Clinical Outcome of Muscle-Preserving Interlaminar Decompression (MILD) for Lumbar Spinal Canal Stenosis: Minimum 5-Year Follow-Up Study

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Abstract:

Introduction: Favorable short-term outcomes have been reported following muscle-preserving interlaminar decompression (MILD), a less invasive decompression surgery for lumbar spinal canal stenosis (LSCS). However, there are no reports of mid- to long-term outcomes. The purpose of this study was to evaluate the clinical outcomes five or more years after treatment of LSCS with MILD.

Methods: Subjects were 84 cases with LSCS (44 males; mean age, 68.7 years) examined five or more years after MILD. All patients had leg pain symptoms, with claudication and/or radicular pain. The patients were divided into three groups depending on the spinal deformity: 44 cases were without deformity (N group); 20 had degenerative spondylolisthesis (DS group); and 20 had degenerative scoliosis (DLS group). The clinical evaluation was performed using Japanese Orthopedic Association (JOA) scores, and revision surgeries were examined. Changes in lumbar alignment and stability were evaluated using plain radiographs.

Results: The overall JOA score recovery rate was 65.5% at final follow-up. The recovery rate was 69.5% in the N group, 65.2% in the DS group, and 54.0% in the DLS group, with the rate of the DLS group being significantly lower. There were 16 revision surgery cases (19.0%): seven in the N group (15.9%), three in the DS group (15.0%) and six in the DLS group (30.0%). There were no significant differences between pre- and postoperative total lumbar alignment or dynamic intervertebral angle in any of the groups, slip percentage in the DS group, or Cobb angle in the DLS group.

Conclusions: The mid-term clinical results of MILD were satisfactory, including in cases with deformity, and there was no major impact on radiologic lumbar alignment or stability. The clinical outcomes of cases with degenerative scoliosis were significantly less favorable and the revision rate was high. This should be taken into consideration when deciding on the surgical procedure.

Keywords:

less-invasive surgery, lumbar spinal canal stenosis, microsurgery, interlaminar decompression, midline approach

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Introduction

In cases where conservative treatment is ineffective for lumbar spinal canal stenosis (LSCS), the first treatment of choice may be posterior decompression. Since performing conventional laminectomy can lead to postoperative segmental instability[1,2], decompression methods have been improved and various less-invasive decompression surgery techniques have been developed[3-7]. As less-invasive decompression surgery clearly causes minimal invasion of the posterior lumbar structures, it is possible that its long-term outcomes may differ from those previously reported following conventional laminectomy[8-10]. MILD is a method of less-invasive decompression surgery developed for treating LSCS with minimal

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Table 1. Total Patients Data.

Gender (Male:Female)	44:40
Average age (yrs.)	68.7 (51-84)
Average follow-up (mos.)	71.3 (60-100)
Diagnosis	
No remarkable deformity (N)	44
Degenerative spondylolisthesis (DS)	20
Degenerative lumbar scoliosis (DLS)	20
Number of decompressed levels	
1 level	32
2 levels	33
>3 levels	19

invasion of the paravertebral muscles, intervertebral facet joints, and the lever arm function of the spinous processes[11]. Preliminary studies have reported favorable short-term outcomes with this method, but the mid- to long-term outcomes are currently unclear.

Whether to treat LSCS cases with spinal deformities, such as degenerative spondylolisthesis (DS) and scoliosis, with decompression only or with decompression with fusion remains a matter of debate. In recent years, with less-invasive decompression surgery gaining increasing attention, the validity of performing spinal fusion to treat all symptomatic stenotic lesions with spinal deformity has been questioned. Furthermore, taking the challenges of complications and cost into consideration, the effectiveness of decompression only is being viewed in a new light[12,13]. There are reports of effective outcomes using various methods of less-invasive decompression surgery to treat LSCS, but many of these involve stenotic lesions with no spinal deformity[3-5,14,15]. There are also reports of treating stenotic lesions with spinal deformity, but a degree of spinal deformity and/or radiologic lumbar instability were criteria for case selection[6,7,16,17]. The limitations of using less-invasive decompression surgery only to treat LSCS with spinal deformities are still unclear.

This study examines the outcomes at a follow-up of at least 5 years in all LSCS cases treated with MILD regardless of the degree of lumbar instability and/or spinal deformity. The mid-term outcomes are also reported and the outcomes in cases with and without spinal deformity are compared.

Methods

Patients

This study was a retrospective review of data collected prospectively on patients who underwent MILD for LSCS. The study design was approved by the institutional review board of the authors' affiliated institutions. The diagnosis of LSCS was made by clinical symptoms such as leg pain, numbness, and intermittent claudication, and spinal canal stenosis was confirmed by magnetic resonance imaging. Surgical indications were resistance to conservative treatment and continuing symptoms. This surgical method was used for all cases, regardless of the degree of preoperative radiologic deformity and/or instability. Patients with radicular pain attributed to lumbar foraminal stenosis were ineligible for this surgery. Between January 2003 and December 2007, 121 consecutive patients with no previous history of lumbar spine surgery were enrolled in this study. Twenty-one patients were lost to follow-up, giving a follow-up rate of 82.6 % (100/121 patients). An additional 16 patients were excluded because of death, cerebral infarction, depressive disorder, dementia, or terminal cancer. Thus, 84 patients with a follow-up period of at least 5 years were included. Patient characteristics are shown in Table 1. The total number of decompressed levels was 164, with three at L1/2, 16 at L2/3, 52 at L3/4, 72 at L4/5, and 17 at L5/S. The patients were classified into three groups according to the degree of preoperative radiologic deformity (Fig. 1): 44 cases with no deformity (N group); 20 with DS group); and 20 with degenerative scoliosis (DLS group). Degenerative spondylolisthesis was diagnosed based on the presence of sagittal vertebral slippage greater than 3 mm in lateral radiographs. Twenty patients had DS and the mean slip percentage was 19.2% ± 5.6% (range, 10%-28%). The Meyerding Grading System classification was Grade I for 17 patients and Grade II for three patients. Degenerative scoliosis was defined as a spinal deformity with a Cobb angle of more than 10° in coronal radiographs. Twenty patients had degenerative scoliosis and the mean Cobb angle for these patients was 14.9° ± 5.5° (range, 10°-31°). Three patients had a Cobb angle exceeding 20°.

Surgical procedure

All surgeries were performed using the original MILD technique as previously described[11]. Briefly, MILD involves making a 30-mm midline skin incision, centered at the interspinous level to be decompressed. Both the caudal part of the upper adjacent spinous process and the cranial part of the lower adjacent one are exposed, and the supraspinous and interspinous ligaments are longitudinally split down the middle. The exposed portions of the spinous processes are removed using the drill burr. The surgical field is gradually expanded by retracting laterally the complex of periosteum, split ligaments, and fascia of bilateral paravertebral muscles using a Gelpi self-retaining retractor. After repeated drilling of the spinous process and expansion of the surgical field, the dorsal level of the spinal canal is exposed. Following partial drilling of the upper and lower adjacent lamina, a dome-like expansion is achieved. The inner laminar plate is removed to expose the cranial edge of the ligamentum flavum. The entire ligamentum flavum is then circumferentially detached from the bone and resected *en bloc*. The nerve root decompressions are accomplished by trimming the medial margins of the lateral recesses using a fine Kerrison rongeur.

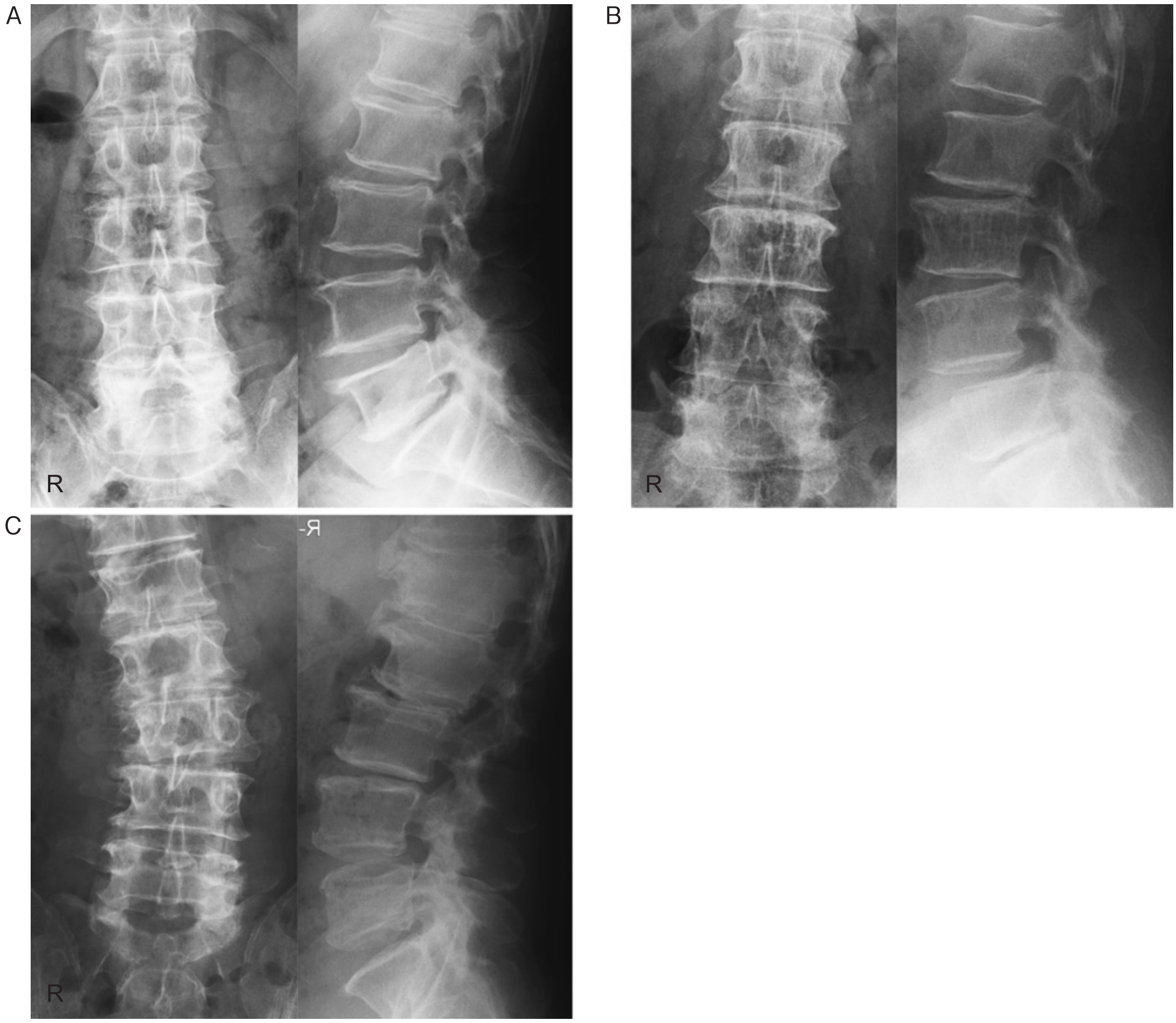

Figure 1. Preoperative standing radiographs illustrating typical cases for each study group: (A) lumbar spinal canal stenosis (LSCS) with no deformity; (B) LSCS with degenerative spondylolisthesis; and (C) LSCS with degenerative scoliosis.

Clinical evaluation

Two authors who were not involved in the surgical procedure reviewed all records. For clinical evaluation, JOA scores were used, and the patient records were examined for complications and revision surgeries. Clinical evaluations based on JOA scores were performed at postoperative years 1 to 2 and at the final follow-up, and the recovery rates were calculated.

Radiographic changes

All patients underwent four radiographs, including an anteroposterior view and three lateral views (maximally flexed, neutral, and maximally extended positions), both preoperatively and at the last follow-up. The angles between L1 and L5 on the neutral lateral view were measured as lumbar lordosis angle. The intervertebral angles at the affected level on the lateral view were measured, and the difference between these angles during flexion and extension was taken as the dynamic intervertebral angle. At 20 sites with DS, the distance between the posterior line of the upper vertebra and the posterior line of the lower vertebra at the affected level was measured on the lateral view as slippage. The slippage divided by the length of the upper line at the lower vertebra gave the slip percentage. Also, the difference in the slippage between the flexion and extension positions was calculated as dynamic slip translation. For 20 patients with degenerative scoliosis, the angle of scoliosis was measured by the Cobb method and the lateral slippage was measured on the anteroposterior view. These parameters were compared for preoperative and final follow-up findings.

Statistical analysis

Statistical analysis was performed using the Wilcoxon signed-rank test, analysis of variance (ANOVA) and the Fisher's protected least significant difference (PLSD) test. A p value of less than 0.05 was considered significant.

Table 2. Comparison of the Demographics and Outcomes for Each Group.

	N n=44	DS n=20	DLS n=20
Gender (Male:Female)	31:13	9:11	4:16
Average age (yrs.)	66.8 (51-84)	70.2 (58-81)	71.2 (61-82)
Number of decompressed levels			
1 level	16	10	6
2 levels	16	8	9
>3 levels	12	2	5
JOA score			
	13.6±4.4	12.7±5.3	13.1±3.5
preop.	(2-22)	(0-22)	(8-20)
postop.	24.5±4.2	24.2±3.9	21.7±5.2
	(15-29)	(14-29)	(12-29)
recovery rate (%)	69.5 (13-100)	65.2 (−13-100)	54.0 (8-100) *

Wilcoxon signed-rank test *: D<0.05

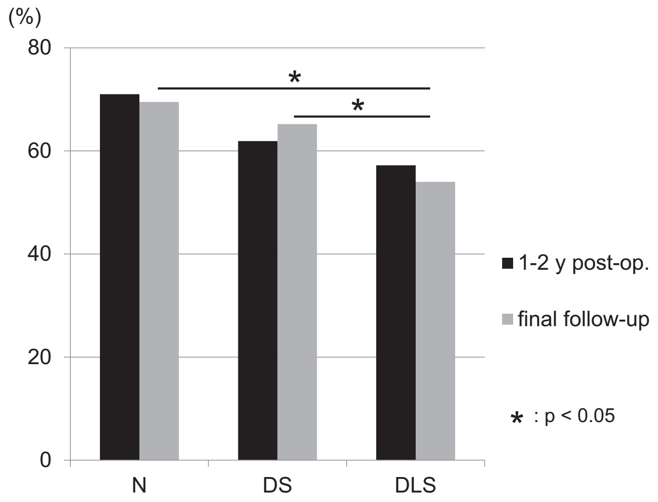

Figure 2. Recovery rates for Japanese Orthopedic Association-scores at postoperative years 1 to 2 and final follow-up: (N) no deformity group; (DS) with degenerative spondylolisthesis; and (DLS) with degenerative scoliosis (lumbar Cobb angle of 10° or more). The recovery rates at postoperative years 1 to 2 were 71.0%, 61.9%, and 57.2% in the N, DS, and DLS groups, respectively, with no significant difference observed. The recovery rates at the final follow-up, however, were 69.5%, 65.2%, and 54.0% in the N, DS, and DLS groups, respectively, with the rate in the DLS group being significantly lower than that in the other two groups.

Results

Clinical results

The mean preoperative JOA score was 13.3 ± 4.4 (range, 0-20); at postoperative years 1 to 2, it had improved to 23.7 ± 4.2 (range, 10-29) and it was 23.8 ± 4.5 (range, 13-29) at the final follow-up. At postoperative years 1 to 2, the recovery rate was 65.5% (range, 8-100), and at the final follow-up it was 64.7% (range, −13-100). Preoperative JOA scores for each study group are shown in Table 2, with no between-group difference observed (Wilcoxon signed-rank test). JOA scores in the N, DS, and DLS groups were 24.6 ± 3.3, 22.9 ± 1.1, and 22.3 ± 4.7, respectively, at postoperative years 1 to 2, and 24.5 ± 4.2, 24.2 ± 3.9, and 21.7 ± 5.2, respectively, at the final follow-up. The recovery rates at postoperative years 1 to 2 were not significantly different among the three groups (Wilcoxon signed-rank test). However, the recovery rate in the DLS group was significantly lower than that in the other two groups at the final follow-up (Wilcoxon signed-rank test, $p < 0.05$) (Fig. 2). In the DLS group, the recovery rate for the three patients with a Cobb angle exceeding 20° was 60.8% (range, 50-70).

Table 3. Comparison of Revision Surgery.

	N n=44	DS n=20	DLS n=20
Number of revision surgery	7	3	6
foraminal stenosis	2	2	2
disc herniation	2	0	2
adjacent level stenosis	3	0	0
facet cyst	0	0	2
same level stenosis	0	1	0
Revision rate (%)	15.9	15.0	30.0

Revision surgery

Revision surgery was performed for 16 cases (19.0%) due to foraminal stenosis (six cases), disc herniation (four cases), adjacent level stenosis (three cases), facet cyst (two cases), and same level stenosis (one case). Comparison of revision surgery data for each study group is shown in Table 3.

Radiographic evaluation

The mean preoperative lumbar lordosis angle for all 84 cases was 23.5° ± 11.5° (range, −7°-51°); it was 23.4° ± 13.4° (range, −12°-54°) postoperatively, with no significant difference observed (ANOVA and Fisher's PLSD test). The preoperative and postoperative values for each group are shown in Table 4, with no significant differences (ANOVA and Fisher's PLSD test). The mean pre- and postoperative

Table 4. Summary of Radiographic Changes.

	N	DS	DLS
lumbar lordosis angle (°)			
preop.	24.2±12.1 (0-51)	25.6±7.9 (8-40)	19.7±12.6 (−7-44)
postop.	24.3±13.2 (0-54)	27.6±11.8 (5-51)	17.2±13.8 (−12-47)
dynamic intervertebral angle (°)			
preop.	3.4±2.7 (0-10)	3.1±2.8 (0-12)	3.2±2.2 (0-8)
postop.	3.1±2.9 (0-13)	3.8±4.1 (0-17)	2.8±3.2 (0-8)

Analysis of variance (ANOVA) and the Fisher's PLSD test.

dynamic intervertebral angles from 164 levels were 3.3° ± 2.6° (range, 0°-12°) and 3.2° ± 3.2° (range, 0°-17°), respectively, with no significant difference observed (ANOVA and Fisher's PLSD test). Pre- and postoperative mean dynamic intervertebral angles for each group are shown in Table 4, with no differences between the groups (ANOVA and Fisher's PLSD test).

In the DS group, the pre- and postoperative slip percentages (19.2% ± 5.6% [range, 10%-28%] vs 21.2% ± 6.0% [range, 10%-30%]) were not significantly different (ANOVA and Fisher's PLSD test). Progression of slippage by 5% or more was observed in three of 20 cases (15.0%). Pre- and postoperative dynamic slip translation values in the DS group were 2.2 ± 1.4 (range, 0-5) and 2.2 ± 1.2 mm (range, 0-4), respectively, with no clear difference observed (ANOVA and Fisher's PLSD test). In the DLS group, pre- and postoperative mean Cobb angles (14.9° ± 5.5° [range, 10°-31°] vs 17.8° ± 6.5° [range, 10°-32°]) did not differ significantly (ANOVA and Fisher's PLSD test). A progressive Cobb angle of 5° or more was observed in six of 20 cases (30.0%). Pre- and postoperative mean lateral slippage values were 3.0 ± 3.7 (range, 0-11) and 4.0 ± 5.0 mm (range, 0-16), respectively, which were not significantly different (ANOVA and Fisher's PLSD test).

Discussion

In lumbar posterior surgery, performing sufficient spinal decompression is invasive for the posterior supporting structures, which leads to segmental instability and poor results. However, performing insufficient spinal decompression in an effort to avoid instability also leads to poor results[1,18]. In other words, achieving sufficient spinal decompression during lumbar posterior surgery while simultaneously maintaining lumbar stability is a major consideration. In recent years, various less-invasive decompression surgery techniques have been developed, and favorable results have been reported[3-7,11,14-17]. Few of the reports, however, discuss performing sufficient spinal decompression while maintaining lumbar stability. MILD is a microsurgery technique using a midline approach to perform decompression[11]. This method has been shown to be superior to other less-invasive surgical techniques in terms of biomechanical postoperative destabilization[19].

In this study, treating LSCS cases with MILD, regardless of the degree of instability and/or deformity, achieved a recovery rate of 65.5% at postoperative years 1 to 2, which was maintained at 64.7% 5 or more years after surgery. Short- to mid-term JOA score recovery rates of 58% to 74% have been reported after less-invasive decompression surgery[5-7,15,17]. All the subjects selected for these studies had a degree of instability and/or deformity. Comparing previous reports with this study shows that, in general, performing MILD to treat LSCS cases, including those with instability and/or deformity, results in favorable outcomes. A comparison of the three groups in this study showed no difference in the recovery rates at postoperative years 1 to 2, regardless of the presence or absence of deformity. However, at postoperative year five or more, the recovery rate of 54.0% in the DLS group was significantly lower. It has been established that using conventional laminectomy to treat LSCS with degenerative scoliosis results in poor outcomes[20,21]. Spinal fusion is recommended for these cases, but its invasiveness poses a risk for complications[13]. In recent years, Toyoda et al. reported that mid-term clinical results 5 or more years after microsurgical bilateral decompression via unilateral approach gave a JOA score recovery rate of 51.6% in a group with degenerative scoliosis, which did not differ clearly from a group without deformity or a group with DS[6]. Kelleher et al. reported that the short-term (more than 2 years post-surgery) clinical results of another less-invasive technique did not differ among three groups in terms of Oswestry Disability Index recovery rates[16].

The radiologic evaluation in our study showed no clear difference in total lumbar lordosis angle or dynamic intervertebral angle of the decompressed level after 5 or more years, regardless of the presence or absence of deformity. Thus, this method of treatment has little influence on radiologic lumbar alignment or stability. In the DS group, no differences between pre- and postoperative slip percentage or dynamic slip translation were observed, and progressive slippage of 5% or more was observed in 15.0% of cases. A study of the natural history of DS reported progressive slippage of 5% or more in 30% of cases at a mean follow-up of 8.2 years[22]. It appears that, with conventional laminectomy, postoperative progression of slippage, and increased lumbar instability have an adverse effect on clinical results[1]. In the DLS group in our study, the mean Cobb angle increased by 2.9°, but this was not statistically significant, and progressive scoliosis was observed in 30.0% of cases after 5 or more years. A report on the natural history of degenerative scoliosis found progressive scoliosis of 4° or more in 46% of cases after a follow-up period of 7 to 13 years[23]. From the above, it is concluded that this method is a less-invasive decompression surgery technique that has little influence on the natural history of DS and scoliosis.

The surgical approach of this method contributes to the favorable results obtained. (1) In a previous report concerning biomechanical evaluation of lumbar stability, the most important factor in obtaining lumbar stability after decompression surgery was shown to be preservation of intervertebral facet joints[24]. With the midline approach in MILD, decompression is possible with minimal invasion of facet joints on either side. (2) It has been reported that separating the paravertebral muscles from the spinous processes with a conventional approach leads to progressive postoperative paravertebral muscle atrophy that can adversely influence clinical results[25]. The midline interlaminar approach used in this technique can prevent local denervation and irreversible damage to the paravertebral muscles[26]. (3) Excision of supra- and interspinous ligaments has been reported to result in postoperative biomechanical lumbar instability[27]. With this method, although spinous processes are partially removed and the supra- and interspinous ligaments are divided, continuity with the paravertebral muscles is maintained, and suturing these ligaments after decompression preserves lever arm function. Previous reports support the view that, compared with other less-invasive procedures, MILD causes less biomechanical destabilization following decompression surgery[19]. Mid-term clinical evaluations also show that this method has no effect on radiologic lumbar alignment and stability; thus, in general, favorable clinical results are obtained.

In this study, revision surgery was performed for 16 cases (19.0%): seven (15.9%) in the N group, three (15.0%) in the DS group, and six (30.0%) in the DLS group. A revision surgery rate of 23% has been reported 7 to 10 years after conventional laminectomy[8,10]. After fusion surgery for degenerative scoliosis, a revision surgery rate of 33% was reported[28]. Similar results appear in other reports,[6,16] with a high revision surgery rate for degenerative lumbar scoliosis. In this study, the revision surgery rate compares favorably with those after conventional laminectomy and/or fusion surgery, but it is high compared with rates for other less-invasive decompression surgery methods[6,7]. This could be because subjects in this study were included regardless of their degree of spinal deformity and/or radiologic lumbar instability. The reason for revision surgery was foraminal stenosis in six of the 19 cases, but, as in previous reports, there may have been problems with the preoperative diagnosis. Improving diagnostic accuracy might help reduce the number of revision cases[29]. There are few cases of revision surgery due to recurrent stenosis[30], which is common, and it is concluded that the goal of obtaining sufficient decompression without adversely affecting lumbar spinal stability can be reached.

This study differed from previous studies in that all cases with DS and/or DLS were selected regardless of whether or not they had spinal deformity and/or radiologic lumbar instability. The results of this study suggest that less-invasive decompression surgery is a viable treatment option for not only LSCS without spinal deformity but also symptomatic spinal canal stenosis with spinal deformity. Nevertheless, for cases with degenerative scoliosis, which have a high revision surgery rate due to unfavorable clinical results, the potential specific risks of fusion surgery must be taken into consideration.

A limitation of this study was the low number of cases (3/20 patients) of severe DLS (exceeding Cobb angle 20°). The current results are obtained from LSCS patients with mild DLS (mean Cobb angle 14.9°). We did not attempt to identify the factors that influenced the poor clinical outcomes in the DLS cases, and further studies should be conducted.

The clinical results 5 or more years after treating LSCS with MILD, including cases with deformity, were generally favorable. There was no significant change in radiologic lumbar alignment and/or stability, and the method had little effect on the natural history of LSCS. However, the clinical results were significantly less favorable in cases with degenerative scoliosis, and the revision surgery rate was high. This should be taken into consideration when selecting the surgical procedure.

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

Author Contributions: Hatta and Tonomura wrote and prepared the manuscript, and all the authors participated in the study design. All authors have read, reviewed, and approved the article.

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