05 - ANALYSIS OF COMPRESSIVE DISTRIBUTIONAL LOAD OF INTERVERTEBRAL DISC L4-L5 BY MEAND OF PHOTOELASTICITY

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INTRODUCTION

In last decade, it has been seen an aging process of world population, due to an increase of life expectancy (SZPALSKI et al., 2003). The aging process is related to a higher rate of spine diseases, such as low back pain. In spite of the high numbers of factors related to development of low back pain and discal hernias. The discal hernias have been pointed as one of the main structures involved to etiology of low back pain (KUSLICH, ULSTROM and MICHAEL,1991). These diseases affect mainly the intervertebral disc L4 and L5, due to highest load (ADAMS et al., 1993; ADAMS et al., 2000; KUSLICH, ULSTROM e MICHAEL, 1991; RANNOU et al., 2001).

The discal cells are sensitive to mechanical involvements, being directly influenced by hydrostatical pressure and compressive load (GUEHRING et al., 2006; HANDA et al., 1997; ISHIHARA et al., 1996). These cells are able to distribute and minimize compressive load between adjacent vertebrae due to viscoelastic properties (ADAMS e DOLAN, 1995; AWAD e MOSKOVISH, 2006; FERGUSON e STEFFEN, 2003). Loads are transmitted through vertebrae plate, by central area, the pulpous nucleus (McNALLY e ADAMS, 1992; McNALLY, NAISH e HALLIWELL, 2000).

Photoelastic is a science that studies physical effects by light due to action of tensions or deformations in transparent elastic bodies (DALLY e RILLEY, 1978; DOYLE e PHILLIPS, 1978) and, it has been one of the techniques available for determining and evaluating the distribution of internal stress in structural systems (MAHLER e PEYTON, 1955). It is an experimental technique that allows a qualitative and quantitative analysis of state of internal stress of materials by means of view of optical effects (HIROKAWA, YAMAMOTO e KAWADA, 1998; RUBO e SOUZA, 2001).

OBJECTIVE

To analyze and compare the inner stress in intervertebral discs between L4 and L5 vertebrae when submitted to compression load using the technique of photoelasticity of plane transmission.

MATERIALS AND METHODS

Two sagittal cutts were performed, two in each area: central and lateral of L4 and L5 vertebral bodies of polyurethane (Nacional™), for obtaining two experimental models. The were performed unilaterally because vertebral bodies are symmetric. The distance between the cutts was 16.0 mm (Figure 1).

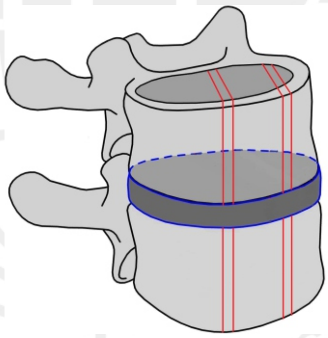

Figure 1 – Localization of central (A) and lateral (B) experimental models of vertebral bodies L4-L5

By these cutts we obtained the geometry of central and lateral intervertebral discs. Anterior part of disc hat 10.0 mm of height and posterior 7.0 mm.

Experimental models obtained were used as mold for its confection in acrylic resin T208, mixed with monomer of styrene and catalyzer. For each 40.0 ml of resin were mixed 3.2 ml of monomer and 0.8 ml of catalyzer. Experimental models in acrylic were positioned in respective mold of Teflon®, where it was add the flexible photoelastic resin epoxy (Polipox™) between them for modeling the intervertebral discs. This resin has elasticity modulus of 4.51MPa and Poisson Coefficient of 0.4 v and, for confection of photoelastic models it was used a proportion of 2.2 ml of resin for 1.0 ml of catalyzer.

We confectioned four photoelastic models from each experimental model (central and lateral). Photoelastic model from central experimental model had 39.4 mm of width and from lateral 26.7 mm. All models had 60.0 mm of length and 8.0 mm of thickness (Figure 2).

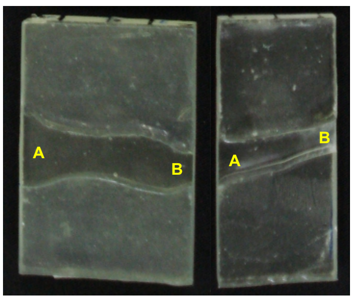

Figure 2 – Photoelastic models with emphases for anterior (A) and posterior (B) area of intervertebral discs of central and lateral experimental models.

The photoelastic analysis was performed in a transmission polariscope by means of an application of compressive load in center of vertebral body using a spring with five spirals, linear dislocation of 4.3 mm and a constant of 0.5674. The inner stress produced on intervertebral discs were qualitative and quantitatively evaluated.

In quantitative analysis we observed the point of beginning and highest concentration of stress. For quantitative analysis we applied a load of 2.3 Kgf registered by using load cell Kratos™, with capacity of 10 Kgf. The shear stress were calculated in a standard way in 16 points, respective to central (figure 3) and lateral (figure 4) models, based on contour of intervertebral disc.

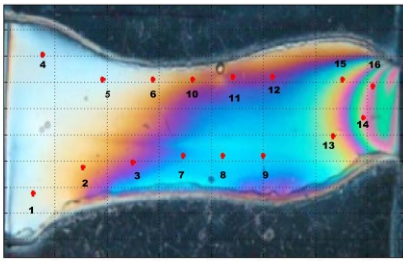

Figure 3 – Distribution of analyzed points in central model.

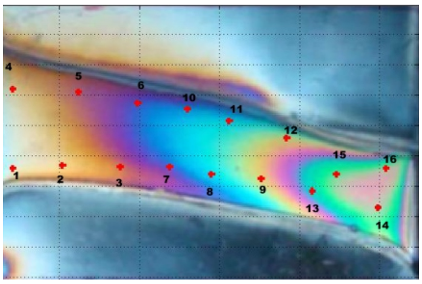

Figure 3 – Distribution of analyzed points in lateral model.

For calculating the shear stress () we used Tardy compensation method, showed by formula (DALLY e RILLEY, 1978):

$$\tau = \frac{\sigma_1 - \sigma_2}{2} = \frac{N \times f_r}{2.h} \quad (1)$$

Where: $_1$, $_{2-}$ Princiapl stress;

N - Fringe orders;

f_{r-} Optical constant of photoelastic model;

h - Thickness of photoelastic model (mm).

RESULTS

By means of qualitative analysis we observed the stress started in posterior part of disc and in there it reached the highest concentration.

Quantitative analysis was used to quantify stress in each area of discs. In central models the posterior area of disc, located in points 13 to 16 showed a mean of (57.74 ± 17.20). The anterior area, points 1 to 6, had lower stress concentration with mean of (20.30 ± 11.24). Medial area of disc, points 7 to 12, showed a stress concentration higher than in anterior area, but lower than in posterior, with mean of (31.97 ± 3.77) (Figure 5).

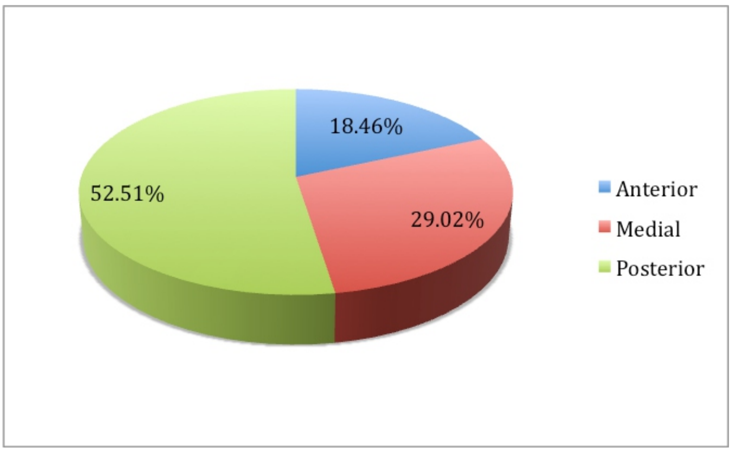

Figure 5 –Stress concentration in anterior, medial and posterior area of central model.

In lateral models the posterior area, points 13 to 16, showed a mean of (75.77 ± 2.10). Anterior area, points 1 to 6, had a lower inner stress with a mean of (32.06 ± 17.12). Medial area, points 7 to 12, had an intermediated stress of (43.86 ± 2.79) (Figure 6).

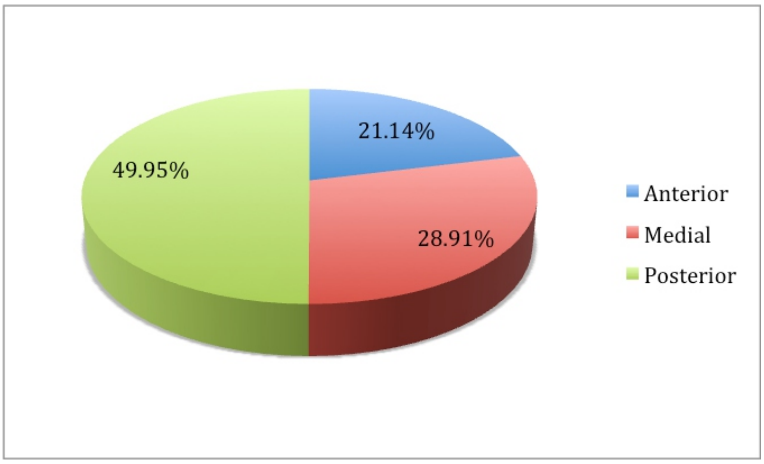

Figure 6 – Stress concentration in anterior, medial and posterior area of lateral model.

Figure 7 shows a mean of shear stress of central and lateral models. The behavior was the same observed in figures 5 and 6.

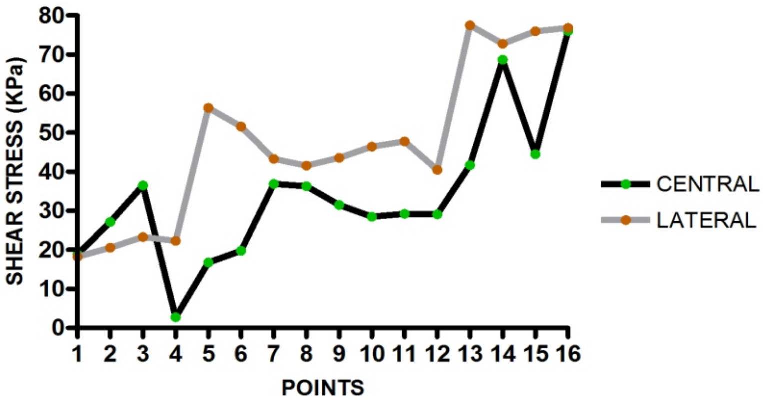

Figure 7 – Mean of values of shear stress of central and lateral models.

DISCUSSION AND CONCLUSION

Photoelasticity showed to be an efficient technique, being able to evaluate the places of higher shear stress based on applied compression load. The load was 2.3 Kgf in order to not deform the models, because of flexible photoelastic epoxy resin has a high optical sensibility and low elasticity modulus. The photoelastic analysis showed the posterior area of intervertebral disc has the highest concentration stress, being probably more susceptible to diseases as low back pain, disc degeneration and disc hernia. There is a lack of literature about this theme using plane transmission photoelasticity that makes difficult to compare our results. However, some authors related, using different techniques, the posterior area is the area of disc with the highest pressure, making easier the appearance of disc degeneration (ADAMS et al., 2000; GUEHRING et al., 2006; IATRIDIS et al., 1999; KROEBER et al, 2005; LOTZ et al., 1998).

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OF COMPRESSIVE DISTRIBUTIONAL LOAD OF INTERVERTEBRAL DISC L4-L5 BY MEAND OFPHOTOELASTICITY

The cells of the intervertebral disc are sensitive to mechanical involvements, being directly influenced by the hydrostatic pressure and compressive loads. The intervertebral disc is capable of distributing and attenuating these compressive loads between the adjacent vertebrae due to its viscoelastic properties. The photoelasticity has been used in researches to determine the distribution of stress in structural systems, thus it allows a qualitative and quantitative analysis by optic elements. It can be used in any state of stress, however, it is more easily used in a plane state. In this research, this technique has been used with the objective of analyzing and comparing the internal stress generated in the intervertebral disc L4-L5 put under efforts of compression. To perform the photoelastic analysis eight photoelastic models have been made and divided in two groups, the first represented by the central sagittal cut of the vertebral body L4-L5 and the second by the lateral cut of these vertebral bodies. The vertebral bodies were used to obtain the geometry of the intervertebral discs. The simulation was performed using a transmission polariscope with a load of 2.3 Kgf. The fringe orders were evaluated according to the contour of the intervertebral discs, using the Tardy compensation method. In all analysed models the shear stress has been determined. The results show that the posterior region of the disc of both models presented more concentration of stress, followed by the medium and anterior region. Therefore, this technique is very efficient, thus, through a quantitative and qualitative analysis it was possible to analyze the intervertebral disc, verifying which region is the most critical and susceptible to pathologies such as the disc degeneration and the disc hernia.

Keywords: L4-L5 Intervertebral disc, Biomechanics, Photoelasticity.

ANALYSE D'DISTRIBUITION DE CHARGEMENT COMPRESSIVE DE DISQUE ENTREVERTÉBRAUX L4-L5 PAR LES D'PHOTOÉLASTICITÉ

Les cellules du disque intervertébraux sont raisonnables aux engagements mécaniques, est droitment influencé par les pressions hidrostáticas et les chargements compresseves. Le disque intervertébraux est capable de distribue et atténue ces chargements compressives entre les vertèbres adjacentes doit ses propriétés vicoélastiques. A photoélasticité a été utilisé dans les recherches pour décide à la distribution de tension dans les systèmes structurels, permet donc une analyse quantitative et qualitative par les opticiens d'éléments. Il peut être utilisé dans n'importe quel état de tension, cependant facilement est plus utilisé dans l'état plat. Dans ce travail a été utilisé cette technique avec l'objectif d'analyse et compare les tensions internes produites dans le disque intervertébraux L4-L5 avec soumis aux efforts de compression. Pour l'accomplissement de l'analyse photoélastiques a été concocté huit modèles photoélastiques a divisé dans deux groupes, le premier un représenter pour le sagital de section central du corps vertébraux L4-L 5 et la seconde, par le sagital de section latéral de ces corps vertébraux. Les corps vertébraux ont été utilisés pour obtient la géométrie des disques intervertebrais. La simulation était l'action utilisant un polariscópio de transmission avec un chargement de 2,3 Kgf. Les ordres de franges ont été évalués selon les contours des disques intervertebraux, utilisant l'approche de compensation de Tardif. Dans tous les modèles analysés a été déterminé les tensions cisalhantes. Les résultats ont montré que la région subséquente du disque des modèles a présenté la plus grande concentration de tension, suivie par la région précédente et moyenne. Etre comme ceci, cette technique est assez efficace, donc, par l'analyse qualitative et quantitative était possible analyse le disque intervertébraux, vérifiant qui est à plus critique et susceptible les pathologies comme discal de dégradation et l'hernie de disque.

Mots-clé: Disque intervertébraux, Biomécanique, Photoélasticité.

DE LA DISTRIBUCIÓN DE ESFUERZOS DE COMPRESIÓN DEL DISCO INTERVERTEBRAL

Las células del disco intervertebral son sensibles a los envolvimientos mecánicos influenciándose directamente por las presiones hidrostatica y las cargas comprensivas. El disco intervertebral es capaz de distribuir y atenuar esas cargas comprensivas entre las vértebras adyacente debió sus propiedades viscoelásticas. La técnica fotoelástica se ha usado en los estudios científicos para definir la distribución de tensión en los sistemas estructurales porque permite una análisis cualitativa y cuantitativa por los elementos ópticos. Puede usarse en cualquier estado de tensión, pero se usa más fácilmente en el estudio del estado plano. En este trabajo esta técnica fue usada para analizar y comparar las tensiónes internas generadas en el disco intervertebral L4-L5 sometido a esfuerzos de compresión. Para realización de las análisis fotoelásticas eran hecho ocho modelos divididos en dos grupos, el primer grupo representado por el corte sagital central del cuerpo vertebral L4-L5 y el segundo, por el corte lateral de esses cuerpos vertebrales. Los cuerpos vertebrales fueron usados para obtener la geometría del disco intervertebral. La simulación se realizó en un polariscópio de transmisión con una carga de 2.3 Kgf. El patrón de franjas fueron evaluados conforme el contorno del disco intervertebral, usando el método de la compensación de Tardy. En todos los modelos analizados era calculado la tensión interna. Los resultados obtenidos mostraron que la parte posterior del disco de los modelos fue más crítica que la parte media y anterior. Así, esta técnica es eficaz porque a través del las análisis cuantitativa y cualitativa fue posible analizar el disco intervertebral, verificando cual es la parte más crítica y susceptible a las patologías como la degeneración y hernia del disco.

Palabras clave: Disco intervertebral L4-L5, Biomecánica, Técnica fotoelástica.