

CHANGES IN THE LUMBAR VERTEBRAL SEGMENT RELATED TO THE CAGE POSITION IN TLIF TECHNIQUE

ALTERAÇÕES DO SEGMENTO VERTEBRAL LOMBAR RELACIONADAS À POSIÇÃO DO CAGE NO TLIF

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ABSTRACT

Objective: To evaluate the morphological changes on the intervertebral foramen and segmental lordosis related to the transforaminal lumbar interbody fusion (TLIF) positioning. **Methods:** PEEK cages were placed in the disc space (L1-S1) of a polyurethane anatomical model. Cages of different heights (8 mm, 10 mm, 12 mm and 14 mm) were positioned in the posterior, medial or anterior part of the vertebral body surface, and the intervertebral foramen and segmental lordosis heights were measured after their insertion. **Results:** The vertebral foramen height decreased in all positions and heights of the cages in relation to the control. The cage posterior positioning induced a smaller reduction in the vertebral foramen height. Vertebral lordosis tended to increase in relation to the control, and the greatest increase occurred with the cage posterior positioning. **Conclusion:** Cage positioning induces changes in the intervertebral foramen height and in the vertebral segment lordosis. Cage posterior positioning induces a smaller reduction of the intervertebral foramen height and increases the vertebral segment lordosis. **Level of evidence III, Therapeutic study.**

Keywords: Spine. Arthrodesis. Biomechanical Phenomena.

RESUMO

Objetivo: Avaliar as alterações morfológicas do forâmen intervertebral e da lordose segmentar relacionadas ao posicionamento do espaçador intersomático na artrodese lombar intersomática transforaminal (TLIF). **Métodos:** Cages de PEEK foram colocados no espaço discal (L1-S1) de modelo anômico de poliuretano. Os cages de diferentes alturas (8 mm, 10 mm, 12 mm e 14 mm) foram posicionados na parte posterior, média ou anterior da superfície do corpo vertebral e a altura do forame intervertebral e lordose segmentar mensuradas após a sua inserção. **Resultados:** Foi observado redução da altura do forame vertebral em todos os posicionamentos e alturas dos cages em relação ao controle. O posicionamento posterior do Cage induziu à menor redução da altura do forame vertebral. A lordose do segmento vertebral apresentou tendência de aumento em relação ao controle, tendo sido observado a maior tendência com o posicionamento posterior do Cage. **Conclusão:** O posicionamento do Cage induz a alterações da altura do forame intervertebral e lordose do segmento vertebral. O posicionamento posterior do Cage induz a menor redução da altura do forame intervertebral e aumento da lordose do segmento vertebral. **Nível de evidência III, Estudo terapêutico.**

Descritores: Coluna Vertebral. Artrodese. Fenômenos Biomecânicos.

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INTRODUCTION

Transforaminal lumbar interbody fusion (TLIF) has been widely used for the treatment of diseases affecting the lumbar spine, especially degenerative diseases.¹⁻³ Restoration or maintenance of the vertebral segment lordosis has guided surgical treatment due to its influence on clinical outcomes.³⁻⁶ Design and positioning

of the vertebral spacers used in TLIF influence the operated vertebral segment lordosis. Cages with lordotic angulation can maintain or restore lordosis due to its geometric shape.⁷ Cages that lack angulation also influence the vertebral segment lordosis depending on their position on the vertebra body surface (anterior, medial or posterior).⁸⁻¹⁰

All authors declare no potential conflict of interest related to this article.

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Although Cage positioning in the vertebral segment lordosis is recognizably important^{11,12}, there is no consensus on the spacer proper positioning on the body surface. According to Kwon et al.¹³, a spacer should be used in the anterior part of the vertebral endplate, achieving greater segment stability and increasing the lordosis of the vertebral segment operated. However, Faundez et al.⁸ found that the spacer positioning did not cause a difference in lumbar lordosis, result corroborated by Ould-Slimane et al.¹⁰ Cage positioning also influences intervertebral foramen.⁹ The contralateral foramen stenosis after performing open TLIF has been related to segmental lordosis hypercorrection.^{14,15} The incidence of contralateral radiculopathy, secondary to the reduction of vertebral foramen dimensions after TLIF, is 5.9%.¹⁴ Contralateral radiculopathy after TLIF has been reported after the open or percutaneous approach.¹⁴⁻¹⁶ The precise compression mechanism of contralateral vertebral foramen is not completely clear and might be related to increased segmental lordosis during surgery.^{9,14} However, indirect decompression by increasing the intervertebral foramen height can be obtained by restoring the intervertebral disc height using Cage.⁹ Although clinical reports describe morphological changes in lumbar intervertebral foramina and the influence of the spacers position on the segmental lordosis after TLIF^{9,11,12}, literature lacks reports of bench tests on the influence of vertebral spacers on the height of the intervertebral foramen and on lordosis of the vertebral segment operated. This study aimed to evaluate height change of intervertebral foramen and of segmental lordosis related to Cage positioning after transforaminal lumbar interbody fusion (TLIF).

METHODS

In the study, an anatomical model of lumbar spine with vertebrae made with solid foam of low-density polyurethane and polyethylene intervertebral disc (Nacional Ossos[®]) was used. Experiments used PEEK (polyether ether ketone) spacers Fusimax TLP[®] model (Vincula, Brazil), 8 mm wide, 29 mm long, 8 mm, 10 mm, 12 mm and 14 mm high, and non-angulated, used for transforaminal lumbar interbody fusion (TLIF) (Figure 1).



Figure 1. Photo of Cage in height ascending order (8 mm, 10 mm, 12 mm and 14 mm)

The experimental model consisted in removing the intervertebral disc, performing bilateral cataract surgery, positioning the intervertebral spacer, applying compression in the vertebral segment, and bilaterally measuring lordosis and craniocaudal diameter of the intervertebral foramen. Spacers 8 mm, 10 mm, 12 mm and 14 mm high were inserted in all disc spaces, except for L1-L2, which could not use the 14 mm spacer because of their height. The study variables were: the positioning of intervertebral spacers (at the posterior, medial or anterior part of the vertebral body upper surface) (Figure 2), and the intervertebral spacers height (8 mm, 10 mm, 12 mm and 14 mm) (Figure 1). Compression of the vertebral segment was performed with compression clamps, and the compression limit was the bone contact of the posterior elements, which was a mechanical obstacle to additionally apply compression in the vertebral segment.

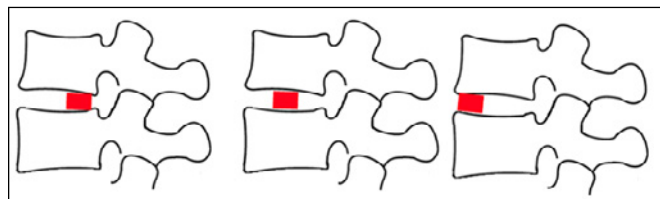


Figure 2. Illustration of the spacer positioning on the vertebral body upper surface (posterior, medial and anterior).

The vertebral segment lordosis was evaluated by measuring the angle formed by the threaded Steinmann pins put inside the vertebral pedicles. The angle was measured before removing the intervertebral disc and after placing the intervertebral spacer and applying compression in the vertebral segment (Figure 3). The craniocaudal diameter of the intervertebral foramen was evaluated by direct measurement with caliper, defined as foramen height. It was bilaterally measured before removing the intervertebral disc and after placing the spacer and applying compression in the vertebral segment. This study was not submitted to the Ethics and Research Committee as it is an experimental study that did not involve human beings at any stage of its realization. For this reason, the Term of Free and Informed Consent was not applied.

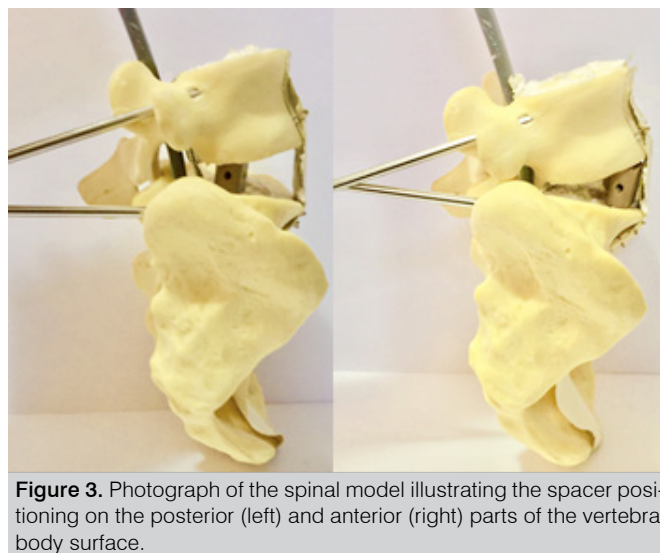


Figure 3. Photograph of the spinal model illustrating the spacer positioning on the posterior (left) and anterior (right) parts of the vertebral body surface.

STATISTICAL ANALYSIS

Statistical analysis was performed using the Kolmogorov-Smirnov test to determine the normality of each group sample. Mood's median test, a nonparametric test, was used to evaluate the influence of intervertebral spacers positioning and height on the intervertebral segment lordosis and intervertebral foramen height, with significance level $p < 0.05$. SAS Institute Inc., SAS/STAT[®] User's Guide, Version 9.4, Cary, NC: SAS Institute Inc., 2012 was used to perform statistical analysis.

RESULTS

The intervertebral foramen height reduced in relation to the values of the control group in all the tests (Mood's test $p < 0.05$). The intervertebral foramen height reduced regardless of the spacers position and height on the vertebra surface (Table 1 and Figure 4). The intervertebral foramen height tended to reduce as the spacer shifted to the anterior position of the vertebral body surface, but without statistical difference (Figures 4-5).

Table 1. Height values of the foramen and vertebral lordosis in the different experimental groups

Cage	Group	Foramen Height (mm)		Lordosis in Degrees	
		Mean (standard deviation)	Mean (standard deviation)	Mean (standard deviation)	Mean (standard deviation)
8	Anterior	11.70 1.75*	9.80 2.28		
	Medial	11.80 1.75*	11.80 2.49		
	Posterior	13.60 1.78*	13.40 4.88		
10	Anterior	12.88 2.17*	10.80 3.27		
	Medial	13.20 1.92*	13.00 5.39		
	Posterior	14.90 1.56*	13.60 5.41		
12	Anterior	13.50 2.12*	13.00 6.28		
	Medial	13.60 2.19*	15.00 6.48		
	Posterior	16.30 1.48*	16.20 6.87		
14	Anterior	15.25 2.90*	17.00 6.16		
	Medial	17.00 2.61*	17.75 7.68		
	Posterior	19.00 1.47*	18.75 7.63		

*: Statistical difference ($p < 0.05$) in relation to the control group.

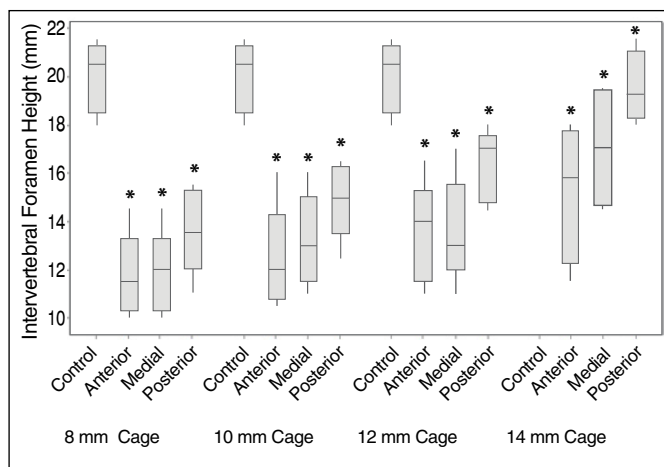


Figure 4. Height values of the vertebral foramen in the different spacers and positioning. Asterisk indicates statistical difference in relation to the control.

In the posterior positioning of the vertebral body surface, the 14 mm high spacer reduced less the intervertebral foramen height with statistical significance (Mood's test $p < 0.05$) when compared with the other spacers with smaller height in the same position.

The vertebral segment lordosis increased in relation to the control in all the variables (spacer positioning in relation to the body surface and spacer height). The spacer posterior positioning on the vertebral body surface and the use of a spacer with increased height tended to obtain higher values of the segment lordosis in which the TLIF was performed. (Table 1 and Figure 5)

The analysis of the results, considering only the use of the vertebral spacer of height close to the intervertebral disc height (spacer height 1 mm lower than disc height), is represented in Table 2.

The use of spacer of height close to the intervertebral disc height showed that the highest value of the vertebral segment lordosis was observed with the spacer posterior positioning. The spacer posterior positioning in this situation was the one that least reduced the intervertebral foramen height.

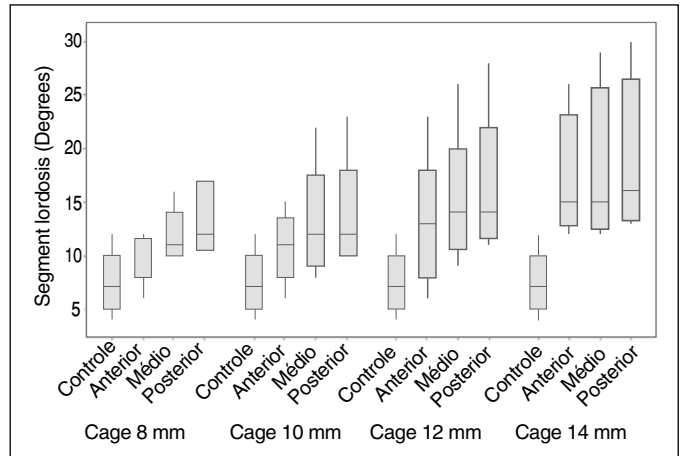


Figure 5. Segmental lordosis values with the use of the different spacers in the different positions.

Table 2. Height values of intervertebral foramen and of segmental lordosis with the use of the vertebral spacer at height close to the intervertebral disc height.

Segment	DH	SH	Foramen Height (mm)			Lordosis in Degrees				
			Post.	Med.	Ant.	Cont.	Post.	Med.	Ant.	Cont.
L1/L2	13	12	17	13	14	18	11	9	6	4
L2/L3	15	14	19	15	17	20.5	13	12	12	6
L3/L4	15	14	18	14.5	14.5	21	16	14	15	8
L4/L5	15	14	19.5	19.5	18	21.5	16	16	15	7
L5/S1	15	14	21.5	19	11.5	19	30	29	26	12

DH: Disc height; SH: Spacer height (mm); Post.: Posterior; Med.: Medial; Ant.: Anterior; Cont.: Control.

The experiment results were validated using trigonometric principles, in which the highest angular value of the vertebral segment was observed with the spacers posterior positioning (Figure 6). We considered "A" as the height of the anterior spacer, "P" the height of the posterior spacer, "d" the distance from the posterior edge of the vertebral body (in the media line) to the posterior edge of the spacer (in the media line), and angle "L" as angle of the segmental lordosis presented. Thus, the formula $A = P + (d \times \sin L)$ allows to demonstrate that the same degree of segmental lordosis was obtained with spacers of different heights positioned in the anterior or posterior part of the vertebral body. For example, the 11.22 mm high anterior spacer and the 8 mm high posterior spacer would produce the same segmental lordosis.

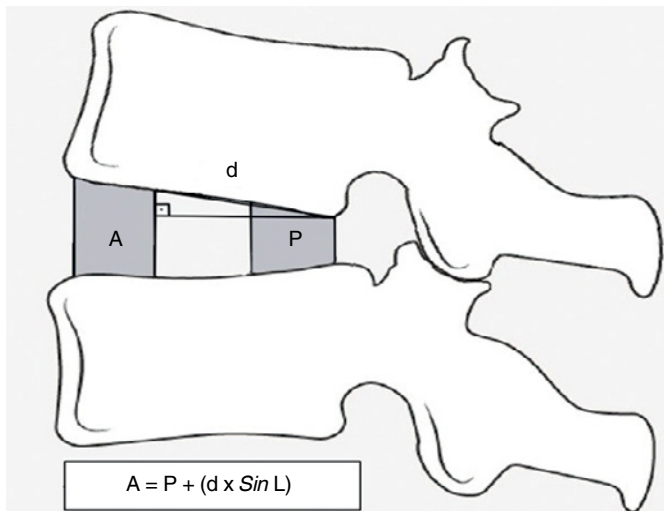


Figure 6. Formula illustration. A: Anterior Cage; P: Posterior Cage; D: Distance from the posterior limit of the posterior cage to the posterior limit of the anterior cage; L: Segment lordosis angle; Sin: Sine.

DISCUSSION

The position of kidney-type spacers in TLIF procedures induces morphological changes in intervertebral foramen and in the lordosis of the operated segment. Contralateral radiculopathy after TLIF is reported ranging from 2% to 8.5% after TLIF-MIS^{16,17} and 1.9% to 5.9% after open TLIF^{14,16} and drew attention to changes in intervertebral foramen after this procedure. Contralateral foraminal stenosis is the most frequent cause of contralateral radiculopathy after the use of a unilateral TLIF. Other factors such as poor screw positioning, disc herniation and hematoma were also reported.¹⁴ In our study, intervertebral foramen height reduction with statistical significance was observed in all the spacers. However, it should be considered that most of the spacers was smaller than the control disc. The original disc height could not be restored with smaller spacers, but the spacers positioning influenced the reduction of the intervertebral foramen height (Table 2). The spacer posterior positioning induced the lower reduction in the intervertebral foramen height in different sizes of spacers. Iwata et al.⁹ also found this result and showed a significant increase in the foramen height with the posterior positioning. The analysis of the results considering only the values corresponding to the spacer height according to the control disc height also showed a tendency of more correction of the segmental lordosis and less reduction in the intervertebral foramen height. The use of the spacer with height close to the intervertebral disc height is similar to the clinical use of spacers, which avoids spacers with superior or inferior height than the intervertebral disc height. Although no statistical difference was seen between the spacer positions on the intervertebral foramen height, the observed tendency is for its lower reduction with posterior positioning. The lower reduction in the intervertebral foramen height with posterior positioning is clinically relevant, because contralateral

radiculopathy can be a result of failure to obtain indirect decompression.¹⁴⁻¹⁶ According to our findings, restoring the disc height should be enough to allow the contralateral foramen indirect decompression with the appropriate spacer height and its posterior position. Contralateral foramen indirect decompression in TLIF depends on the spacer height and position.

Originally, the TLIF technique was described to use two titanium spacers in the mid or posterior third of the intervertebral space and fill with bone graft anteriorly behind the anterior longitudinal ligament. Spacers must provide initial distraction and segmental stability, as well as the support of axial loads.¹ Biomechanics studies suggested anteriorly positioning spacers would result in better load sharing and increase stability.^{8,18} Although spacers anterior positioning can improve the instrumentation stiffness of the vertebral segment, it reduces the intervertebral foramen height, causing contralateral intervertebral foramen stenosis. *In vitro* mechanical studies presented a different conclusion, recommending the posterolateral positioning of spacers used in the TLIF to obtain better mechanical stability and high fusion consolidation rates.¹⁹

The ideal alignment of the lumbar spine sagittal plane is still unknown. However, the positive correlation between reconstruction or maintenance of lumbar lordosis and clinical outcomes has been widely reported.^{5,20} To avoid “flatback syndrome”, segmental lordoses must be maintained or reconstructed.

The increase in lordosis in relation to control values occurred with the use of spacers of different heights, as well as in their location. Spacers located in the posterior position on the vertebral endplate tended to obtain greater lordosis. Production of segmental lordosis is associated with decreased intervertebral foramen height. A negative correlation is visible between increased segmental lordotic angle and changes in foraminal morphology and in transverse area of intervertebral foramen.⁹ The increase in lordosis during TLIF may affect the contralateral foramen.^{9,16} The segmental lordotic angle is significantly higher in symptomatic patients with contralateral radiculopathy when compared with asymptomatic patients.¹⁶

The analysis of the results must consider that the model has different characteristics from those biological and biomechanical lumbar spine characteristics. Ligaments and other structures, part of the lumbar spine biomechanical properties, are absent in the artificial model. The results reflect only the geometric changes in the model after inserting the Cage in the different positions. However, they open the perspective for a critical analysis of changes induced by intervertebral spacers, as well as the motivation to study these changes using human vertebrae for more accurate observation of changes induced by vertebral spacers.

The spacer must be able to restore the intervertebral disc height and maintain or restore the segmental lordosis. According to the results of our study, spacers should be placed in the posterior part of the spine to reach the objectives.

CONCLUSIONS

The results indicate that the posterior positioning of the vertebral spacer induces a lower reduction in the intervertebral foramen height and increased vertebral segment lordosis.

AUTHORS' CONTRIBUTION: Each author contributed individually and significantly to the development of this article. TDM: substantial contributions to the study conception; data acquisition and interpretation. Final approval of the manuscript version to be published; RBCF: contribution to data collection and analysis; KOT: contribution to data collection and analysis; VR: article review and intellectual analysis; HLAD: final approval of the manuscript version to be published and contributions to the analysis and interpretation of the study data.

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