Change of Clinical and Radiologic Parameters after Minimally Invasive Decompression in Patients with Lumbar Spinal Stenosis. A Prospective Study with Long-term Follow-up

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Abstract

Background The impact of minimally invasive decompression (MID) techniques on spinopelvic parameters and on the sagittal alignment remains a controversial topic. Here we studied the changes in clinical and radiologic parameters and their relationships in a series of lumbar spinal stenosis (LSS) submitted to MID with a minimum follow-up (FU) of 24 months.

Methods We prospectively collected clinical and radiologic data of 20 consecutive patients who were evaluated preoperatively, at the 6-month FU, and at the 24-month FU. Visual analog scale (VAS) for back and leg pain, Oswestry disability index (ODI), neck disability index (NDI), sagittal vertical axis (SVA), C7 slope (C7S), lumbar lordosis (LL), pelvic incidence (PI), pelvic tilt (PT), and sacral slope (SS) were assessed for each patient. Moreover, the percentage variation of clinical and radiologic factors at the 24-month FU compared with the preoperative factors was calculated to perform correlation studies among these variables.

Results We reported a significant improvement of all clinical parameters. A significant increase of LL and SS and a significant decrease of PT and SVA were observed. The preoperative values of ODI, LL, SS, PT, and SVA significantly affect the 24-month FU values, and the percentage improvement of SVA at the 24-month FU compared with the preoperative values was significantly related to the percentage improvement of LL.

Conclusions MID is clinically effective in patients with LSS and improves the spinopelvic parameters and the global sagittal balance of the spine. The preoperative spinal alignment affects the spinal alignment at FU. The improvement of SVA was strictly related to the improvement of LL.

Keywords
► sagittal balance
► minimally invasive decompression
► lumbar spinal stenosis
► spine surgery

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Introduction

Lumbar spinal stenosis (LSS) is one of the most common degenerative diseases of the elderly population and is associated with low back pain (LBP) and neurogenic claudication. LSS is the consequence of a degenerative cascade due to the loss of disk height and hypertrophy of ligamentum flavum and facet joints.[1,2] These events lead to several compensatory modifications, namely, a decrease of lumbar lordosis (LL) and an increase in pelvic tilt (PT) overall causing an anterior sagittal imbalance[3,4] that can ultimately negatively affect the symptoms. When symptoms are present, surgical decompression has been demonstrated to improve quality-of-life outcomes in patients with LSS.[5] Minimally invasive decompression (MID) techniques have gained attention in the last few years due to their reported surgical advantages, such as shorter operation and lower surgical complications leading to a decrease of hospitalization-related costs.[6] MID techniques aim to remove the hypertrophic ligamentum flavum and a little portion of lamina, thereby alleviating pressure on neural structures, thus improving the clinical outcome. The restoration of a normal sagittal balance in corrective surgery for spinal deformity is a key factor in determining the clinical success[7]; however, the impact of MID on spinopelvic parameters and the sagittal balance has not been well established and remains controversial. In fact, among few published studies on this topic,[8–14] to the best of our knowledge, only three were prospectively collected series with a maximum follow-up (FU) of 1 year.[15–17] Here we studied the changes in clinical and radiologic parameters and their correlations in a prospectively collected series of patients submitted to MID for an LSS with a minimum FU of 2 years.

Methods

We prospectively collected the clinical and radiologic data of 24 consecutive patients (16 females and 8 males) submitted to MID[18] for the treatment of LSS, from January to March 2019. One of the patients declined after reading the informed consent, two patients were excluded because they were affected by rheumatic disorder (polymyalgia rheumatic), and one was affected by lumbar spondylolisthesis. Therefore, the number of patients enrolled was 20 (14 females and 6 males; see ►**Table 1**). All the patients provided a written informed consent, which was approved by the local ethical committee. The mean age was 71.68 ± 8.59 years. All patients had no previous lumbar spine operation and complained of lumbar/legs pain and/or neurogenic claudication unresponsive to conservative treatments for at least 1 year. Patients with spondylolisthesis, scoliosis with a Cobb angle of more than 20 degrees, and neurologic, oncologic, and rheumatic disorders were excluded from this study. All patients were evaluated for clinical and radiologic parameters preoperatively, at 6 months of FU, and at 24 months of FU. Preoperatively each patient underwent lumbar spine magnetic resonance imaging (MRI), full-body X-ray (in anterior and lateral projections), and lumbosacral X-ray. Full-body X-ray and lumbosacral X-ray were also performed at 6 and 24 months of FU. Visual analog scale (VAS) for both LBP and legs pain, Oswestry Disability Index (ODI), and Neck Disability Index (NDI) were evaluated as clinical parameters. Sagittal vertical axis (SVA), C7 slope (C7S), LL, pelvic incidence (PI), PT, and sacral slope (SS) were assessed for each patient.[16,19] The percentage variation of clinical and radiologic factors at the 24-month FU were calculated to perform correlation studies among these variables.

Table 1 Demographic data of 20 patients submitted to minimally invasive decompression for lumbar spinal stenosis, from January to March 2019

Patients	20
Sex (F/M)	14/6
Mean age (y)	71.68 ± 8.59
Number of operated levels	
1	1
2	14
3	5

Surgical Technique

The surgical procedure has been previously reported.[18] Briefly, under general anesthesia and in the prone position, the correct level of surgery is confirmed using intraoperative imaging. A midline skin incision is made and the fascia is incised bilaterally preserving the supraspinous and interspinous ligaments and the spinous processes. After exposing the laminae and the facet joints, under microscopic view, a larger interlaminar space is made by removing a little rim of bone from the caudal aspect of the cranial lamina and the cranial aspect of the caudal lamina. The ligamentum flavum is then removed bilaterally and the spinal recess is opened bilaterally by undercutting minimal portions of the medial facet joints. At the end of the procedure, the dural sac and the nerve root are bilaterally decompressed.

Statistical Analysis

Statistical comparison of continuous variables and ordinal variables was performed by the Student's *t*-test and by Wilcoxon signed-rank test, as appropriate. Correlation studies were performed using Spearman's rank correlation test. Differences were considered significant at $p < 0.05$. Statistical analyses were conducted using StatView, version 5, software (SAS Institute Inc., Cary, North Carolina, United States).

Results

Clinical Parameters

The preoperative, 6-month FU, and 24-month FU clinical scores are reported in ►**Table 2**.

Briefly there was a statistically significant improvement of 6-month FU and 24-month FU LBP compared with preoperative LBP ($p < 0.0001$ and < 0.0001, respectively). The 6- and 24-month FU leg pain was also significantly improved

Table 2 Preoperative and FU clinical parameters of 20 patients included in this study

	Preoperative	6-mo FU	24-mo FU
VAS LBP	8.52 ± 1.02	3.52 ± 2.29	2.05 ± 2.19
VAS legs	8.42 ± 0.83	3.57 ± 2.16	1.63 ± 1.95
ODI (%)	63.81 ± 13.39	28.72 ± 16.61	18.64 ± 15.17
NDI (%)	37.72 ± 13.61	17.78 ± 15.32	14.16 ± 14.32

Abbreviations: FU, follow-up; LBP, low back pain; NDI, Neck Disability Index; ODI, Oswestry Disability Index; VAS, visual analog scale.

compared with the preoperative leg pain ($p < 0.0002$ and <0.0001, respectively). Considering the degree of disability, we observed a statistically significant improvement of ODI score at the 6- and 24-month FU compared with the preoperative score ($p < 0.0001$ and <0.0001, respectively) and of NDI score at the 6- and 24-month FU compared with the preoperative score ($p = 0.0001$ and 0.0050, respectively).

Radiologic Parameters

The preoperative, 6-month FU, and 24-month FU radiologic parameters are reported in ►**Table 3**.

We found a statistically significant LL increase at the 6- and 24-month FU compared with the preoperative LL ($p = 0.0084$ and 0.0004, respectively) and SS ($p = 0.0084$ and 0.0011, respectively), while a significant PT decrease at the 6 and 24-month FU compared with the preoperative PT ($p = 0.0027$ and 0.0003) and SVA ($p = 0.0079$ and 0.0123) was observed. Two illustrative cases are reported in ►**Figs. 1** and **2**.

Table 3 Preoperative and FU radiologic parameters of 20 patients included in this study

	Preoperative	6-mo FU	24-mo FU
SVA	52.60 ± 55.72	39.37 ± 38.24	34.11 ± 35.55
C7 slope	28.71 ± 12.52	27.52 ± 12.33	29.41 ± 10.11
LL	48.61 ± 12.55	54.72 ± 11.41	58.64 ± 11.27
PI	61.01 ± 9.41	62.10 ± 10.11	61.55 ± 11.32
PT	25.61 ± 8.93	22.51 ± 7.23	20.51 ± 7.63
SS	35.57 ± 9.02	38.37 ± 8.91	40.62 ± 9.77

Abbreviations: FU, follow-up; LL, lumbar lordosis; PI, pelvic incidence; PT, pelvic tilt; SS, sacral slope; SVA, sagittal vertical axis.

Correlation Studies

We found a correlation between the preoperative and 24-month FU ODI ($p = 0.0188$; ►**Fig. 3A**), SVA ($p = 0.0042$; ►**Fig. 3B**), LL ($p = 0.0146$; ►**Fig. 3C**), PT ($p = 0.0002$, ►**Fig. 3D**), and SS ($p = 0.0013$; ►**Fig. 3E**). No correlation between the preoperative and 24-month FU VAS and NDI scores was found.

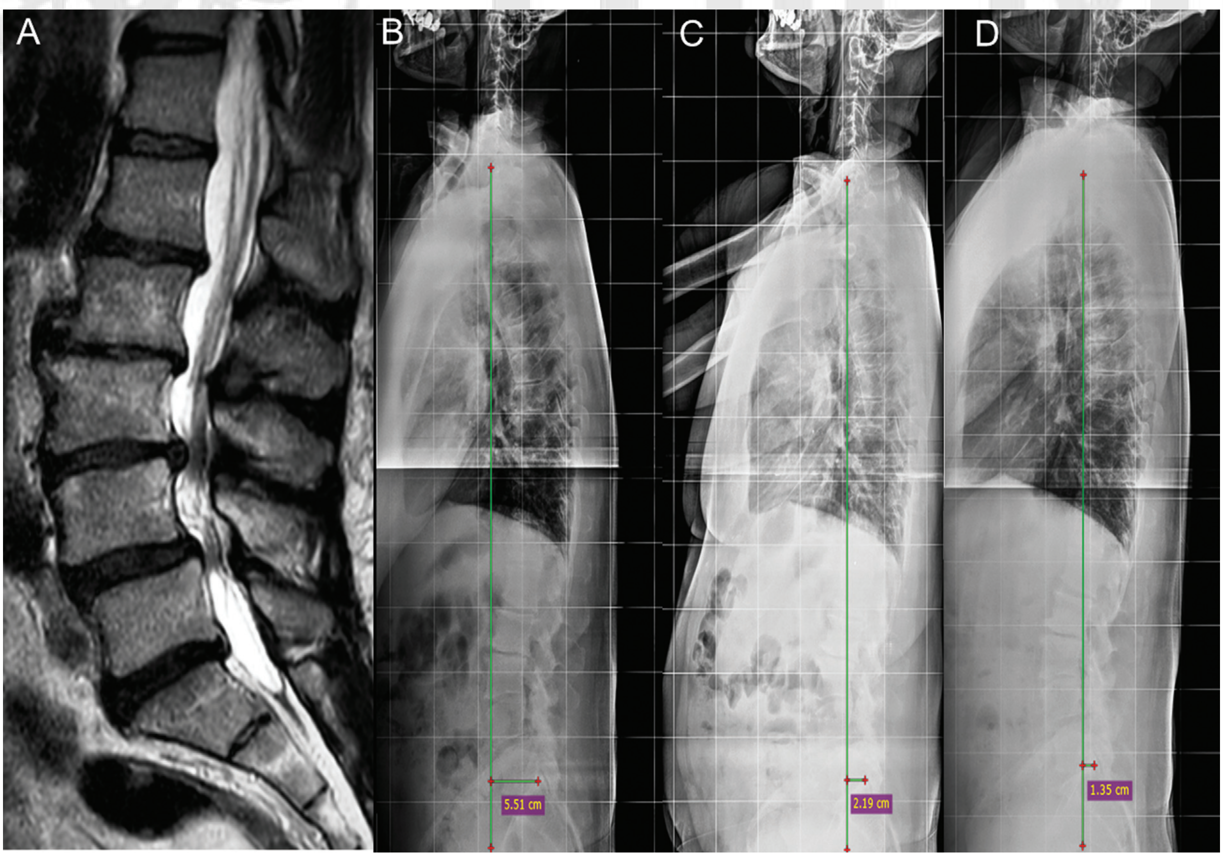

Fig. 1 (**A**) Preoperative T2-weighted lumbar sagittal magnetic resonance imaging (MRI) of a 59-year-old man with a lumbar spinal stenosis at the L3–L4 and L4–L5 levels. (**B**) Preoperative and (**C**) 6-month and (**D**) 24-month follow-up full-body X-ray showing a progressive decrease of sagittal vertical axis (SVA) from 5.51 to 1.35 cm after minimally invasive decompression (MID).

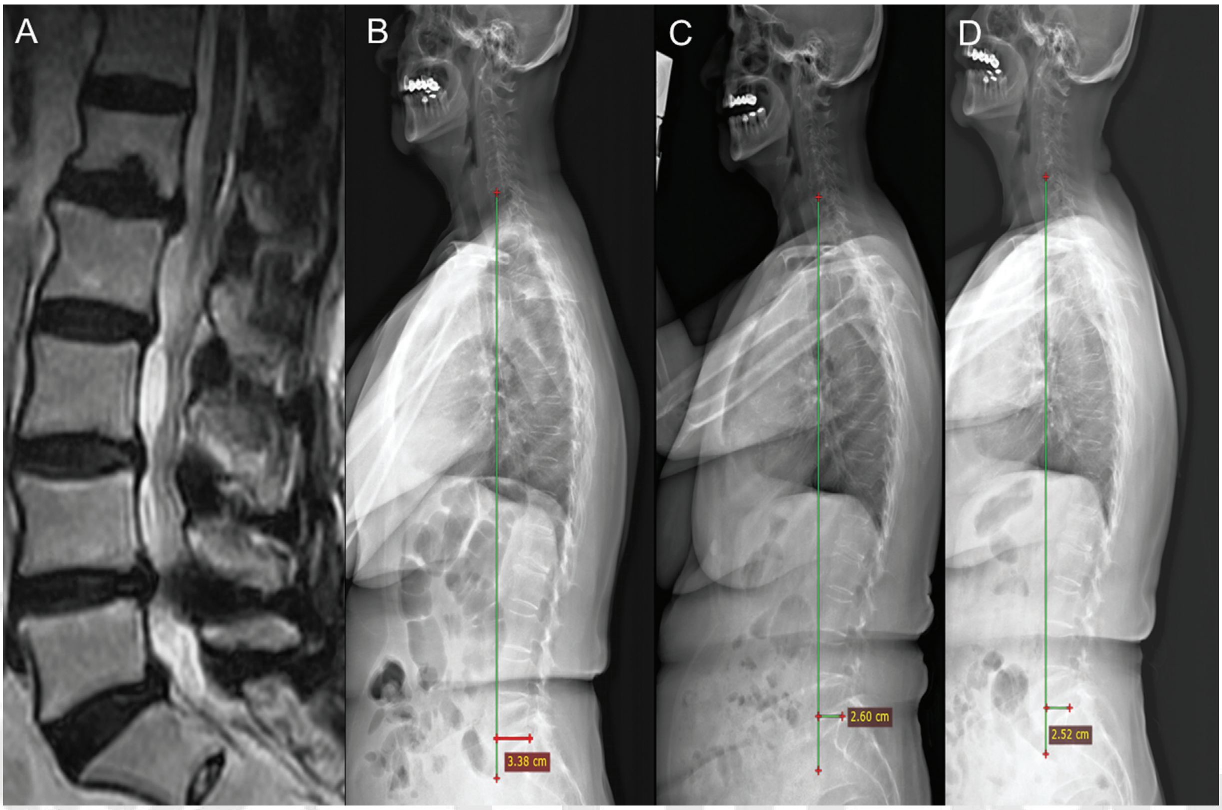

Fig. 2 (**A**) Preoperative T2-weighted lumbar sagittal magnetic resonance imaging (MRI) of a 78-year-old woman with a lumbar spinal stenosis at the L4–L5 level. (**B**) Preoperative and (**C**) 6-month and (**D**) 24-month follow-up full body X-ray showing a progressive decrease of sagittal vertical axis (SVA) from 3.38 to 2.52 cm after minimally invasive decompression (MID).

The mean percentage variation of clinical and radiologic parameters is reported in ►**Table 4**. We found a statistically significant correlation between ΔLL and ΔSVA ($p = 0.0069$; ►**Fig. 3F**); no correlation between radiologic parameters and clinical outcome was found.

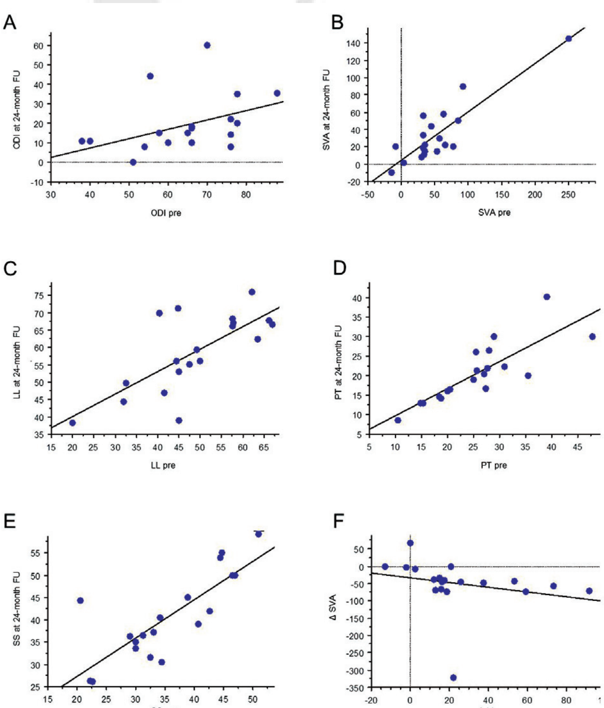

Fig. 3 (**A–F**) Scatter plots showing the correlations of studied factors (see text). (FU, follow-up; LL, lumbar lordosis; ODI, Oswestry Disability Index; PT, pelvic tilt; SVA, sagittal vertical axis.)

Table 4 Mean percentage variation at 24-month follow-up of clinical parameters of 20 patients included in this study

Δ VAS LBP	77.28%
Δ VAS legs	80.52%
Δ ODI	74.24%
Δ NDI	63.74%
Δ SVA	51.41%
Δ LL	25.24%
Δ PT	19.24%
Δ SS	16.93%

Abbreviations: LBP, low back pain; LL, lumbar lordosis; NDI, Neck Disability Index; ODI, Oswestry Disability Index; PT, pelvic tilt; SS, sacral slope; SVA, sagittal vertical axis; VAS, visual analog scale.

Discussion

Degenerative lumbar stenosis is the most frequent disease in elderly patients undergoing spinal surgery. Surgical treatment usually obtains relief in neurogenic symptoms as neurogenic claudication and radicular pain in lower limbs, thus resulting in improvement of functional status. In this

Table 5 Prospective studies on relationship between minimally invasive decompression, spinopelvic parameters, and sagittal balance

Study	No. of patients	Follow-up max (mo)	Surgery technique	Aim of study	Results
Chang[15]	48	6	Unilateral laminotomy for bilateral decompression	To study the relationship between spinopelvic parameters and clinical outcome	Correlation between clinical outcome and postoperative spinopelvic parameters
Madkouri et al[16]	72	12	Bilateral laminotomy	To evaluate the spinopelvic and sagittal vertical axis (SVA) modification after posterior decompression surgery	Improvement of SVA and lumbar lordosis (LL) after surgery
Costa et al[17]	104	12	Uni- or bilateral interlaminar approach, flavectomy and laminotomy or partial medial facetectomy	To determine the relationship between preoperative sagittal alignment and clinical outcomes after surgery	No correlation between preoperative sagittal alignment and clinical outcome

work, we studied the changes of clinical and radiologic parameters after MID in a prospectively collected series of patients treated for LSS. Moreover, we tried to clarify the mutual relationship between these parameters. To our knowledge, only three prospective studies have been previously published, although with different aims and study design (►**Table 5**).[15–17] The main results of our study can be summarized as follows: (1) all studied clinical parameters significantly improved after MID; (2) among radiologic parameters, LL, SS, PT, and SVA significantly improved after MID; (3) the preoperative values of ODI, LL, SS, PT, and SVA significantly affect the 24-month FU values; (4) the percentage improvement of SVA at the 24-month FU compared with the preoperative SVA is significantly related to the percentage improvement of LL; and (5) no correlation between the percentage variation of clinical and radiologic parameters was found. The advantages powered by the restoration of sagittal alignment in patients affected by spinal deformity are widely reported in the literature and the instrumentation has become the treatment of choice in these patients.[20] Conversely, there are poor evidences concerning the relationship between MID without instrumentation in treatment of LSS and sagittal alignment. Indeed, only few articles reported spontaneous correction of sagittal alignment after decompressive surgery without fusion.[12,14] MID has been proved as a viable option in treatment of LSS, even when it was associated with degenerative spondylolisthesis.[18] Given the morbidity and the cost of spinal fusion surgery and the growing attention about minimally invasive techniques, improving knowledge on the relationship between the sagittal alignment and MID in the treatment of LSS is an unmet need in spine surgery. In the last decade, several authors investigated the sagittal alignment and compensatory mechanisms in patients with lumbar degenerative disease (LDD).[1,21] Barrey et al reported how the shape and inclination of the pelvis appear to influence the type of degenerative disease in the lumbar spine (disk disease, spondylolisthesis).[1] As outlined by Suzuki et al, patients affected by LSS show pelvic back tilt and forward bending of the trunk as an adaptive posture, to compensate the increased epidural pressure and achieve pain relief.[22] However, a long course of forward bending causes an anterior sagittal imbalance with an increased SVA value.[16] Madkouri et al reported significant improvement of SVA after recalibration surgery in patients affected by LSS at the 12-month FU.[16] Also, Chang reported a significant variation of SVA in the patient undergoing minimally invasive surgery with a maximum FU period of 6 months.[15] Accordingly, we found a significant decrease of SVA at the 6- and 24-month FUs. To the best of our knowledge, this is the first prospective study reporting a progressive improvement of SVA at up to 24 months of FU. A possible explanation of our results may be the low preoperative imbalance of our cohort (SVA ranged between 50 and 80 mm). This condition may have facilitated the progressive reduction of SVA during the time. According to Hikata et al,[13] a preoperative SVA > 80 mm could be predictive of residual sagittal imbalance after surgery. In our case series, we had three patients with SVA > 80 mm, showing an improvement of alignment in the postoperative course, albeit with a residual imbalance at the end of FU. An imbalance condition leads to compensatory variations of other spinopelvic parameters in an attempt to maintain alignment.[22,23] As outlined, LDDs are usually characterized by reduction of LL and pelvic retroversion with an increased PT.[23,24] In our study, we found that MID surgery leads to correction of these parameters to a physiologic condition. In fact, LL and SS showed a statistically significant increase, while PT had a significant decrease at 6 and 24 months of FU compared with the preoperative ones. The change of spinopelvic parameters was associated with the reduction of SVA with the effect of recovering a satisfactory balance. Fujii et al reported that the MID in LSS leads to the breakup of forward-bending posture to reach a global balance.[12] Supporting the hypothesis of a strong relation between LL and SVA, we found a statistically significant correlation between the percentage variation of LL and SVA (►Fig. 3F). Concerning the other correlation analysis (►Fig. 3), we found a correlation between the preoperative and the 24-month FU SVA, LL, PT, and SS. This analysis confirms that the entity of preoperative imbalance and of pelvic parameters affects the radiologic outcomes after surgery in terms of satisfactory global alignment. We found a statistically significant improvement at the 6- and 24-month FU of all clinical lumbar scores (VAS LBP, VAS leg, and ODI). Moreover, we observed in our patients a significant decrease of NDI score. In our opinion, these data are interesting and a possible explanation might be that the improvement of SVA might positively affect the cervical disability. Nonetheless, further studies are needed to prove this association as we did not find a significant variation of C7S, which has been related to the cervical balance.[25] The correlation between radiologic parameters and clinical outcomes remains a controversial topic.[12,13] Regarding this debated issue, Chang[15] reported a correlation between spinopelvic parameters and clinical outcomes. In our series, we did not find a clear correlation between modifications in spinopelvic parameters and improvement of pain scores. These findings are supported by others studies.[13,17] Costa et al,[17] in a retrospective analysis of 104 patients, showed no correlation between the improvement of spinopelvic parameters and the clinical outcomes after a decompression surgery for LSS. Hikata et al[13] found no correlation between the SVA value and the Japanese Orthopaedic Association score (JOA score) in their series. We think that the improvement of lumbar pain scores after MID in LSS is mainly related to the decompression of neural structures after the operation regardless of the correction of the spinopelvic parameters and the SVA. The improvement of these last parameters, which is usually a slow process, might in part positively affect the overall disability of patients (ODI and NDI improvement), but it is difficult to demonstrate that from a statistical point of view. Furthermore, we may speculate that an improvement of global spine alignment could restore a better spine functioning due to a lower overload of paravertebral muscles. However, further studies are required to investigate these issues.

Limitations

The main limitations of this study were the small sample size and the lack of a control group. Furthermore, the relative low preoperative imbalance could affect the FU results and explain the improvement of SVA in our patients.

Conclusion

MID is clinically effective in patients with LSS and improves the spinopelvic parameters and the global sagittal balance of the spine. The entity of spinopelvic parameters and sagittal balance improvement are related to the preoperative values. The percentage improvement of sagittal alignment was strictly related to the percentage improvement of LL.

Conflict of Interest
None declared.

Ethics Approval
Ethical approval was waived by the local Ethics Committee of Catholic University because all the procedures being performed were part of the routine care.

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