

# IMPACT OF SPINO-PELVIC BALANCE ON CLINICAL AND FUNCTIONAL RESULTS AFTER INSTRUMENTED FUSION IN PATIENTS WITH DEGENERATIVE SPONDYLOLISTHESIS

*IMPACTO DO EQUILÍBRIO ESPINOPÉLVICO NOS RESULTADOS CLÍNICOS E FUNCIONAIS APÓS ARTRODESE INSTRUMENTADA EM DOENTES COM ESPONDILOLISTESE DEGENERATIVA*

*IMPACTO DEL EQUILIBRIO ESPINOPÉLVICO EN LOS RESULTADOS CLÍNICOS Y FUNCIONALES DESPUÉS DE ARTRODESIS INSTRUMENTADA EN PACIENTES CON ESPONDILOLISTESIS DEGENERATIVA*

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## ABSTRACT

**Objective:** There has been an increasing recognition in the literature of the importance of ensuring a correct sagittal and pelvic balance after a surgical procedure in lumbar spine. Recent studies clearly demonstrated a correlation between pelvic balance and surgical outcomes. As the degenerative deformity gradually progresses there is evidence of corresponding alterations in spinopelvic parameters. Therefore, the aim of this work was to study the influence of spinopelvic balance in clinical and functional outcomes after surgery for degenerative spondylolisthesis. **Methods:** Retrospective study with 29 subjects (20 females/9 males) with DS submitted to lumbar decompression and fusion between 2006 and 2010. Mean age 65,45 ( $\pm$  8,15) years old. Mean follow-up 2,1 years. Clinical, functional and radiological evaluation. VAS; Satisfaction; Oswestry disability Index (ODI). Spinopelvic parameters: Pelvic Incidence, Sacral Slope, Pelvic Tilt and Lumbar Lordosis. Two study groups: Group A (n=14) no improvement in pelvic tilt postoperatively (increased or unchanged); Group B (n=15) improvement in pelvic tilt postoperatively (decreased). Statistical analysis with SPSS19<sup>®</sup>. **Results:** The surgery is beneficial in reducing pain and improving quality of life. Patients in Group B (improved spinopelvic balance) have the best clinical and functional results ( $p < 0.05$ ) and also greater pelvic incidence values compared with group A. **Conclusion:** This study confirms the importance of spinopelvic balance in surgical planning: restoring the original spinopelvic balance seems to produce better outcomes.

**Keywords:** Spondylolisthesis; Postural balance; Spinal fusion; Lumbar vertebrae/injuries; Lumbar vertebrae/radiography.

## RESUMO

**Objetivo:** Garantir o equilíbrio sagital e pélvico depois de correção cirúrgica de deformidade lombar tem sido alvo de atenção crescente na literatura. Estudos recentes demonstraram uma relação entre o equilíbrio espinopélvico e o resultado pós-operatório. Com a progressão da deformidade degenerativa, as alterações correspondentes dos parâmetros pélvicos são evidentes. Assim, os autores pretendem estudar a influência do equilíbrio espinopélvico nos resultados clínicos e funcionais após cirurgia de espondilolistese degenerativa (ED). **Métodos:** Estudo retrospectivo. Amostra com 29 indivíduos com ED submetidos a descompressão e artrodeose instrumentada entre 2006 e 2010. Média de idade 65,45 ( $\pm$  8,15) anos. 20 mulheres e 9 homens. Acompanhamento médio - 2,1 anos. Avaliação clínica, funcional e radiológica. VAS, satisfação global, Oswestry Disability Index modificado. Cálculo de incidência pélvica, inclinação sacral, versão pélvica e lordose lombar. Dois grupos de estudo: A (n = 14): sem melhoria da versão pélvica (aumentada ou inalterada) no pós-operatório. B (n = 15): com melhoria da versão pélvica (diminuída). Estudo estatístico com SPSS<sup>®</sup>. **Resultados:** A cirurgia é benéfica, reduz significativamente a dor e melhora a qualidade de vida. Os pacientes do grupo B (restituição do balanço original) apresentam melhores resultados clínicos e funcionais ( $p < 0,05$ ) e valores superiores de incidência pélvica relativamente ao grupo A. **Conclusão:** Este trabalho confirma a importância do equilíbrio espinopélvico como objetivo no planeamento cirúrgico e que a restituição do equilíbrio original parece obter melhores resultados.

**Descritores:** Espondilolistese; Equilíbrio postural; Fusão vertebral; Vértebras lombares/lesões; Vértebras lombares/radiografia.

## RESUMEN

**Objetivo:** Asegurar el equilibrio sagital y pélvico, después de corrección quirúrgica de deformidad lumbar, ha sido un asunto de creciente atención en la literatura. Los estudios recientes demostraron que hay una relación entre el equilibrio espinopélvico y el resultado posoperatorio. Con el avance de la deformidad degenerativa, son evidentes las alteraciones correspondientes de los parámetros pélvicos. Así, los autores tuvieron la finalidad de estudiar la influencia del equilibrio espinopélvico en los resultados clínicos y funcionales, después de cirugía de espondilolistesis degenerativa (ED). **Métodos:** Estudio retrospectivo. Muestra con 29 individuos, con ED, sometidos a descompresión y artrodesis instrumentada entre 2006 y 2010. Promedio de edad 65,45 ( $\pm$  8,15) años. 20 mujeres y 9 hombres. Acompañamiento promedio de 2,1 años. Evaluación clínica, funcional y radiológica. VAS, satisfacción global, modificación del Índice de Discapacitación de Oswestry. Cálculo de incidencia pélvica, inclinación sacral, inclinación pélvica y lordosis lumbar. Dos grupos de estudio: A (n = 14): sin mejoría de la inclinación pélvica (aumentada o inalterada) en el posoperatorio. B (n = 15): con mejoría de la inclinación pélvica (disminuida). Estudio estadístico con SPSS<sup>®</sup>. **Resultados:** La cirugía es benéfica, reduce significativamente el dolor y mejora la calidad de vida. Los pacientes del grupo B (restitución del equilibrio original) presentan mejores resultados clínicos y funcionales ( $p < 0,05$ ) y valores superiores de incidencia pélvica en comparación con el grupo A. **Conclusión:** Este trabajo confirma la importancia del equilibrio espinopélvico como objetivo en el planeamiento quirúrgico, y que la restitución del equilibrio postural parece obtener mejores resultados.

**Descriptor:** Espondilolistesis; Equilíbrio postural; Fusión vertebral; Vértebras lombares/lesiones; Vértebras lombares/ radiografía.

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## INTRODUCTION

The impact of sagittal alignment on the treatment of spinal pathology has taken on increasing importance in the monitoring of such patients. The non-recognition of an imbalance in this plane may have a negative impact on the residual pain and quality of life. The spine is comprised of varying kyphotic and lordotic curves, which, in conjunction with the pelvis and lower limbs, allow for the harmonious and balanced distribution of forces by the human skeleton. Changing this balance through pathological processes or aging results in deformity and adaptive changes in the spine, pelvis, and lower limbs.<sup>1</sup>

The pelvic incidence (PI) angle describes the relationship between the sacrum and femoral heads. It is a morphological parameter that is constant for each individual starting at skeletal maturity and determines the capacity of the pelvis to rotate about the femoral heads along the hip axis. Two other parameters are directly related to the PI: pelvic tilt (PT) which varies with the rotation of the pelvis, i.e., the PT increases when the pelvis rotates posteriorly (in retroversion), and the PT decreases with the anteversion of the pelvis. The sacral slope (SS) is defined by the orientation of the S1 platform in the horizontal plane. These last two parameters are positional and dependent on the pelvic incidence, so that  $PI = SS + PT$ . Thus for a constant PI, if the PT increases the SS decreases and vice versa.<sup>2</sup>

From a pathophysiological viewpoint, the spine undergoes degenerative changes with age. In the context of degenerative spondylolisthesis, the change in sagittal balance relates to postural and structural factors. The degeneration and slipping of intervertebral discs result in the loss of lumbar lordosis and the subsequent straightening of this segment. Similarly, the antalgic posture of the trunk in anterior flexion leads to the reduction of lumbar lordosis. The center of gravity (C7 plumb line) moves anteriorly and to compensate for this imbalance, the patient's pelvis promotes retroversion, that is, the pelvis rotates posteriorly and inferiorly on the femoral heads causing a decrease in SS and an increase in PT, resulting in the verticalization of the sacrum. (Figure 1) This mechanism is broader or more ample the larger the PI, since it is this latter value which determines the pelvis's ability to rotate.<sup>3</sup> Thus, sagittal imbalance (C7 plumb line) is rarely observed in patients with degenerative spondylolisthesis because they compensate for the changes described.<sup>2</sup>

Barrey et al.<sup>3</sup> and Morel et al.<sup>4</sup> demonstrated that patients with degenerative spondylolisthesis have a significantly elevated PI angle compared to the population that is asymptomatic and without deformity, and is considered a possible risk factor for the disease. With the onset of the disease and its progression, a decrease in the SS and loss of lumbar lordosis are observed. Therefore, the PT is increased in these patients as a sign of pelvic retroversion.

Thus, the objectives of this study are: 1) to study the relationship between the pelvic parameters and clinical and functional results after spinal decompression and fusion; 2) to determine whether

these parameters have predictive value for the postoperative result. If we seek to restore the original spino-pelvic balance, we hope to decrease the retroversion of the pelvis postoperatively, i.e., to decrease the PT.

## MATERIAL AND METHODS

We developed a retrospective study evaluating 29 patients (9 men and 20 women) with a mean age of 65.54 years (51-81), who underwent decompression and posterior lumbar arthrodesis between 2006 and May 2010.

Inclusion criteria were: 1) degenerative listhesis at only one level; 2) surgical treatment via a posterior approach (circumferential or posterolateral arthrodesis); 3) evidence of arthrodesis post-surgery in follow-up radiographs or computed tomography; 4) minimum of 18 months follow-up.

Exclusion criteria were: 1) more than one level instrumented; 2) patients with a history of previous surgery to the lumbar spine; 3) patients with concomitant spinal deformities (scoliosis, tumor, or trauma).

Symptoms lasting more than 24 months before the surgery. Level involved: L3-L4 in one patient; L4-L5 in 25 patients, and L5-S1 in three patients. Neurogenic claudication in 13 patients, lumbosciatica in 13 patients, and only low back pain in three patients.

### Clinical and functional assessment

Clinical evaluation of pain consisted of the completion of the Visual Analogue Pain Score (VAS) and patients answered the Oswestry disability index (ODI) questionnaire<sup>5</sup> regarding the impact of the disease on their quality of life.

The functional and clinical results were evaluated by calculating the difference between the preoperative VAS and ODI with the results obtained in the final observation, and translated into a percentage, i.e. the change in the VAS ( $\Delta VAS = \text{preoperative VAS} - \text{current VAS}$ ) and change in the ODI ( $\Delta ODI = \text{preoperative ODI} - \text{current ODI}$ ).

### Spino-pelvic parameters

Spino-pelvic parameters were measured on radiographs taken in the standing position with the knees extended. Long chassis view with lateral profile and exposure of the skull to the proximal femur. All measurements were performed by the same author (FD) and repeated twice.

Pelvic parameters included in this study were: pelvic incidence (PI), the sacral slope (SS), and pelvic tilt (PT). Measurements were made according to the criteria of Duval-Beaupère and Robain.<sup>6</sup> The vertebral parameters included were the lumbar lordosis (LL) and the sacrum-C7 plumb line distance (SC7D).

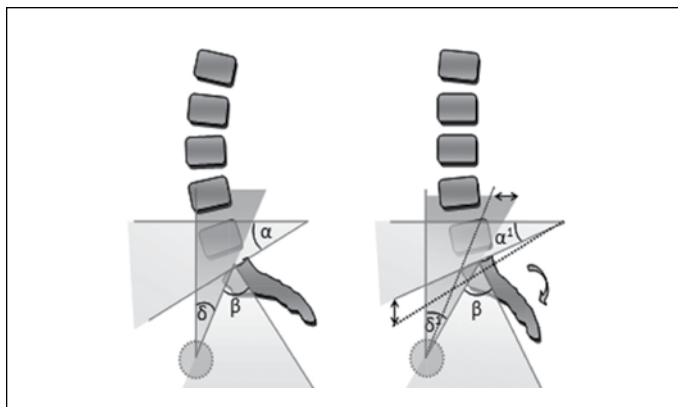
The pelvic incidence angle is defined as the angle between the line perpendicular to the S1 platform and the line that connects the midpoint of the S1 platform with the hip axis. (Figure 1 –  $\beta$ )

The sacral slope is equivalent to the angle between the S1 platform and the horizontal plane. (Figure 1 –  $\alpha$ )

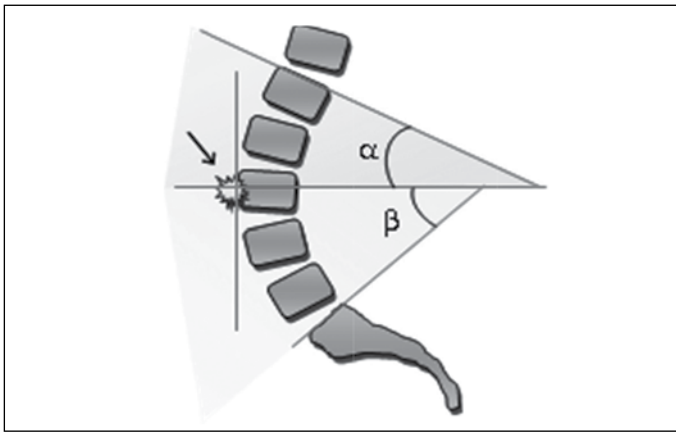
The pelvic tilt corresponds to the angle between the vertical plane and the line connecting the midpoint of the S1 platform with the hip axis. (Figure 1 –  $\delta$ )

Lumbar lordosis was measured according to the model proposed by Berthonnaud<sup>7</sup> by the two arches method. The most anterior point of the lumbar lordotic curvature (apex) was located and a horizontal line was drawn at this level. The distal arch forms an angle to the S1 platform and the proximal arch forms an angle with the line tangential to the upper edge of the vertebra, corresponding to the inflection point of the curve. The LL is the sum of the amplitude of the two arches. (Figure 2)

The C7 plumb line is identified as a vertical line starting at C7 and should intersect the S1 platform. The horizontal distance between the end of the C7 plumb line and the S1 platform is the sacrum-C7 plumb line distance (SC7D).



**Figure 1.** Changes in pelvic balance in lumbar spine degeneration.  $\alpha$ -sacral slope;  $\beta$ -pelvic incidence,  $\delta$ -pelvic tilt. Note the increase in pelvic tilt with retroversion of the pelvis –  $\delta 1$  and the decrease in sacral slope –  $\alpha 1$ .



**Figure 2.** Calculation of lumbar lordosis.  $\alpha$ -proximal arch.  $\beta$ -distal arch. Arrow – tangent to the most anterior point of the lumbar spine (Apex).

### Clinical study

Patients were divided into two groups according to the changes of the PT in the last observation: Group A: no decrease in PT (further increased or remained constant after surgery); Group B: decrease in PT (i.e., having a PT increased in the preoperative caused by retroversion of the pelvis, this value decreased postoperatively in order to achieve the original pelvic balance).

We then performed the statistical comparison of clinical and functional results between the two groups.

### Statistical study

Statistical analysis was performed with SPSS 19<sup>®</sup> software. Descriptive and epidemiological analysis of the study sample, as well as analysis of the spino-pelvic parameters within the sample. The Wilcoxon's rank sum test was used to compare the preoperative data with current results. The Mann-Whitney U-test was used to compare the two groups at the clinical (VAS) and functional (ODI) level and the level of differences between the spino-pelvic parameters. There have been several statistical correlations between the clinical and functional data and the spino-pelvic parameters, using the Pearson's coefficient.

## RESULTS

Fourteen patients were included in Group A and fifteen were included in Group B. Demographic data were summarized in Table 1.

**Table 1.** Epidemiological and preoperative data.

Variable	Group	
	Group A (n=14)	Group B (n=15)
Sex (M:F)	6:8	3:12
Average age	63.4 ± 9.6	67.3 ± 6.3
Level affected		
L3-L4	0	1
L4-L5	12	13
L5-S1	2	1

### General statistics

From the global point of view, the surgery was beneficial for patients, translating into decreased pain and improved quality of life.

The preoperative mean VAS in the total sample was 9.1 (± 0.8), with the current being 3.9 (± 1.2) which is an improvement in mean VAS of 58.9%. Similarly, the preoperative mean ODI was 79.4% (± 5.6), with a significant improvement in the last follow-up visit, a current mean ODI of 29.2% (± 10.9), which is a 63.3% improvement in ODI.

Regarding the spino-pelvic parameters, the pelvic incidence angle averaged 62.4° (± 14.2°), the preoperative mean pelvic tilt was 21.6° (± 7.3), the current mean pelvic tilt was 21.6° (± 5.4), the preoperative mean sacral slope was 40.8° (± 11.7), and the current mean sacral slope was 39.7° (± 12.2); preoperative mean lumbar lordosis was 60.4° (± 14.7), and current mean lordosis was 61.8° (± 15).

### Comparison of the two groups

The clinical and functional results of the groups are summarized in Table 2. No statistically significant differences were found between the two groups for the preoperative VAS and ODI values. However, the difference was significant for the current VAS and ODI values and the changes in these scores. In Group A, the current mean VAS was 4.5, and in Group B it was 3.4, which corresponds to an improvement of 50.7% in group A and 62.7% in Group B ( $p < 0.05$ ).

Regarding the functional score, the current mean ODI value was 80.7% for Group A and 78.1% for Group B. This improvement in score was 55.9% in group A and 70.2% in Group B ( $p < 0.05$ ).

The values for the spino-pelvic parameters are summarized in Table 3. Comparing the preoperative results for each spino-pelvic parameter with the current did not comprise statistically significant differences except for the PT in both groups. In the comparison between Groups A and B, differences between the pelvic incidence values and also in respect to the preoperative and current PT values stood out. There were no differences in the other parameters measured.

Statistical correlations using Pearson's coefficient were performed between the clinical and functional results and the spino-pelvic parameters measured. Group A showed a negative relationship between the change in VAS and the current PT value. Similarly, a negative relationship was found between the ODI change and the current PT value. A positive relationship was also found in Group A when comparing changes in the ODI with the pelvic incidence value. No statistical relationship calculated by Pearson's coefficient was found in Group B between the clinical and functional results and the spino-pelvic parameters. (Table 4)

**Table 2.** Clinical and functional comparison between the two groups according to whether or not the PT improved (Values shown correspond to the means with standard deviation).

Group	VAS		Improvement (%)	ODI		Improvement (%)
	Pre-op	Current		Pre-op	Current	
A (n=14)	9.1 ± 0.8	4.5 ± 1.3	50.7*	80.7 ± 5.4	35.7 ± 12.0	55.9*
B (n=15)	9.1 ± 0.8	3.4 ± 1.1	62.7*	78.1 ± 5.8	23.1 ± 4.4	70.2*
$p^\dagger$	ns	<0.05	<0.05	ns	<0.01	<0.05

† Differences between group A and group B calculated with Mann-Whitney U-test.

\*  $p < 0.05$  – Statistically significant differences between the current values and the preoperative values calculated with Wilcoxon's rank sum test.

**Table 3.** Comparison of pelvic parameters between the two groups according to the postoperative PT.

Variable	Pelvic tilt (°) (12-18°)		Sacral slope (°) (36-42°)		Lumbar lordosis (°) (43-61°)		Pelvic incidence (°) (48-55°)
	Pre-op	Current	Pre-op	Current	Pre-op	Current	
A (n=14)	17.5 ± 7.3	24.4 ± 5.3 <sup>†</sup>	37.9 ± 12.2	34.6 ± 12.1	57.4 ± 15.6	56.7 ± 16.7	55.3 ± 13
B (n=15)	25.5 ± 4.9	18.9 ± 4.2 <sup>†</sup>	43.6 ± 10.8	44.5 ± 10.5	63.2 ± 13.7	66.6 ± 11.8	69.1 ± 12.1
$p^\ddagger$	<0.01	<0.01	ns	ns	ns	ns	<0.01

\* Average reference values of several studies published in asymptomatic individuals without deformity.

†  $p < 0.05$  – Statistically significant differences between the current values and the preoperative values calculated with Wilcoxon's rank sum test.

‡  $p < 0.05$  – Statistically significant differences between the two groups calculated by Mann-Whitney U-test.

**Table 4.** Pearson's correlation. \*  $p < 0.05$ .

Parameter		Group A (n=14)		Group B (n=15)	
		ΔVAS	ΔODI	ΔVAS	ΔODI
Sacral slope	Pre-op	ns	ns	ns	ns
	Current	ns	ns	ns	ns
Lumbar lordosis	Pre-op	ns	ns	ns	ns
	Current	ns	ns	ns	ns
Pelvic tilt	Pre-op	ns	ns	ns	ns
	Current	-0.86*	-0.79*	ns	ns
Pelvic incidence		ns	0.82*	ns	ns

## DISCUSSION

The compensatory pelvic tilt observed in degenerative spondylolisthesis makes the sagittal imbalance a rarity in patients with this type of spine pathology.<sup>3</sup> Minor changes such as those found in the spino-pelvic parameters may be responsible for postoperative residual pain and even for the decompensation of the adjacent level.<sup>8</sup> Lazennec et al.<sup>9</sup> found a relationship between post-fusion pain and pelvic parameters, with the postoperative pain being associated with an elevated PT. Le Huec and Roussouly<sup>2</sup> have even suggested that in case of surgery, the original spino-pelvic balance should be reestablished or the spine would be permanently fused in retroversion, with consequences in postoperative pain.

Several published studies have demonstrated various relationships between pain perceived by patients (VAS) and imaging parameters to other clinical entities. In the case of vertebral deformities, the work of Glassman et al.<sup>8,10</sup> also allowed for the establishment of a relationship between quality of life (ODI) and imaging parameters.

In this study, patients with a decreased PT (group B) showed better results in the variables measured. Assuming that changes in pelvic tilt may influence clinical and functional outcomes<sup>9</sup> we may say with our study that there is a clear relationship between the surgical restoration of the original spino-pelvic balance and the improved pain and quality of life of patients.

The statistical correlations made within the group with no decrease in PT (group A) found a negative relationship between the current PT value and the improvement in VAS and ODI, which allows us to affirm that, even in this group, the patients with the worst outcomes are those who have higher PT.

The analysis of the pelvic incidence angle found values that were clearly higher ( $p < 0.05$ ) in group B than in group A. Assuming the hypothesis that the larger this angle, the greater the ability to compensate for changes in the spino-pelvic balance, we can deduce that the group B patients better offset the changes they have undergone, and therefore more easily restore the original values. The same is supported by the positive correlation between the improvement of the ODI with the PI value, i.e., the greater the PI angle, the greater the improvement in the quality of life after surgery.

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In terms of spino-pelvic parameters, major sagittal imbalance is defined by loss of lordosis, anterior deviation of the C7 plumb line and retroversion of the pelvis with verticalization of the sacrum (increased PT).<sup>11</sup> In this study sample, we observed elevated current global PT values compared to reference values. However, no individual showed changes consistent with major sagittal imbalance when measuring the distance from the sacrum to the end of the C7 plumb line, supporting the theory of a greater ability to compensate for changes in spino-pelvic balance.

Currently, the literature places greater emphasis on the role of morphology and spino-pelvic positioning in the study of sagittal balance. This study demonstrates that pelvic positioning – here represented by the PT – is related to the quality of life of patients and cannot be ignored in the preoperative planning of a patient. Surgery should aim to restore the original PT to restore spino-pelvic balance.

Although lumbar lordosis has also been related to the improvement of clinical and functional results in other studies, this relationship was not proven in this study. Kim et al.<sup>12</sup> reported that after lumbar fusion there is a relationship between the spines that remained hypolordotic and more pain and a reduced quality of life. The same authors suggest that in these cases the patients benefit from increased intraoperative lumbar lordosis during the fusion. By comparing their results with those of our study, we found differences in the values of lumbar lordosis (preoperative mean LL of 42.9° and current mean LL of 47.8°) that differ significantly from those we encountered: a preoperative mean LL of 60.40° (± 14.69) and a current mean LL of 61.82° (± 15).

Despite the apparent importance to the outcome of patients, studies poring over the impact of sagittal and spino-pelvic balance on the surgical results of degenerative spondylolisthesis are scarce. Limitations of this study include those inherent in the retrospective design used together with the small sample size. Thus, these results should be interpreted cautiously.

## CONCLUSION

The variation of the pelvic tilt and pelvic incidence proved to be determining factors in the outcome after the surgical treatment of degenerative spondylolisthesis.

Currently, the emphasis on sagittal balance appears to have reached consensus and shown evidence that it is too important to be ignored. This study is in line with a multifactorial approach in lumbar surgery for the treatment of this pathology: besides correcting the deformity, the surgeon should be aware of the characteristics and morphology of the spine, while seeking to restore the original balance of each patient.

All authors declare no potential conflict of interest concerning this article.