

# Semi-Circumferential Decompression: Total En-Bloc Ligamentum Flavectomy to Treat Lumbar Spinal Stenosis with Two-Level Degenerative Spondylolisthesis

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## Abstract:

**Introduction:** Despite technical developments in decompression without fusion, many studies still assert that instability could be increased in patients with spinal stenosis and lumbar degenerative spondylolisthesis after spinal decompression surgery without fusion. Thus, this study aimed to describe and assess the clinical outcomes of the semi-circumferential decompression (SCD) technique used for microsurgical en-bloc total ligamentum flavectomy with preservation of the facet joint in treating patients who have lumbar spinal stenosis with two-level degenerative spondylolisthesis.

**Methods:** We retrospectively analyzed the clinical and radiologic outcomes of 14 patients who had spinal stenosis with two-level Meyerding grade I degenerative spondylolisthesis. We evaluated improvements in back pain and radiating pain using a visual analogue scale (VAS) and the Oswestry Disability Index (ODI). We have also examined the occurrence of spinal instability on a radiological exam using slip percentage and slip angle.

**Results:** The mean VAS score of back pain and radiating pain has been determined to decrease significantly from 6.7 to 3.3 and from 8.6 to 2.7, respectively. Meanwhile, the ODI score significantly improved from 27.3 preoperatively to 9.8 postoperatively. Statistically significant change was not observed in the slip percentage in both upper and lower levels. Dynamic slip percentage, which is defined as the difference in the slip percentage between flexion and extension, also did not significantly change. No statistically significant change was found in the slip angle and dynamic slip angle.

**Conclusions:** SCD is a recommendable procedure that can improve clinical results. This procedure does not cause spinal instability when treating patients who have spinal stenosis with two-level degenerative spondylolisthesis.

## Keywords:

Two-level degenerative spondylolisthesis, semi-circumferential decompression, total ligamentum flavectomy, slip percentage, slip angle

Spine Surg Relat Res 2021; 5(2): 91-97  
[dx.doi.org/10.22603/ssrr.2020-0146](https://doi.org/10.22603/ssrr.2020-0146)

## Introduction

“Decompression and fusion” has been preferred in the treatment of lumbar spinal stenosis with degenerative spondylolisthesis<sup>1)</sup>: if decompression alone is performed, the instability of lumbar degenerative spondylolisthesis increases<sup>2,3)</sup>. Despite the recent developments in the technique for decompression without fusion, many studies still claim that instability in patients with spinal stenosis accompanied by lumbar degenerative spondylolisthesis could not be improved by spinal decompression surgery without fusion<sup>4-6)</sup>. In clinical practice, there are several cases where only decom-

pression surgery without fusion is performed<sup>7,8)</sup>.

In previous years, we performed surgery on patients with lumbar spinal stenosis with one-level degenerative spondylolisthesis following the semi-circumferential decompression (SCD)<sup>9)</sup>. The results suggest that SCD is a clinically recommendable procedure that can improve pain and does not cause spinal instability<sup>9)</sup>. In this study, we assessed the clinical effectiveness of SCD for posterior decompression in treating patients who have lumbar spinal stenosis with two-level degenerative spondylolisthesis.

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Received: July 30, 2020, Accepted: September 8, 2020, Advance Publication: October 9, 2020

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## Materials and Methods

### Population

We retrospectively analyzed the outcomes of 20 patients who underwent SCD for lumbar spinal stenosis with two-level degenerative spondylolisthesis, from 2008 to 2019. Six patients who had bilateral foraminal stenosis were excluded from the study. Finally, 14 patients were selected (mean age, 72.5 years; 3 men, 11 women). The mean follow-up period was 28.3 months (range, 15 to 41 months). Mean lumbar lordosis angle was 30.3°, and no patients showed stooping posture (Table 1). In all the patients, the main symptoms were radiating pain and neurologic intermittent claudication (NIC) due to spinal stenosis, whereas back pain was a secondary symptom to varying degrees. No motor weakness was observed.

Most patients had the operation level of L3-4-5 (87.5%). Discs were mostly degenerated without prominent collapse (75.0%), which corresponds to grade IV degeneration according to the classification of Pfirrmann<sup>10</sup>. Most endplates (67.9%) of vertebrae did not have any Modic change. In all the patients, magnetic resonance imaging showed central and lateral recess stenosis at the degenerative spondylolisthesis site (Table 1).

All the patients have been determined to have grade I spondylolisthesis according to Meyerding's classification. According to the definition of White and Panjabi<sup>11</sup>, lumbar segmental instability is defined as sagittal plane translation >4.5 mm or 15% or sagittal plane rotation >15° at L1-2, L 2-3, and L3-4, >20° at L4-5, and >25° at L5-S1 in flexion-extension radiographs. In this study, no instability was detected in all the patients.

### Surgical technique

SCD is a method known as total "en-bloc" ligamentum flavectomy (Fig. 1)<sup>12,13</sup>. In this technique, a medial skin incision is created, and the supraspinous ligament is detached from the spinous process, moving toward the side with no damage. Minimal resection of the inferior border of the spinous process is then performed to secure the operation-visual field. By using curette, the ligamentum flavum is detached from the inferior 1/3 of the lamina, and by using a high-speed burr, we thinned the lamina and performed partial laminectomy using Kerrison rongeur. Finally, total "en-bloc" removal of the ligamentum flavum is performed by detaching the inner part of the lamina and facet joint (Fig. 2). The facet joint is then preserved by leaving the superior articular process un-excised. All decompression procedure is performed using a microscope. During closure, the detached supraspinous ligament is aligned to its original position and sutured with the fascia. On postoperative day 2, patients were allowed to begin ambulation and were encouraged to use a corset brace for 6 weeks.

**Table 1.** Basic Characteristics of the Study Population.

		Mean±SD (range) or n (%)
Total patients		14
Age (years)		72.5±6.2 (60–81)
Sex		Men: 3 (21.4) Women: 11 (78.6)
Follow-up period (months)		28.3±10.8 (15–41)
Operation level		L3-4-5: 12 (85.7) L4-5-S1: 2 (14.3)
Lumbar lordosis angle (L1-S1)		30.3±16.1 (6–60)
Disc degeneration (grade)	Upper level	III: 1 (7.1) IV: 12 (85.8) V: 1 (7.1)
	Lower level	IV: 9 (64.3) V: 5 (35.7)
Modic change of endplate (type)	Upper level	II: 2 (14.2) III: 2 (14.2)
	Lower level	I: 1 (7.1) II: 2 (14.2) III: 2 (14.2)

SD, standard deviation

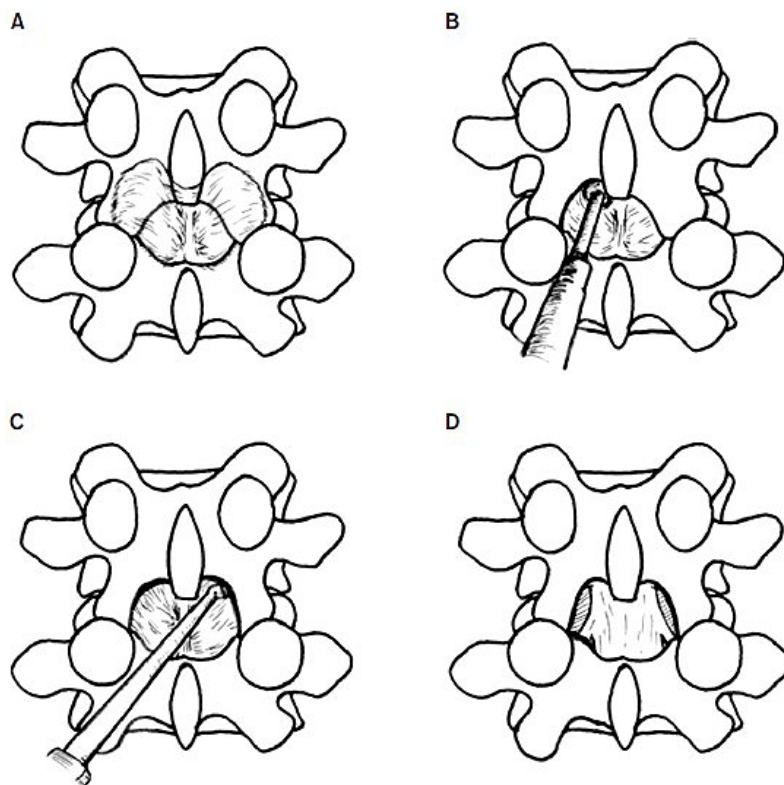
### Data analysis

Preoperative and postoperative pain relief was estimated using the visual analogue scale (VAS) score and the Oswestry Disability Index (ODI). We compared preoperative and last follow-up radiographs. All patients underwent dynamic (flexion/extension) lateral radiographs. These results were then used to estimate the slip percentage and slip angle and assess instability and progression of the lumbar degenerative spondylolisthesis. The slip percentage and slip angle were estimated using Taillard's and Boxall's methods, respectively (Fig. 3)<sup>14,15</sup>. We then estimated the dynamic slip percentage (preoperative and postoperative changes in the slip percentage) and dynamic slip angle (preoperative and postoperative changes in the slip angle) and further analyzed the occurrence of vertebral instability. We performed the Wilcoxon signed-rank test and used IBM® SPSS® ver. 21.0 (IBM Co., Armonk, NY, USA) in detecting any postoperative changes. A *p*-value of less than 0.05 was considered statistically significant.

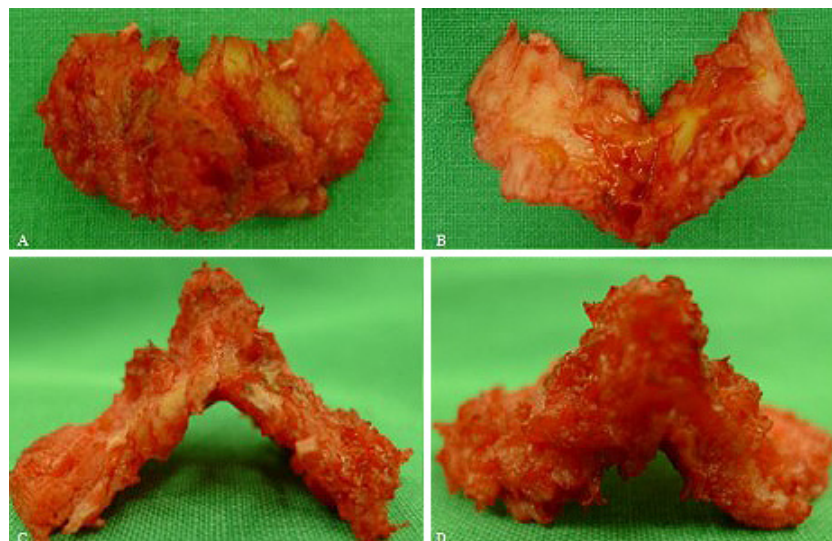
## Results

### Clinical manifestation

Mean back pain VAS score has been observed to reduce from 6.7 to 3.3 (*p*<0.01). Mean radicular pain VAS score also reduced significantly from 8.6 to 2.7 (*p*<0.01). Mean ODI score (maximum of 45 points) decreased significantly from 27.3 to 9.8 (*p*<0.01) (Table 2).



**Figure 1.** (A) Ligamentum flavum (preoperative state). (B), (C) Ligamentum flavum is detached from the lamina using a curette. (D) After *en-bloc* ligamentum flavectomy, the dura mater is exposed.

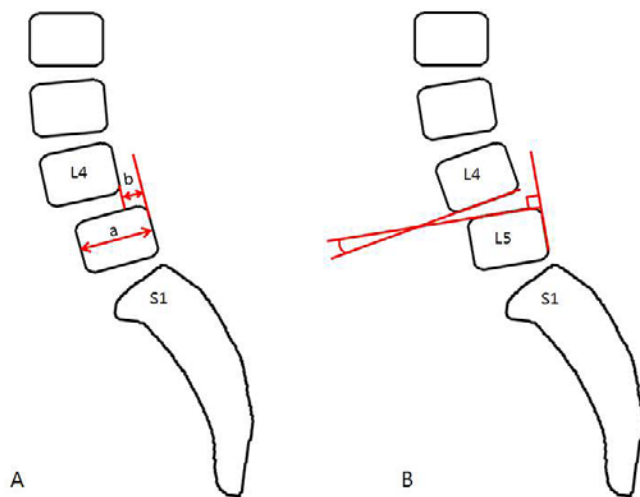


**Figure 2.** Ligamentum flavum, which is shaped like a butterfly, was removed en-bloc. (A) dorsal surface, (B) ventral surface, (C) distal margin, and (D) proximal margin.

**Radiological evaluation**

The change in the slip percentage in the upper and lower level increased slightly (from 11% to 11.3% and from 10.5% to 11.5%, respectively); however, this difference was not statistically significant. Similarly, the changes in the dynamic slip percentage in the upper and lower levels did not

show any statistically significant change postoperatively (5.2% vs. 5.5% in the upper level, 5.8% vs. 6.2% in the lower level). The change in the slip angle in patients who underwent SCD did not show a statistically significant difference (3.5° vs. 3.8° in the upper level, 3.6° vs. 3.9° in the lower level) at the last follow-up. The dynamic slip angle also did not suggest any statistically significant change (7.9°



**Figure 3.** (A) Slip percentage (b/a) and (B) slip angle.

**Table 2.** Clinical Outcomes of the Subjects (Mean±Standard Deviation).

	Preoperative	Last follow-up	p-value
VAS (Back)	6.7±0.7	3.3±0.5	<0.01
VAS (Leg)	8.6±0.5	2.7±0.6	<0.01
ODI	27.3±2.1	9.8±1.1	<0.01

ODI, Oswestry Disability Index; SCD, semi-circumferential decompression; VAS, visual analogue scale

vs. 8.0° in the upper level; 8.1° vs. 9.1° in the lower level) (Table 3, 4).

### Discussion

In this retrospective study, we identified clinical improvement without aggravation of vertebral instability after SCD surgery, in patients of lumbar spinal stenosis with two-level degenerative spondylolisthesis.

Weiner et al.<sup>4)</sup> suggested a surgical procedure where the spinous process is repositioned after spinous process osteotomies and decompression while preserving the interspinous and supraspinous ligament. A recent study tried bilateral decompression using a unilateral approach in minimizing vertebral instability<sup>5)</sup>. Among these various surgical techniques, the SCD has been also introduced to attain vertebral stability.

Anatomical research on ligamentum flavum by Okuda et al.<sup>16)</sup> showed that in patients with degenerative spondylosis, nerve root compression is most severe in the proximal portion of the ligamentum flavum because the strongest thickening of ligamentum flavum occurs in this area (Fig. 2).

The proximal part of the ligamentum flavum is then attached parallel to the inner surface of the pars interarticularis just below the upper vertebral pedicle, so when the ligamentum flavum is not completely removed, it can continuously compress the nerve root<sup>16)</sup>. However, when the ligamentum flavum is removed by en-bloc resection, we can

**Table 3.** Radiographic Changes in the Upper Level (Mean±Standard Deviation).

	Preoperative	Last follow-up	p-value
Slippage (%)			
Neutral	11.0±2.8	11.3±1.8	0.719
Flexion	14.0±4.3	14.7±3.9	0.421
Extension	8.8±3.1	9.2±3.6	0.530
Dynamic	5.2±2.3	5.5±1.7	0.677
Slip angle (°)			
Neutral	3.5±2.1	3.8±2.6	0.694
Flexion	-3.0±2.6	-3.1±2.0	0.911
Extension	4.9±2.9	4.9±2.3	1.000
Dynamic	7.9±3.6	8.0±2.5	0.939

**Table 4.** Radiographic Changes in the Lower Level (Mean±Standard Deviation).

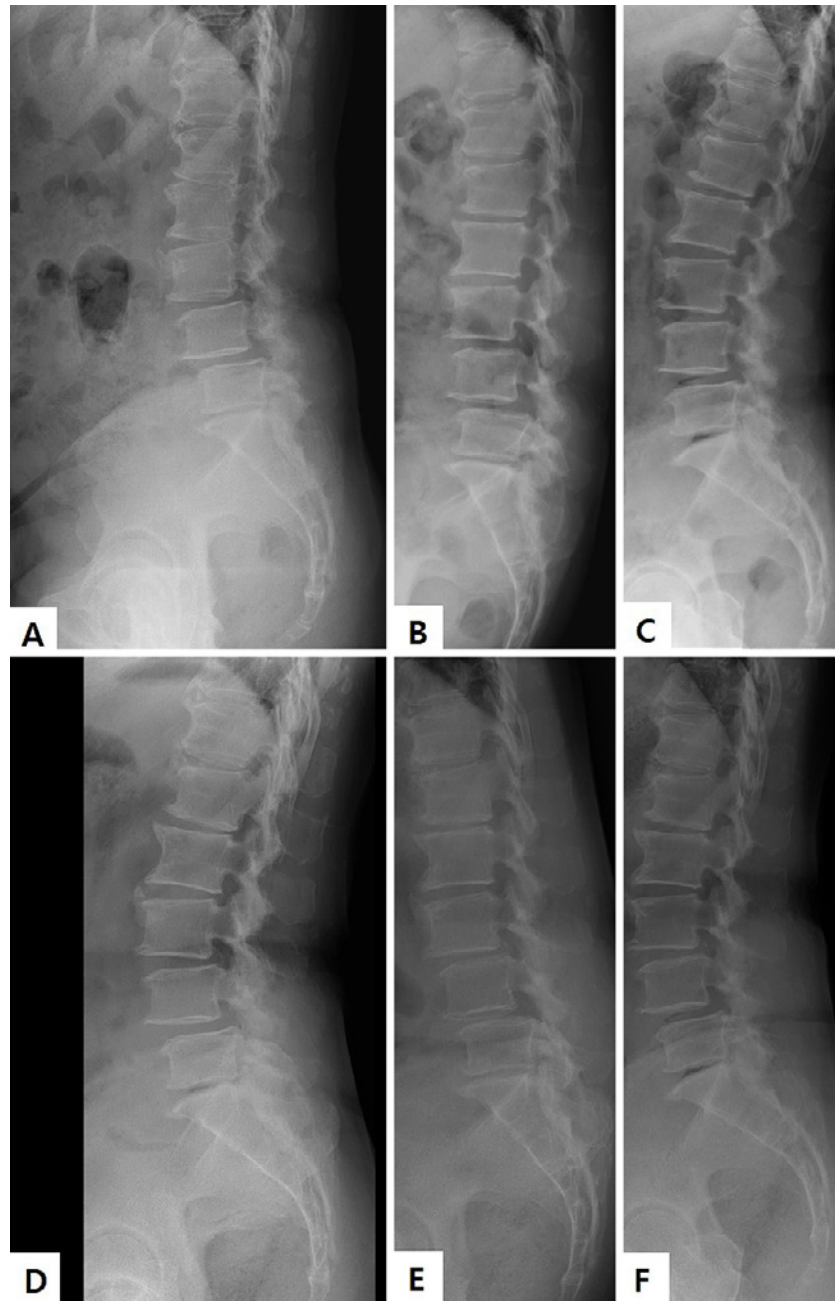
	Preoperative	Last follow-up	p-value
Slippage (%)			
Neutral	10.5±3.1	11.5±1.9	0.281
Flexion	13.6±1.5	14.6±2.1	0.178
Extension	7.8±3.0	8.4±1.4	0.475
Dynamic	5.8±3.1	6.2±1.6	0.729
Slip angle (°)			
Neutral	3.6±2.3	3.9±2.5	0.716
Flexion	-3.1±2.4	-3.7±2.4	0.579
Extension	5.0±2.1	5.4±1.3	0.642
Dynamic	8.1±2.0	9.1±2.2	0.291

assess the sufficiency of the decompression by observing the resected ligamentum flavum.

Abumi et al.<sup>17)</sup> proved biomechanically that spinal instability does not develop when the posterior facet is conserved and only the interspinous and supraspinous ligament are detached. According to these studies, SCD, which involves decompression by total excision of the ligamentum flavum and conserves the posterior facet with excision of only the interspinous and supraspinous ligament, can improve clinical manifestations and does not cause spinal instability<sup>9)</sup>. Therefore, SCD can be performed in spinal stenosis with degenerative spondylolisthesis<sup>9)</sup>.

Posterior decompression with fusion has been determined as a standard method for degenerative spondylolisthesis<sup>18-20)</sup>, but fusion surgery causes massive hemorrhage and long-term hospitalization and high cost<sup>21,22)</sup>. Furthermore, fusion surgery can cause pseudo-arthrosis, adjacent segmental degenerative changes, and other postoperative side effects. There have been several studies on only decompression surgery<sup>23-25)</sup>; however, they were mostly retrospective studies, and only a few studies conducted long-term follow-ups of patients. Although a prospective randomized study is needed, our study showed that decompression surgery by SCD can be deemed effective for spinal stenosis with two-level degenerative spondylolisthesis (Fig. 4, 5).

We then performed SCD technique using a microscope.



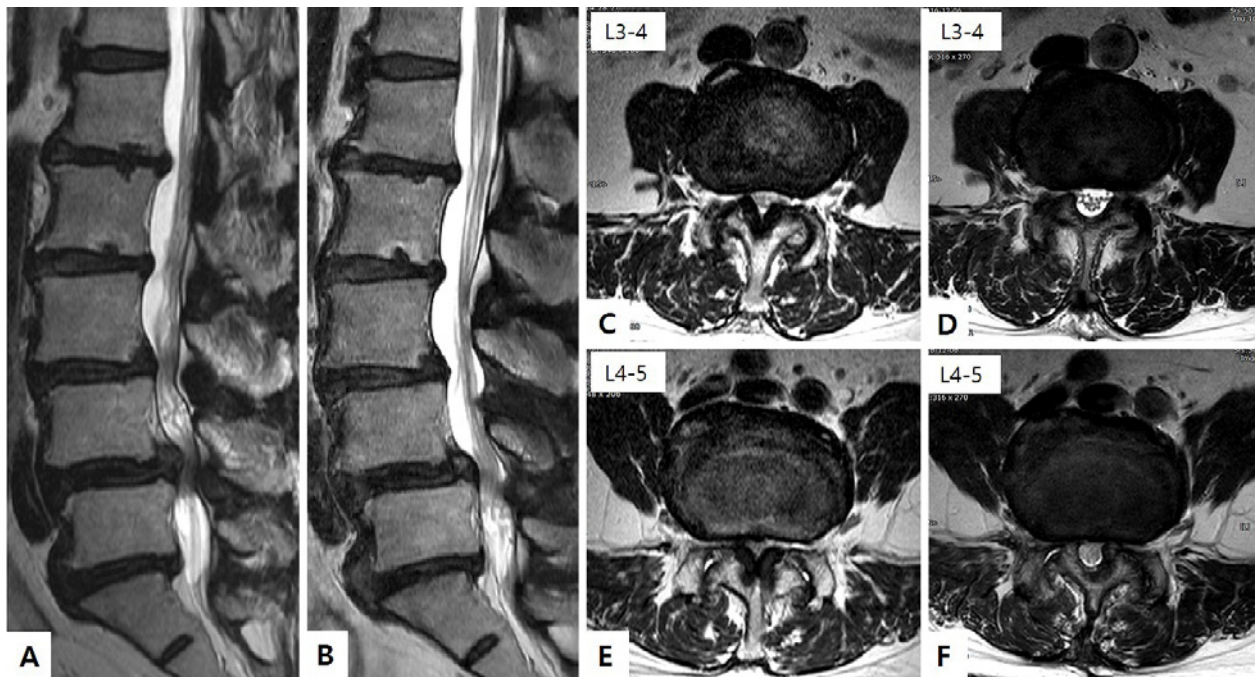
**Figure 4.** (A, B, C) Preoperative and (D, E, F) postoperative X-ray images of a 61-year-old female. (A, D) Standing lateral and (B, C, E, F) flexion-extension standing lateral X-rays show no significant changes before and after surgery (pre- and postoperative dynamic slippage and dynamic slip angle: 5% vs 5%, and 6° vs 3° in the upper level, and 6% vs 7%, and 11° vs 11° in the lower level).

Compared to the traditional open decompression technique<sup>4,26)</sup>, the manipulation of surgical instruments can be more precise by using a magnified view of surgical field. Compared to endoscopic decompression technique<sup>27-30)</sup>, SCD has an advantage of a three-dimensional view and freer manipulation of surgical instruments with less angular limitation.

However, SCD do have limitations. In our early practices, we experienced several facet cysts after several months of SCD surgeries. Injury of the facet joint capsule during the removal of ligamentum flavum in the lateral recess area

seems to be related with this complication. In addition, risk of nerve root injury has been noted because of the preservation of the facet joint and narrow visual field. We have experienced a few root injury cases in our early practices. We are planning to analyze the complications of SCD in the next study.

This study had some limitations. First, there was no comparison with the procedures that involved spinal fusion. Second, our sample size was relatively small, owing to the rarity of two-level degenerative spondylolisthesis compared to one-level degenerative spondylolisthesis. Third, our subjects



**Figure 5.** (A, C, E) Preoperative and (B, D, F) postoperative MRI images of a 61-year-old female. Sagittal and axial T2-weighted images show preoperative narrowing of the spinal canal and thickened ligamentum flavum in L3-4 and L4-5 level. Postoperatively, ligamentum flavum was removed, and compression of the dural sac was relieved.

had relatively mild vertebral slippage with normal posture (Fig. 4), which may have affected the clinical results of decompression without fusion. Further studies with more various degrees of vertebral slippage and posture are needed in order to determine the conclusive clinical effectiveness of SCD.

In conclusion, our results suggest that SCD is a clinically recommendable procedure. SCD technique can improve clinical outcomes and does not cause spinal instability when treating patients who have a spinal stenosis with two-level degenerative spondylolisthesis.

**Conflicts of Interest:** The authors declare that there are no relevant conflicts of interest.

**Ethical Approval:** None. This study was a retrospective review of medical records and images.

**Author Contributions:** Young Sang Lee conceived and designed the study, and analyzed the data. Soo-Bin Lee conceived and designed the study, collected and analyzed the data. Jin Kim collected and analyzed the data, and prepared the manuscripts. All of the authors participated in the study design. All authors have read, reviewed, and approved the final version of the manuscript.

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