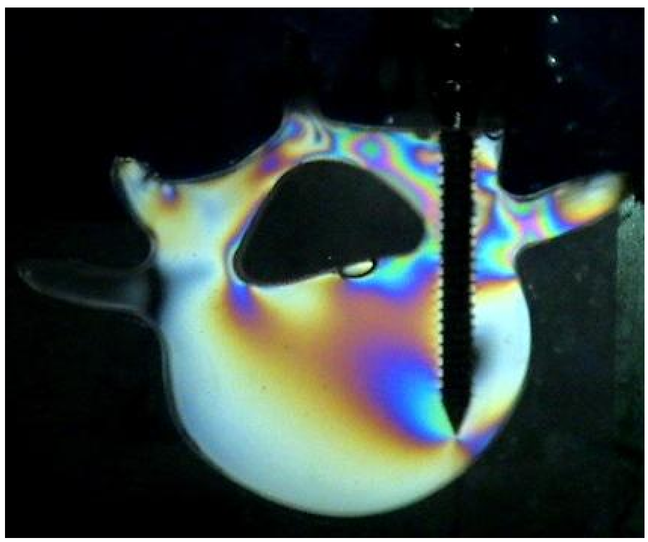

Figure 4. Distribution of the internal stress along the pedicular screw of a vertebrae model L5

3. RESULTS

The regions of greatest concentrations of stress were observed between the medullar canal and the curves of the transversal process, and on the medial face of the distal portion of the screw.

The Figure 5 shows the average values of principal shear stress of the eighteen points analyzes for each screw.

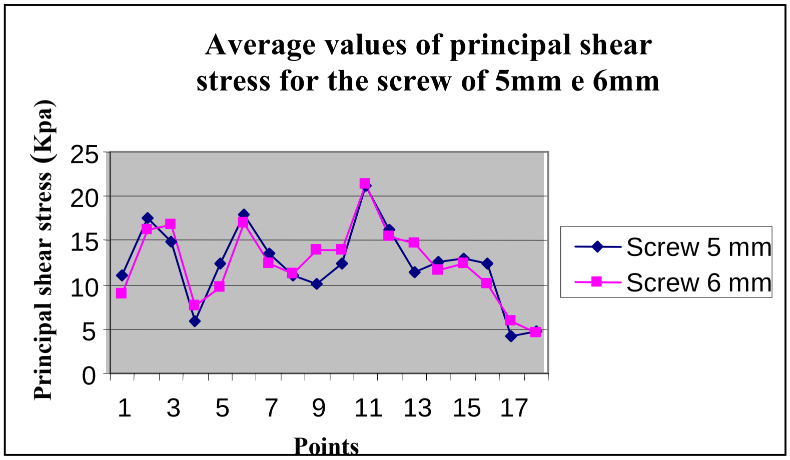

Figure 5. Average values of principal shear stress of screws of both 5mm and 6mm.

The average of the principal shear stress for the screw of 5mm was (12.37 ± 5.06)Kpa, and for the screw of 6mm it was (12.44 ± 5.35)Kpa. There was statistical difference between the screws (p=0.05). The screw of 6mm did not present significant superior values related to the screw of 5mm (p=0.99).

4. DISCUSSION

By analyzing the global model, it was observed that the higher concentration of stress occurred in the regions where there were more shaped structures around the screw, as the region next to the medullar canal, the curves of the transversal projects and on the tip of the screw on the medial face.

These concentrations of stress probably occur due to the geometry of the vertebrae.

The tip of the screw presented higher stress on the medial face compared to the lateral face. This is due to the fact that when we perform the traction of the screw, the model shows a rotational moment (it tends to spin on its own axis – gravity center) opposite to the clockwise rotation, because the screw is not placed in the middle of the model. This rotation provides an increase of the concentration of stress on the tip of the screw´s medial face.

Comparing the points, we can observe that the point 11 (located between the medullar canal and the internal face of the screw), was the one that received the greatest stress, more than any other point analyzed.

Related to the photoelastic plain analysis, the tests are done using models, where the transition of the obtained results or the transition of model/prototype can be understood using the "Theory of Materials" (GOMIDE, 1990). Therefore, the behavior of the stress in a vertebrae model made by photoelastic material is similar to the one found in a human vertebrae, considering the influence of the structure geometry on the stress distribution around the screw.

As said Mahler, Peyton (1955), the strength applied on the patterns in test produces stress that are distributed according to the direction of the strength, the shape and the manner of sustainment of the pattern.

5. CONCLUSION

It was verified that the average of the stress behaves similarly between the screws, increasing progressively according to the external diameters. The highest average number of stress was observed on the irregular areas of the model and on the medial face of the distal portion of the screw.

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7. RESPONSABILITY NOTICE

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