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SPINOPELVIC PARAMETERS AFTER POSTERIOR LUMBAR ARTHRODESIS IN DEGENERATIVE SPINAL DISEASES

PARÂMETROS ESPINOPÉLVICOS APÓS ARTRODESE LOMBAR POSTERIOR EM DOENÇAS DEGENERATIVAS DA COLUNA VERTEBRAL

PARÁMETROS ESPINOPÉLVICOS TRAS ARTRODESIS LUMBAR POSTERIOR EN ENFERMEDADES DEGENERATIVAS DE LA COLUNA VERTEBRAL

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ABSTRACT

Introduction:Spinopelvic parameters related to sagittal balance have become increasinglyimportantamong spine surgeons due to their correlation with patient satisfaction rates. Objective:The goal of this study was to evaluate changes in spinal sagittal balance after lumbar spine surgery using PLIF, the posterior lumbar interbody fusion technique. Methods: The sample consisted of adult patients with degenerative spinal disease submitted to posterior lumbar arthrodesis. Patients between 18 and 70 years of agewho underwent surgeryfrom 2015 to 2017 were included in the study and divided into short (1 level) and long arthrodesis (2 to 4 levels) groups. Radiographic analysis of the spinopelvic parameters, measured before and after lumbar arthrodesis, was conducted using the SURGIMAP software. Then we evaluated the variation between pre- and postoperative measurements and performed correlation and linear regression analyses between the parameters. Results:The sample was composed of 80 patients (48 men). The mean age was lower in the short arthrodesis group than in the long arthrodesis group (52.67 ± 9.66 years versus 59.37 ± 9.30 years, respectively; $p<0.0025$). Significant variations in lumbar lordosis, pelvic tilt, sagittal vertical axis, T1 pelvic angle, and pelvic incidence minus lumbar lordosis were found in both short and long arthrodesis groups. The variation was significantly larger in the long than in the short arthrodesis group. Conclusion: In adult degenerative spine disease, short and long arthrodesis of the lumbar spine by PLIF allows correction of the spinopelvic parameters. ***Level of evidence III; Retrospective, comparative study.***

Keywords: Arthrodesis; Lordosis; Spine.

RESUMO

Introdução:Os parâmetros espinopélvicos relacionados ao equilíbrio sagital vêm ganhando cada vez mais importância devido a sua correlação com as taxas de satisfação dos pacientes. Objetivo:O objetivo do estudo foi avaliar as alterações no equilíbrio sagital após cirurgia da coluna lombar com a técnica PLIF, fusão intersomática lombar posterior. Métodos: A população do estudo foi composta por pacientes adultos com doença degenerativa da coluna submetidos a artrodese da coluna lombar por via posterior. Foram incluídos pacientes com idade entre 18 e 70 anos, submetidos àcirurgia no período de 2015 a 2017, divididos em grupo de artrodese curta (1 nível) e grupo de artrodese longa (2 a 4 níveis). Foi realizada análise radiográfica dos parâmetros espinopélvicos,medidos antes e após a artrodese lombar, utilizando o softwareSURGIMAP. Em seguida, a variação entre as medidas pré e pós-operatórias foi avaliada e foram realizadas análises de correlação e regressão linear entre os parâmetros. Resultados: A amostra foi composta por 80 pacientes (48 homens). A média de idade dos pacientes do grupo artrodese curta foi inferior à do grupo artrodese longa (52,67 ± 9,66 anos versus 59,37 ± 9,30, respectivamente; $p<0,0025$). Foram identificadas variações significativas na lordose lombar, inclinação pélvica, eixo vertical sagital, ângulo pélvico T1 e incidência pélvica menos lordose lombar tanto no grupo de artrodese curta e como de artrodese longa. A variação foi significativamente maior no grupo de artrodese longa do que no grupo de artrodese curta.Conclusão: Em adultos com doença degenerativa da coluna lombar, a artrodese curta e longa usando atécnica PLIF permite a correção dos parâmetros espinopélvicos. ***Nível de evidência III; Estudo retrospectivo comparativo.***

Descritores: *Artrodese; Lordose; Coluna Vertebral.*

RESUMEN

Introducción:Los parámetros espinopélvicos relacionados con el equilibrio sagital han ido ganando cada vez más importancia debido a su correlación con los índices de satisfacción de los pacientes. Objetivo: El objetivo del estudio fue evaluar los cambios en el equilibrio sagital después de la cirugía de columna lumbar con la técnica PLIF, fusión intersomática lumbar posterior.Métodos: La población de estudio fue compuesta por pacientes adultos con enfermedad degenerativa de la columna sometidos a artrodesis de columna lumbar por vía posterior. Se incluyeron pacientes entre 18 y 70 años, sometidos a cirugíaentre 2015 y 2017, divididos en grupos de artrodesis corta

Study conducted at the Instituto Nacional de Traumatologia e Ortopedia Jamil Haddad, Rio de Janeiro, RJ, Brazil.
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(1 nivel) y grupo de artrodesis larga (2 a 4 niveles). El análisis radiográfico de los parámetros espinopélvicos, medidos antes y después de la artrodesis lumbar,se realizó utilizando el software SURGIMAP. A continuación, se evaluó la variación entre las mediciones pre y postoperatorias y se realizaron análisis de correlación y regresión entre los parámetros.Resultados: La muestra estabacompuesta por 80 pacientes (48 hombres). La edad media de los pacientes del grupo de artrodesis corta era inferior a la del grupo de artrodesis larga (52,67 ± 9,66 años frente a 59,37 ± 9,30, respectivamente; p<0,0025).Se identificaron variaciones significativas en cuanto a lordosis lumbar, inclinación pélvica, eje vertical sagital, ángulo pélvico T1 e incidencia pélvica menos lordosis lumbar en los grupos de artrodesis corta y larga. La variación fue significativamente mayor en el grupo de artrodesis larga que en el de artrodesis corta..Conclusión: En adultos con enfermedad degenerativa de la columna lumbar, la artrodesis corta y larga mediante la técnica PLIF permite corregir los parámetros espinopélvicos. ***Nivel de evidencia III; Estudio retrospectivo comparativo .***

Descriptores: *Artrodesis; Lordosis; Columna Vertebral.*

INTRODUCTION

The incidence of degenerative spinal disease in the Western population has increased by 60% over the last 60 years, and is an important public health concern due to its association with lumbar pain leading to disability and a worsening quality of life.[1-3]

The main mechanisms associated with vertebral degeneration are characterized by the anterior displacement of the center of gravity, thoracic and lumbar hyperkyphosis, lumbar hyperlordosis, and pelvic retroversion, which increase the energy expenditure required to maintain orthostatic posture, leading to fatigue, pain, and early functional impairment.[4] Sagittal imbalance has been recognized as an important factor related to degenerative spinal disease.[5] Degenerative spinal disease can activate compensatory mechanisms, and it is not clear whether there is a cause-and-effect relationship between the loss of spinopelvic alignment and early disk degeneration.[6-8]

The current classification for degenerative spinal disease, known as SRS-Schwab, considers the type ofcurvature in the coronal aspect and, using radiographic parameters, defines three sagittal modifiers: pelvic incidence minus lumbar lordosis (PI-LL), sagittal vertical axis (SVA) and pelvic version (PV).[4] These spinopelvic parameters predict disability and provide a guide for patient evaluation.[1,9,10] Surgical outcomes and post-operative satisfaction are closely related to the restoration of sagittal balance to the normal range.[4]

Posterior lumbar interbody fusion (PLIF) surgery has many advantages sincemost surgeons are familiar with it. The posterior approach allows good exposure of the nerve roots and vascular structures, and enables both the adequate restoration of disk height and ampleneural decompression.[11] Moreover, PLIF allows anterior and posterior fusion through the same incision,[12] although it is not as effective at restoring lumbar lordosis as other techniques.[13-15]

The goal of this study was to evaluate the pattern of sagittal alignment modifications in patients who underwent short and long lumbar arthrodesis through posterior lumbar interbody fusion.

METHODS

Participants

A total of 80 patients, who underwent lumbar arthrodesis to treat degenerative spinal diseaseat the Institute between January 2015 and December 2017,were included in the study. Patients with a previous history of spinal trauma or spine or hip surgery were excluded. Non-ambulating patients, patients with previous bone pathologies, such as osteoporosis and rheumatoid arthritis, patients with congenital spinal deformities, patients with coronal spinal deformities or pathologies with increased lumbar lordosis, and patients who had not completed the six-month post-operative period necessary for bone consolidation were also excluded (Figure 1).

The study was approved by the Institutional Review Board (CAAE 80228717.3.0000.5273).

Radiographic assessment

Data were evaluated by comparing pre- and postoperative evaluations, which had a mean elapsed time between them of 7.9 ± 2.3 months (min. 5 months, max. 14 months). Groups were established according to the number of arthrodesis levels: short arthrodesis involving one level and long arthrodesisinvolving from 2 to 4 levels. The surgical procedure consisted of decompression, internal fixation with pedicle screws, and fusion.[16]

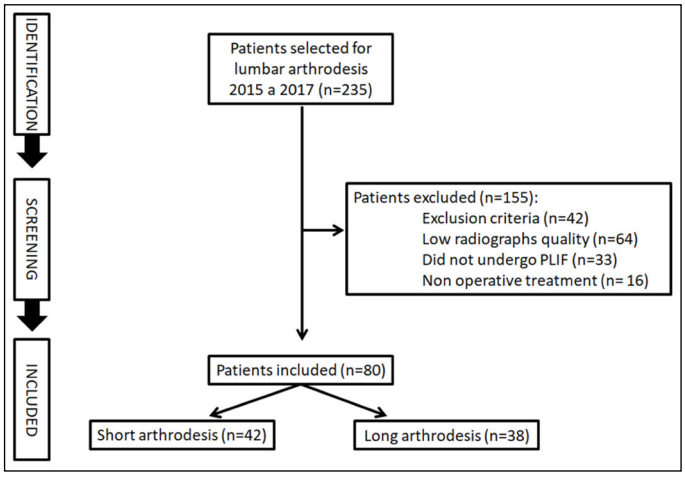


Figure 1. Study flowchart.

The radiographic analysis usedpanoramic,full-body, orthostatic, antero-posterior and lateral views of the spine. Images were available in digital format, as standard institutional procedure (mDicom Viewer 3.0.0, Microdata), and analyzed using Surgimap® software (Nemaris Inc., Massachusetts, USA) (Figure 2). The following spinopelvic parameters were evaluated before and after posterior lumbar arthrodesis: lumbar lordosis (LL), measured as the Cobb angle between L1 and S1; pelvic incidence (PI), measured as the angle subtended by the line drawn from the hip axis to the midpoint of the upper sacral endplate and the line perpendicular to the sacral endplate; pelvic tilt (PT), measured as the angle subtended by the vertical line and the line drawn from the hip axis to the midpoint of the upper sacral endplate; sagittal vertical axis (SVA), measured as the distance between the C7 plumb line and the posterior edge of the upper sacral endplate; T1-pelvic angle (TPA), measured by a line from the femoral heads to the center of the T1 vertebral body and a line from the femoral heads to the center of the superior sacral endplate, and pelvic incidence minus lumbar lordosis (PI-LL).

Statistical analysis

Data were collected and stored in a Microsoft Excel 2010® spreadsheet, and then analyzed using the GraphPad Prism 5 for Windows 6.0software (GraphPad Holdings, California, USA).Comparisons were performed with the unpaired tand two-way ANOVA tests. Variation between the parameters was also calculated (Δ) as the difference between postoperative and preoperative measurements. Data were presented as mean value ± standard deviation and statistical significance was indicated at $p<0.05$.

RESULTS

Participants

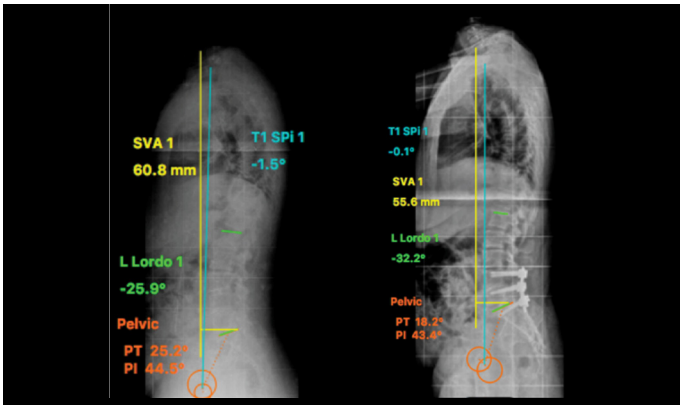
A total of 80 patients (48 men and 32 women) were included in the study and divided into the short (38 patients) and long (42 patients) arthrodesis groups. Patients in the short arthrodesis group were younger than those in the long arthrodesis group (52.67 ± 9.66 yearsvs. 59.37 ± 9.30 years, respectively; p<0.0025).

Spinopelvic parameters

Table 1 displays a comparative analysis of the sagittal parameters of patients included in both groups.

Lumbar lordosis

LL increased significantly in both short (pre 27.83° ± 1.03° vs.post 30.58° ± 1.06°; p<0.0001) and long (pre 23.38° ± 0.7° vs.post 33.26° ± 0.89°; p<0.0001) arthrodesis groups. However, the short arthrodesis group presented higher preoperative LL than the long arthrodesis group (short 27.83° ± 1.03° vs.long 23.38° ± 0.7°; p=0.0008). Postoperatively, this relationship was inverted but showed no statistical significance (p=0.0532) (Figure 3A).



LL: lumbarlordosis, PI: pelvic incidence, PT: pelvic tilt, PI-LL: pelvic incidence minus lumbar lordosis, SVA: sagittal vertical axis,TPA: T1-pelvic angle.

Figure 2. Example of the measurements of spinopelvicparameters.

Table 1. Sagittal parameters of patients who underwent short and long arthrodesis.

	Short Arthrodesis (n = 42)		LongArthrodesis (n = 38)	
	Preoperative	Postoperative	Preoperative	Postoperative
LL	27.83° ± 1.03°	30.58° ± 1.06°	23.38° ± 0.7°	33.26° ± 0.81°
PI	41.53° ± 0.94°	41.64° ± 0.91°	46.02° ± 0.89°	45.99° ± 0.89°
PT	18.56° ± 0.75°	17.17° ± 0.59°	26.79° ± 0.87°	18.44° ± 0.83°
PI-LL	13.7° ± 0.73°	11.06° ± 0.74°	22.64° ± 0.87°	12.73° ± 0.87°
SVA	32.9 ± 1.9 mm	29.6 ± 1.8 mm	49.4 ± 2.3 mm	24.4 ± 1.8 mm
TPA	18.79° ± 0.67°	16.99° ± 0.62°	24.99° ± 0.71°	17.37° ± 0.7°

LL: lumbar lordosis, PI: pelvic incidence, PT: pelvic tilt, PI-LL: pelvic incidence minus lumbar lordosis, SVA: sagittal vertical axis,TPA: T1-pelvic angle. Values presented as mean ± standard deviation.

Pelvic incidence

Preoperative PI was lower in the short than in thelong arthrodesis group (41.53° ± 0.94° vs. 46.02 ± 0.89°; p=0.001). It did not change in either the short (41.53° ± 0.94° vs. 41.64° ± 0.91°; p=0.19) or long arthrodesis group (46.02 ± 0.89° vs. 45.99° ± 0.89°; p=0.75). Hence, PIremained lower following surgery in the short arthrodesis group (46.02 ± 0.89° short ***vs***. 45.99° ± 0.89° long; p=0.0011) (Figure 3B).

Pelvic tilt

Preoperative PT was lower in the short than in the long arthrodesis group (short 18.56° ± 0.75° vs.long 26.79° ± 0.87°; p<0.0001). Postoperative PT decreased both in short(pre 18.56° ± 0.75° vs. post 17.17° ± 0.59°; p=0.0003) and long arthrodesis (pre 26.79° ± 0.87° vs. post 18.42° ± 0.83°; p<0.0001) groups. There was no statistically significant postoperative differencein PT between the groups(p=0.22) (Figure 3C).

Sagittal vertical axis

Postoperative SVA was lower in the short when compared to long arthrodesis group (pre 32.9 ± 1.9 mm vs.post 49.4 ± 2.3 mm; p<0.0001). Postoperatively, SVA decreased both in short (pre 32.9 ± 1.9 mm vs. post 29.6 ± 1.8 mm; p=0.0006) and long arthrodesis (pre49.4 ± 2.3 mm vs. post 22.4 ± 1.8 mm; p<0.0001). groups. There were no statistically significant differences in postoperative SVA between the groups (p=0.0509)(Figure 4A).

T1-Pelvic angle

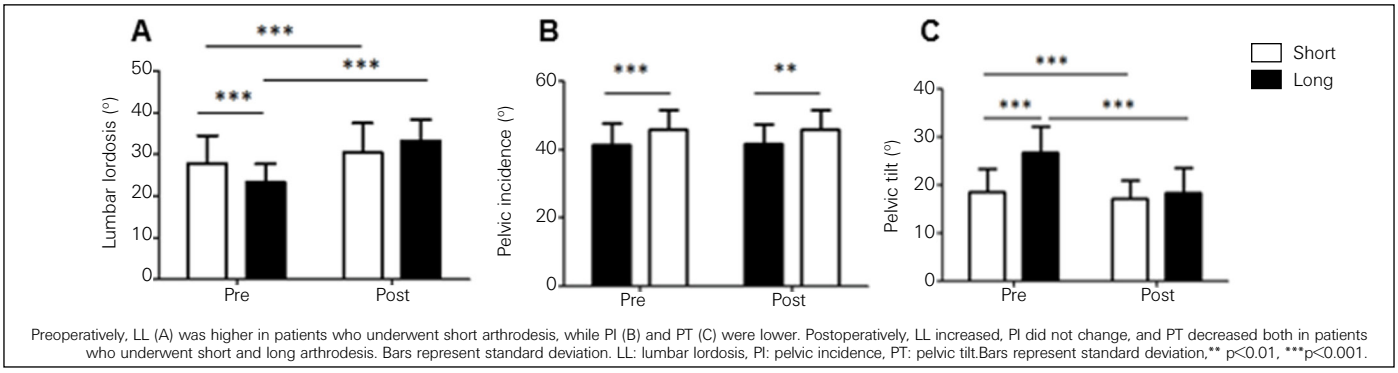
Postoperative TPA was lower in the short as compared to the long arthrodesis group (short 18.79° ± 0.67° vs.long 24.99° ± 0.71°; p<0.0001). Postoperative TPA decreased both in short (pre 18.79° ± 0.67° vs. post 16.99° ± 0.62°; p<0.0001) and long arthrodesis (pre 24.99° ± 0.71° vs. post 17.37° ± 0.7; p<0.0001) groups. There was no statistically significant difference in postoperative TPA between groups (p=0.62) (Figure 4B).

Pelvic incidence minus lumbar lordosis

Postoperative PI-LL was lower in the short than inthe long arthrodesis group (short 13.7 ± 0.73 vs.long 22.64 ± 0.87; p<0.0001). Postoperative PI-LL decreased both in short (pre 13.7 ± 0.73 vs. post 11.06 ± 0.87; p<0.0001) and long arthrodesis (pre 22.64 ± 0.87 vs. post 12.73 ± 0.87; p<0.0001) groups. There was no statistically significant difference in postoperative PI-LL between the groups (p=0.14) (Figure 4C).

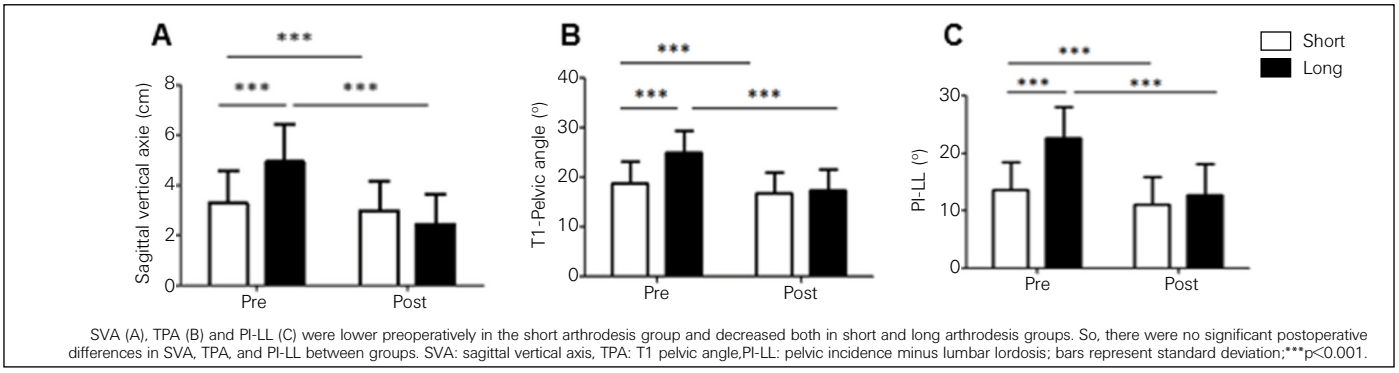
Variance for spinopelvic parameters

Table 2 displays a comparative study of meanvariance by spinopelvic parameter. The variations in the spinopelvic parameters of the short arthrodesis groupwere smaller than those of the long arthrodesis group and the difference was statistically significant.



Preoperatively, LL (A) was higher in patients who underwent short arthrodesis, while PI (B) and PT (C) were lower. Postoperatively, LL increased, PI did not change, and PT decreased both in patients who underwent short and long arthrodesis. Bars represent standard deviation. LL: lumbar lordosis, PI: pelvic incidence, PT: pelvic tilt.Bars represent standard deviation,** p<0.01, ***p<0.001.

Figure 3. Spinopelvic parameters in short and long arthrodesis.



SVA (A), TPA (B) and PI-LL (C) were lower preoperatively in the short arthrodesis group and decreased both in short and long arthrodesis groups. So, there were no significant postoperative differences in SVA, TPA, and PI-LL between groups. SVA: sagittal vertical axis, TPA: T1 pelvic angle,PI-LL: pelvic incidence minus lumbar lordosis; bars represent standard deviation;***p<0.001.

Figure 4. Spinopelvic parameters in short and long arthrodesis.

Table 2. Variance in spinopelvic parameters between short and long arthrodesis groups.

	Short Arthrodesis	Long Arthrodesis	p
Δ LL	2.5 ± 0.47°	9.8 ± 0.41°	<0.0001
Δ PT	-1.38 ± 0.35°	-8.38 ± 0.36°	<0.0001
Δ SS	1.49 ± 0.36°	8.36 ± 0.36°	<0.0001
Δ PI-LL	-2.64 ± 0.49°	-9.90 ± 0,40°	<0.0001
Δ SVA	-3.2 ± 0.8 mm	-24.2 ± 1,6 mm	<0.0001
Δ TPA	-1.87 ± 0.36°	-7.61 ± 0,4°	<0.0001

LL: lumbar lordosis; PT: pelvic tilt, SS: sacral slope, PI-LL: pelvic incidence minus lumbar lordosis, SVA: sagittal vertical axis,TPA: T1-pelvic angle. Values presented as mean ± standard deviation. Δ: variation, p: p value.

DISCUSSION

Since sagittal spinopelvic balance is related to the quality of life of patients with degenerative spinal disease, previous studies tried to correlate radiographic parameters and postoperative scores to assist with surgical planning and evaluate degenerative spinal disease outcomes.[17] A recently published narrative review focused on the most useful spinopelvic parameters for clinical practice,[18] which were the same parameters used in this study. Furthermore, a study suggested the normal range values for spinopelvic parameters in asymptomatic Brazilians and reported higher values for SVA and TPA, in addition to a physiological tilt of the spine with aging.[19]

In this study, LL increased significantly after surgery in both fusion groups (short and long), considering radiographs taken 6 months after the procedure. In addition, there was a significant change in the LL of the study patients, with an inversion in the relationship between groups but without statistical significance. Our results demonstrated that in both short and long fusion groups there was a significant increase in this parameter, indicating restoration of LL. These results conflict with previous studies that used posterior fusion techniques and reported thatonly multiple-level fusions presented improvements in lordosis.[20, 21] Previous studies reported that neither transforaminal single-level TLIF nor posterior PLIF increased lumbar lordosis significantly.[22, 23]

After LL restoration, other spinopelvic parameters presented corresponding variations in both groups. PT, PI-LL, SVA, and TPAdecreased significantly, suggesting that these parameters responded to LL modification. In a study with similar methodology, reduction in PT, PI-LL, and SVA was verified only in one-level arthrodesis.[21]

In the long arthrodesis group, the PT and SVA angles decreased, along with the increase in LL towards the reference values.[1,9,10] In the short arthrodesis group, PT and SVA were already below reference levels in the preoperative evaluation, explaining the lower impact on sagittal balance in this group due to the lesser magnitude of the deformity in a single-level fusion.

Regarding the discrepancy in PI-LL, there was a significant decrease of values in both groups, though more evident in the long arthrodesis group. The final correction of this parameter got close to the reference levels reported in the literature.[1,18] Postoperative TPA did not achieve the previously established reference values of between 10° and 14°,as measured by the Cobb angle,[24] in either group, even though they presented a statistically significant decrease.

The comparison between the mean variation of each parameter by group evidenced significant differences amongthe group means. The reduction of all parameters was more relevant in the long than in the short arthrodesis group, presenting significant differences between groups, in accordance with previous studies.[21]

PT and LL were correlated with relief from painful symptoms and greater patient satisfaction, considering the evaluation through scores.[1,25] Hence, patients whose postoperative PT value was greater than 20°, as measured by the Cobb angle, presented worse residual pain results[26] and patients withan SVA greater than 40 mm presented worse postoperative satisfaction outcomes.[27] PT, PI-LL, and SVA predict patient disability in the population with degenerative spinal disease[28] and are considered positive predictive sagittal modifiers both for surgical results and the clinical response prognosis.[4,10]

To obtain optimal postoperative radiographic parameters, the relationships associated with compensatory mechanisms must be established. Spinopelvic sagittal alignment is based on compensatory modification following LL reconstruction in accordance with the correlation between LL and the other parameters.[6] Although important parameters such as SVA and PT are not controllable during surgery, LL is the main parameter that can be precisely manipulated.

Regarding the limitations of this study, we can cite the study population, which, due to the characteristics of the institution, included people from different ethnic groups, socioeconomic levels, and stages of disease evolution. These factors may have some influence on the natural history of adult degenerative spinal disease and its compensatory mechanisms. As a result, these variations may affect the sensitivity and the precision of the evaluation. It has already been suggested that ethnic group may affect natural spinopelvic alignment.[29] However, it is important to remember that the Brazilian population has its own characteristics. Another study demonstrated a physiological tilt of the trunk with aging, which may influence the spinopelvic parameters.[21] To minimize the negative effect of this limitation, we investigated the proportion of each disease in the subpopulation by fusion level. We discovered that most patients in the short arthrodesis group were younger, compromised at one level, andwith more spinal flexibility. On the other hand, patients in long arthrodesis group were mostly older, with multiple levels affected. This can be explained by the natural history of the disease, whereby younger patients present fewer affected levels and so require arthrodesis of fewer levels.

In addition, comparative studies between pre- and postoperative parameters in each subpopulation by fusion level evidenced statistically significant differences, which suggest that two or more instrumentation and fusion levels were more efficient in lumbar lordosis reconstruction, even for a relatively rigid spine, due to a more prolongedprocess of degeneration and compensatory mechanism development.[21]

As regards TPA, while a reductionto the reference level was

not achieved in the long arthrodesis group, a significant mean correction(-7.61^{o} ± 0.4)was observed, with significant correlation to LL restoration. Larger studies can be conducted to evaluate the efficacy of PLIF surgeryfor the correction of this parameter.

CONCLUSION

In the treatment of adult degenerative spinal diseases, performing short and long arthrodesis of up to four levels using the PLIF technique restores LL, PT, PI-LL, SVA, and TPA. The group that underwent short arthrodesis presented less variation between pre- and postoperative measurements, suggesting that there was less need for the correction.

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