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

Introduction

“Decompression and fusion” has been preferred in the treatment of lumbar spinal stenosis with degenerative spondylolisthesis: if decompression alone is performed, the instability of lumbar degenerative spondylolisthesis increases. 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. In clinical practice, there are several cases where only decompression surgery without fusion is performed.

In previous years, we performed surgery on patients with lumbar spinal stenosis with one-level degenerative spondylolisthesis following the semi-circumferential decompression (SCD) technique. The results suggest that SCD is a clinically recommendable procedure that can improve pain and does not cause spinal instability. 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.
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. Most endplates (67.9%) of vertebral 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, 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). 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. |
|-----------------------------------|------------------|------------------|------------------|
| Total patients                    | 14               | Age (years)      | 72.5±6.2 (60–81) |
| Sex                               | Women: 11 (78.6) | Operation level  | L-3-4-5: 12 (85.7)|
|                                   | Men: 3 (21.4)    | L-4-5-S1: 2 (14.3)|
| Follow-up period (months)         | 28.3±10.8 (15–41)| Operation level  | L-3-4-5: 12 (85.7)|
|                                   | Sex              | Lumbar lordosis angle (L1-S1) | 30.3±16.1 (6–60)|
|                                   | Age (years)      | Disc degeneration | Upper level | III: 1 (7.1) |
|                                   | Operation level  | (grade)          | IV: 12 (85.8) | V: 1 (7.1) |
|                                   | Lower level      | Modic change of endplate (type) | Upper level | II: 2 (14.2) |
|                                   | Modic change of endplate (type) | Lower level | II: 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). 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).
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°
mizing vertebral instability lateral decompression using a unilateral approach in mini-spinous and supraspinous ligament. A recent study tried biotomies and decompression while preserving the inter-spinous process is repositioned after spinous process osteotomy 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.

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

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

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   |

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. suggested a surgical procedure where the spinous process is repositioned after spinous process osteotomies and decompression while preserving the inter-spinous and supraspinous ligament. A recent study tried bilateral decompression using a unilateral approach in minimizing vertebral instability. Among these various surgical techniques, the SCD has been also introduced to attain vertebral stability.

Anatomical research on ligamentum flavum by Okuda et al. showed that in patients with degenerative spondylolisthesis, 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. However, when the ligamentum flavum is removed by en-bloc resection, we can assess the sufficiency of the decompression by observing the resected ligamentum flavum.

Abumi et al. 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. Therefore, SCD can be performed in spinal stenosis with degenerative spondylolisthesis.

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

Posterior decompression with fusion has been determined as a standard method for degenerative spondylolisthesis, but fusion surgery causes massive hemorrhage and long-term hospitalization and high cost. Furthermore, fusion surgery can cause pseudoarthrosis, adjacent segmental degenerative changes, and other postoperative side effects. There have been several studies on only decompression surgery, 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.
Compared to the traditional open decompression technique, the manipulation of surgical instruments can be more precise by using a magnified view of surgical field. Compared to endoscopic decompression technique, 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 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).
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.

References
1. Fischgrund JS, Mackay M, Herkowitz HN, et al. 1997 Volvo Award winner in clinical studies. Degenerative lumbar spondylolisthesis with spinal stenosis: a prospective, randomized study comparing decompressive laminectomy and arthrodesis with and without spinal instrumentation. Spine. 1997;22(24):2807-12.
2. Mullin BB, Rea GL, Irsik R, et al. The effect of postlaminectomy spinal instability on the outcome of lumbar spinal stenosis patients. J Spinal Disord. 1996;9(2):107-16.
3. Gillespie KA, Dickey JP. Biomechanical role of lumbar spine ligaments in flexion and extension: determination using a parallel linkage robot and a porcine model. Spine. 2004;29(11):1208-16.
4. Weiner BK, Fraser RD, Peterson M. Spinous process osteotomies to facilitate lumbar decompressive surgery. Spine. 1999;24(1):62-6.
5. Nakanishi K, Tanaka N, Fujimoto Y, et al. Medium-term clinical results of microsurgical lumbar flavectomy that preserves facet joints in cases of lumbar degenerative spondylolisthesis: comparison of bilateral laminotomy with bilateral decompression by a unilateral approach. J Spinal Disord Tech. 2013;26(7):351-8.
6. Musluman AM, Cansever T, Yilmaz A, et al. Midterm outcome after a microsurgical unilateral approach for bilateral decompression of lumbar degenerative spondylolisthesis. J Neurosurg Spine. 2012;16(1):68-76.
7. Zander T, Rohlmann A, Klockner C, et al. Influence of graded facetectomy and laminectomy on spinal biomechanics. Eur Spine J. 2003;12(4):427-34.
8. Hamasaki T, Tanaka N, Kim J, et al. Biomechanical assessment of minimally invasive decompression for lumbar spinal canal stenosis: a cadaver study. J Spinal Disord Tech. 2009;22(7):486-91.
9. Lee YS, Choi JC, Oh SH, et al. Semi-circumferential decompression: microsurgical total en bloc ligamentum flavectomy to treat lumbar spinal stenosis with grade I degenerative spondylolisthesis. Clin Orthop Surg. 2015;7(4):470-5.
10. Pfirrmann CW, Metzdorf A, Zanetti M, et al. Magnetic resonance classification of lumbar intervertebral disc degeneration. Spine. 2001;26(17):1873-8.
11. White AA, Panjabi MM. Clinical biomechanics of the spine. Philadelphia: Lippincott; 1990. xxiii, 722 p.
12. Miyauchi A, Sumita T, Hideki M, et al. Clinical results of semi-
circumferential decompression (SCD) for degenerative spondylolisthesis. The Central Japan Journal of Orthopaedic Surgery & Traumatology. 2004;47(4):829-30.

13. Fujiwara Y, Manabe H, Sumida T, et al. Facet preserving technique by en bloc flavectomy in microscopic posterior decompression surgery for lumbar spinal stenosis: Semicircumferential Decompression (SCD). Clin Spine Surg. 2017;30(5):197-203.

14. Taillard W. Le Spondylolisthesis Chez L’enfant et L’adolescent (Etude de 50 cas). Acta Orthop Scand. 1954;24(1-4):115-44.

15. Boxall D, Bradford DS, Winter RB, et al. Management of severe spondylolisthesis in children and adolescents. J Bone Joint Surg Am. 1979;61(4):479-95.

16. Okuda T, Fujimoto Y, Tanaka N, et al. Morphological changes of the ligamentum flavum as a cause of nerve root compression. Eur Spine J. 2005;14(3):277-86.

17. Abumi K, Panjabi MM, Kramer KM, et al. Biomechanical evaluation of lumbar spinal stability after graded facetectomies. Spine. 1990;15(11):1142-7.

18. Sengupta DK, Herkowitz HN. Degenerative spondylolisthesis: review of current trends and controversies. Spine. 2005;30(6 Suppl):S71-81.

19. Matsunaga S, Sakou T, Morizono Y, et al. Natural history of degenerative spondylolisthesis. Pathogenesis and natural course of the slippage. Spine. 1990;15(11):1204-10.

20. Mardjetko SM, Connolly PJ, Shott S. Degenerative lumbar spondylolisthesis. A meta-analysis of literature 1970-1993. Spine. 1994;19(20 Suppl):225S-65S.

21. Genevay S, Atlas SJ. Lumbar spinal stenosis. Best Pract Res Clin Rheumatol. 2010;24(2):253-65.

22. Carreon LY, Puno RM, Dimar JR, 2nd, et al. Perioperative complications of posterior lumbar decompression and arthrodesis in older adults. J Bone Joint Surg Am. 2003;85(11):2089-92.

23. Arnoldi CC, Brodsky AE, Cauchoir J, et al. Lumbar spinal stenosis and nerve root entrapment syndromes. Definition and classification. Clin Orthop Relat Res. 1976(115):4-5.

24. Adachi K, Futami T, Ebihara A, et al. Spinal canal enlargement procedure by restorative laminoplasty for the treatment of lumbar canal stenosis. Spine J. 2003;3(6):471-8.

25. Natarajan RN, Andersson GB, Patwardhan AG, et al. Study on effect of graded facetectomy on change in lumbar motion segment torsional flexibility using three-dimensional continuum contact representation for facet joints. J Biomech Eng. 1999;121(2):215-21.

26. Hatta Y, Tonomura H, Nagae M, et al. Clinical outcome of Muscle-Preserving Interlaminar Decompression (MILD) for lumbar spinal canal stenosis: minimum 3-year follow-up study. Spine Surg Relat Res. 2019;3(1):54-60.

27. Kim H-S, Choi S-H, Shim D-M, et al. Advantages of new endoscopic Unilateral Laminection for Bilateral Decompression (ULBD) over conventional microscopic ULBD. Clin Orthop Surg. 2020;12.

28. Kim JE, Choi DJ, Park EJJ, et al. Biportal endoscopic spinal surgery for lumbar spinal stenosis. Asian Spine J. 2019;13(2):334-42.

29. Minamide A, Yoshida M, Simpson AK, et al. Minimally invasive spinal decompression for degenerative lumbar spondylolisthesis and stenosis maintains stability and may avoid the need for fusion. Bone Joint J. 2018;100-B(4):499-506.

30. Minamide A, Simpson AK, Okada M, et al. Microendoscopic decompression for lumbar spinal stenosis with degenerative spondylolisthesis: the influence of spondylolisthesis stage (disc height and static and dynamic translation) on clinical outcomes. Clin Spine Surg. 2019;32(1):E20-E6.