Eur Spine J (2011) 20:947–953
DOI 10.1007/s00586-010-1597-1

ORIGINAL ARTICLE

# Clinical outcomes of microscopic decompression for degenerative lumbar foraminal stenosis: a comparison between patients with and without degenerative lumbar scoliosis

**Kentaro Yamada · Hideki Matsuda · Masaharu Nabeta · Hiroshi Habunaga · Akinobu Suzuki · Hiroaki Nakamura**

Received: 23 March 2010 / Revised: 23 August 2010 / Accepted: 25 September 2010 / Published online: 15 October 2010


**Abstract** We performed microscopic lumbar foraminotomy in all the patients diagnosed with degenerative lumbar foraminal stenosis (DLFS) and retrospectively reviewed the clinical outcomes and the factors influencing them. The preoperative Japanese Orthopaedic Association (JOA) score of 13.8 significantly improved to 21.9 postoperatively. Although leg pain reduced in 44 patients (95.7%) immediately after surgery, it recurred in 9 patients (19.6%). The recurrence frequency was significantly higher and the JOA score improvement ratios significantly lower in patients with degenerative lumbar scoliosis (DLS) than in those without DLS. Even among patients with DLS, those with <3° Cobb angle difference between the supine and standing positions showed satisfactory results, with no recurrence. In conclusion, microscopic lumbar foraminotomy for DLFS produced satisfactory clinical outcomes even in patients with DLS. However, the outcomes were poor in patients with unstable DLS.

K. Yamada · H. Matsuda · H. Habunaga
Department of Orthopaedic Surgery, Ishikiriseiki Hospital, 18-28, Yayoi-cho, Higashiosaka, Osaka, Japan

M. Nabeta
Department of Orthopaedic Surgery, Ikeda Hospital, Higashiosaka, Japan

A. Suzuki · H. Nakamura
Department of Orthopaedic Surgery, Osaka City University Graduate School of Medicine, Osaka, Japan

K. Yamada (✉)
Department of Orthopaedic Surgery, Osaka City University Graduate School of Medicine, 1-4-3, Asahi-machi, Abeno-ku, Osaka, Japan
e-mail: yamachen@msic.med.osaka-cu.ac.jp

**Keywords** Degenerative lumbar scoliosis · Foraminal stenosis · Microsurgical decompression · Less-invasive surgery

## Introduction

Degenerative lumbar foraminal stenosis (DLFS) is a relatively common cause of lumbar radiculopathy, with a reported incidence rate of 8–11% [9, 10, 14, 17]. It is characterized by the narrowing of the canal space for the exiting nerve root, caused by osseous and ligamentous hypertrophy [8]. In addition, the L5 nerve root may be compressed by the L5 transverse process, sacral ala, or lumbosacral ligament in the extraforaminal zone [11, 18]. There are two surgical treatment options for DLFS: decompression without fusion and decompression with spinal fusion [1, 3, 6, 8–10, 12, 14]. With development in spinal instrumentation, fusion surgery is preferred, especially in patients with degenerative lumbar scoliosis (DLS) due to malalignment and instability. However, fusion surgery poses problems, such as adjacent segment disease and pseudoarthrosis [2, 4, 19]. Because patients with DLS are often elderly, surgical invasion and instrumentation failure due to osteoporosis also create problems in fusion surgery. Decompression without fusion is considered less invasive and capable of avoiding spinal fusion-associated sequelae, but recurrent radiculopathy may become a problem, especially in patients with deformity and/or instability [3, 5, 10, 16]. Many clinical studies have shown satisfactory clinical outcomes of foraminal decompression without fusion for lumbar foraminal disc herniation, but there have been only a few studies on DLFS [1, 5, 6, 12, 14] and no detailed analysis of the influence of DLS on the outcomes.

We developed a less-invasive microscopic lumbar foraminotomy procedure for decompressing the compressed nerve root and minimizing invasion into the spinal posterior structure. We, then performed microscopic lumbar foraminotomy in all the patients diagnosed with DLFS, including even those with DLS. In the present study, we investigated the clinical outcomes of this surgical procedure and frequency of recurrent leg pain and evaluated the influence of DLS on the outcomes. Preoperative and postoperative radiographic features of leg pain recurrence in patients with DLS were also investigated.

## Materials and methods

### Patients and methods

Between 2005 and 2008, 51 patients diagnosed with DLFS were treated with microscopic lumbar foraminotomy at our institution. DLFS was diagnosed on the basis of the symptoms, neurological examination results, selective nerve root block, and presence of foraminal stenosis on computed tomography (CT) and magnetic resonance (MR) images. Surgical treatment was indicated only in patients who showed severe muscle weakness or intolerable leg pain even after conservative treatment, including nonsteroidal antiinflammatory medication, physical therapy, and selective nerve root block. Selective nerve root block was performed under fluoroscopic guidance. All patients who underwent surgeries for leg pain showed a good response to nerve block, but complained of leg pain again after a certain period. Patients with obvious disc herniation, isthmic spondylolisthesis, and congenital stenosis were excluded. Four patients were lost to follow-up, and one had an incomplete preoperative radiographic assessment. Thus, 46 patients (29 men and 17 women) who were followed up for >1 year were included in this study. The age at the time of surgery was 39–87 years (mean, 67.3 years). The follow-up period was 12–41 months (mean, 21.9 months).

### Operative technique

All operations were performed or supervised by one senior author (H.M.). Under fluoroscopic guidance, a 3-cm skin incision was made, centered at the intervertebral foramen to be decompressed. After splitting, the erector spinae muscles, a self-retaining retractor and surgical microscope were set up.

The superolateral part of the superior articular process of the lower vertebrae and the lower border of the upper transverse process were resected using a high-speed drill. Tilting the surgical microscope to the medial side, the lateral part of the pars interarticularis and the superomedial part of the superior articular process were resected. By resecting the ligamentum flavum and the medial part of the intertransverse ligament, the foramen was unroofed. To confirm adequate decompression, probing with a Watson-Cheyne dissector, from the medial side of the foramen to the lateral extraforaminal zone, was carefully performed to confirm the movability of the decompressed nerve root (Fig. 1a).

On the basis of the preoperative or intraoperative findings, partial pediculectomy or discectomy were additionally performed in patients with stenosis in the craniocaudal direction. In partial pediculectomy, the inferior part of the pedicle (total length, 4–5 mm) was resected using the intrapedicular approach, similar to the method adopted by Kunogi and Hasue [10] or Sheehan et al. [15].

If patients had extraforaminal stenosis at the L5–S1 intervertebral level, additional extraforaminal decompression was performed by tilting the surgical microscope to the lateral side: the lower part of the L5 transverse process, superomedial part of the sacral ala, and lumbosacral ligament were resected (Fig. 1b).

Further, if patients showed intracanal stenosis on preoperative CT or MR images, an additional medial facetectomy, which decompressed the lateral recess to the medial aspect of the pedicle, was performed via the midline approach.

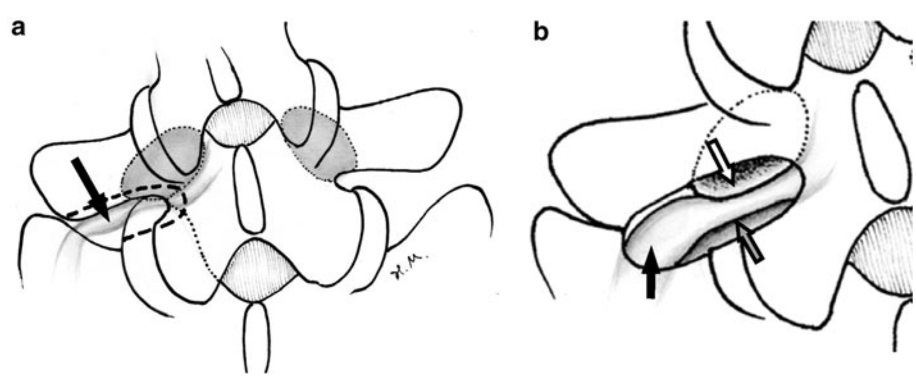


**Fig. 1** Schematic representation of our decompression procedure. **a** The arrow indicates the area of unroofing at the foramen. **b** Additional decompression was performed depending on the stenotic condition: the white, gray, and black arrows indicate the areas of partial pediculectomy, discectomy, and extraforaminal decompression, respectively

### Clinical and radiological evaluation

Patient data, including demographic information, duration of symptoms, level of operation, additional procedures, surgical complications, and revision surgery, were obtained from their clinical records. Revision surgeries were defined as the surgical procedures performed at the same decompressed level.

Clinical outcomes were evaluated using the Japanese Orthopaedic Association (JOA) scores obtained preoperatively and at the latest follow-up. When revision surgery for recurrent leg pain was performed, the score at the latest follow-up was obtained before the surgery. Ratios of JOA score improvement from preoperative evaluation to the latest follow-up were calculated using the formula proposed by Hirabayashi [7]. Clinical outcomes were classified into 4 categories according to the JOA score improvement ratios: (1) poor, <25%; (2) fair, 25–50%; (3) good, 50–75%; (4) excellent, ≥75%. Intensity of leg pain was evaluated according to the JOA score: 0 = frequent or continuous severe leg pain, 1 = continuous slight or occasional severe leg pain, 2 = occasional mild leg pain, and 3 = no pain. Recurrent leg pain was defined as leg pain similar to preoperative leg pain that had worsened to the 0 or 1 level at the latest follow-up, after postoperative improvement.

Radiological evaluation was performed by obtaining preoperative and postoperative plain radiograms. On the preoperative anteroposterior lumbar radiograms, Cobb angle was measured both in the supine and standing positions. The patients were classified into two groups according to the coronal standing Cobb angle: Group 1 (with DLS) comprised patients with ≥10° Cobb angle, and Group 2 (without DLS) comprised patients with <10° Cobb angle. Leg pain recurrence and clinical outcomes in the two groups were compared. Further, to clarify the factors associated with the recurrent leg pain in Group 1, other radiological parameters were investigated. Lateral rotatory olisthesis was considered present when >3 mm of lateral vertebral displacement was observed on anteroposterior radiograms. Sagittal olisthesis was considered present when >3 mm of vertebral displacement was observed on lateral neutral-position plain radiograms. Wedging angles were measured on the standing radiograms of the affected intervertebral level. Disc heights were measured as the distance between the posterior edges of the vertebral bodies on lateral radiograms. Range of motion (ROM) in flexion–extension and lateral bending was measured on dynamic lumbar radiograms. Cobb angle progression was evaluated on the latest postoperative standing lumbar radiograms. Curve progression was defined as positive when >5° progression was observed. Data are expressed as average ± standard deviation (SD). Statistical analysis was performed using StatView 5.0 (Abacus Concepts, Berkeley, CA) and the unpaired nonparametric Mann–Whitney test at a 95% confidence level or Chi-square test. A $p$ value of <0.05 was considered statistically significant.

## Results

The affected nerve roots and the procedures combined with the usual lateral lumbar foraminotomy are shown in Table 1. The most common nerve root decompressed was the L5 nerve root (79.2%), followed by the L4 nerve root (18.9%) and the L3 nerve root (1.9%). The preoperative JOA scores of 13.8 ± 4.4 significantly improved to 21.9 ± 5.5 postoperatively. The average JOA score improvement ratio was 54%. Good or excellent outcomes were shown by 28 patients (60.9%). Although leg pain reduced in 44 patients (95.7%) immediately after surgery, it recurred in 9 patients (19.6%) during the follow-up period.

Postoperative hematoma occurred in one patient, which was removed because of intractable leg pain. No other complications occurred in this series.

Revision surgeries for residual leg pain due to insufficient initial decompression were performed in two patients (2 and 12 weeks after the initial surgery), after which the symptoms decreased immediately. Revision surgeries for recurrent leg pain were performed in three patients. One of them underwent posterior lumbar interbody fusion 17 months after the first surgery. The other two patients underwent additional decompression surgery of the lateral intervertebral foramen (17 and 20 months after the initial surgery). The leg pain immediately disappeared after the revision surgery.

### Comparison between patients with and without DLS

Depending on the Cobb angle, 26 and 20 patients were classified in Group 1 (with DLS) and Group 2 (without DLS), respectively. There were no significant differences in the other parameters, including follow-up period, between the two groups (Table 2). In Group 1, 27 of the 30

**Table 1** Surgical procedures performed in Groups 1 and 2

| | Group 1 | Group 2 |
|---|---|---|
| No. of nerve roots targeted for decompression | 30 | 23 |
| L3 | 1 | 0 |
| L4 | 8 | 2 |
| L5 | 21 | 21 |
| No. of additional procedures | | |
| Partial pediculectomy | 11 | 12 |
| Discectomy | 10 | 5 |
| Extraforaminal decompression | 3 | 3 |
| Medial facetectomy | 6 | 9 |

**Table 2** Demographic data of patients in Groups 1 and 2

| | Group 1 | Group 2 | *P* value |
|---|---|---|---|
| No. of patients | 26 | 20 | |
| Preoperative Cobb angle (°) | 15.0 ± 4.2 | 5.8 ± 2.7 | **<0.0001** |
| Preoperative JOA score (points) | 14.3 ± 4.8 | 13.1 ± 3.8 | 0.351 |
| Duration of symptoms (mo) | 11.9 ± 12.6 | 10.8 ± 13.2 | 0.973 |
| Follow-up period (mo) | 23.0 ± 8.9 | 20.6 ± 7.1 | 0.387 |

Bold value is statistically significant

*JOA score* Japanese Orthopaedic Association score for low-back pain assessment

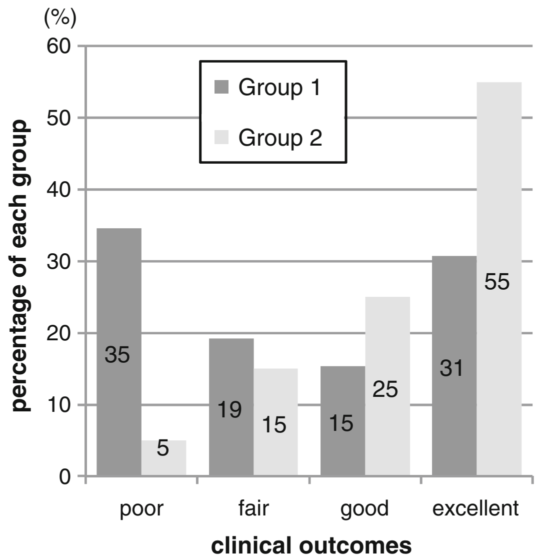


**Fig. 2** Patient distribution with regard to clinical outcomes classified into four categories according to the JOA score. In Groups 1 and 2, 46 and 80% patients showed good or excellent results, respectively

nerve roots involved were at the concave side of their segmental curves. The JOA score improvement ratio in Group 2 was significantly higher than that in Group 1 ($p = 0.027$). The categorized outcomes are shown in Fig. 2.

Recurrent leg pain was observed in eight patients (30.8%) in Group 1 and in one patient (5%) in Group 2. The incidence was significantly higher in Group 1 ($p = 0.029$). Revision surgeries for recurrent leg pain were performed for two patients in Group 1 and for one patient in Group 2.

Overall, the postoperative clinical outcomes were better in patients without DLS than in those with DLS. Additionally, after the patients were divided into two groups on the basis of the follow-up period (lesser or greater than 24 months), same trends were observed in the recurrence ratio and improvement of JOA score between the DLS and non-DLS groups.

## Radiographic features of patients with recurrent leg pain in Group 1

Table 3 shows the summarized data of patients with recurrent leg pain in Group 1.

Preoperative radiograms showed that the Cobb angles and angle differences between the standing and supine positions were significantly greater in patients with recurrent radiculopathy than in those without recurrent radiculopathy ($p = 0.007$ and $p = 0.006$, respectively). These two significantly correlated with each other ($R = 0.44$, $p = 0.023$). ROM in lateral bending was larger in patients with recurrence, although this difference was not statistically significant ($p = 0.052$). Postoperative curve progression was observed in four patients, but it was not related to recurrent radiculopathy (Table 4).

Patients in Group 1 were further divided into two groups on the basis of the presence of ≥3° and <3° Cobb angle difference between the standing and supine positions. No patient with <3° difference had recurrent radiculopathy during the follow-up, and 70% patients showed good or

**Table 3** Summary of cases of leg pain recurrence in Group 1

| Case no. | Age (year)/sex | Cobb angle (°) | Target nerve root | Additional procedure | Time to recurrence (mo) | JOA score | | Treatment |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Latest leg pain (points) | Improvement ratio (%) | |
| 1 | 67/M | 25 | L5 | PP | 9 | 1 | 41.2 | Conservative |
| 2 | 71/M | 20 | L5 | PP | 3 | 0 | 0.0 | Conservative |
| 3 | 73/M | 18 | L5 | PP, D | 21 | 1 | −12.5 | Conservative |
| 4 | 78/F | 16 | L5 | None | 1 | 1 | 0.0 | Surgical (PLIF) |
| 5 | 74/F | 16 | L5 | None | 5 | 1 | 31.6 | Conservative |
| 6 | 60/M | 16 | L4 | D | 3 | 0 | 26.1 | Surgical (decompression) |
| 7 | 69/F | 15 | L5 | PP, D | 9 | 0 | 39.1 | Conservative |
| 8 | 79/F | 15 | L5 | None | 6 | 0 | 5.0 | Conservative |

*PP* partial pediculectomy, *D* discectomy, *PLIF* posterior lumbar interbody fusion, *JOA* Japanese Orthopaedic Association score for low-back pain assessment

**Table 4** Radiographic evaluation of patients with and without recurrence in Group 1

| | With recurrence | Without recurrence | *P* value |
|---|---|---|---|
| Cobb angle (°) | 17.8 ± 3.2 | 13.8 ± 4.1 | **0.007** |
| Cobb angle difference between supine and standing positions (°) | 4.4 ± 1.3 | 2.4 ± 1.5 | **0.006** |
| No. of patients with lateral rotatory olisthesis | 2 | 5 | 0.671 |
| No. of patients with sagittal olisthesis | Anterior: 1 | Anterior: 2<br>Posterior: 5 | 0.335 |
| Coronal wedging angle | 6.4 ± 3.6 | 4.6 ± 2.7 | 0.159 |
| Disc height (mm) | 3.7 ± 1.7 | 2.9 ± 1.1 | 0.250 |
| ROM in flexion–extension (°) | 9.9 ± 5.1 | 6.7 ± 3.1 | 0.146 |
| ROM in lateral bending (°) | 5.8 ± 4.0 | 3.1 ± 2.3 | 0.052 |
| No. of patients with postoperative curve progression (≥5°) | 2 | 2 | 0.365 |

Bold values are statistically significant

*ROM* range of motion

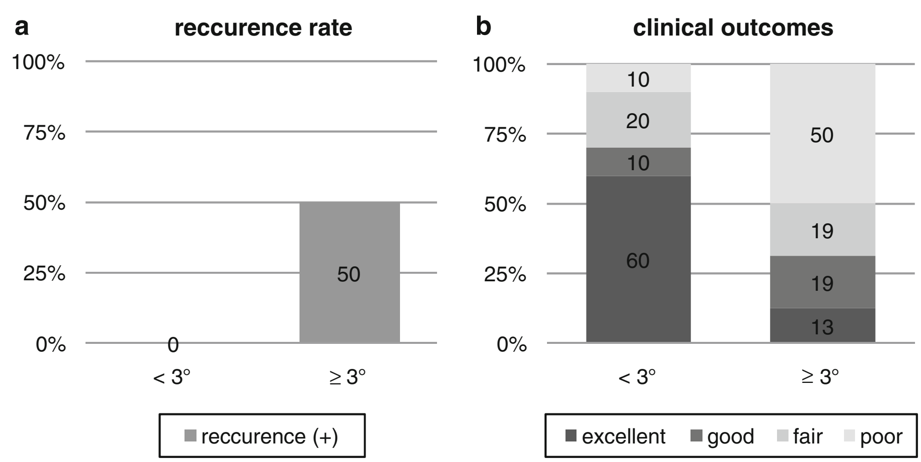


**Fig. 3** Recurrence rate (**a**) and clinical outcomes (**b**) of patients with ≥3° and <3° Cobb angle difference between the standing and supine positions in Group 1. Patients with <3° difference showed a better clinical outcome than those with ≥3° difference

excellent results according to the JOA score improvement ratios. On the other hand, 50% patients with ≥3° difference had recurrent radiculopathy, and only 32% showed good or excellent results (Fig. 3).

A representative case

A 76-year-old woman had been experiencing right leg pain for 3 years. Her preoperative radiogram showed DLS with a 15° Cobb angle and L5 sacralization. Her preoperative CT and MR images showed foraminal stenosis at the right L4–L5 and intracanal stenosis at L3–L4. A microscopic lumbar foraminotomy at the right L4–L5 was followed by a partial pediculectomy at the left L4 and a medial facetectomy at L3–L4. After surgery, the leg pain completely disappeared. At 12 months after surgery, the patient had only mild low-back pain, and the JOA score improvement ratio was 75% (Fig. 4).

## Discussion

In this series, we not only performed unroofing at the foramen but also partial resection of the pedicle, disc, transverse process, and/or sacral ala according to each patient's pathology using a microscope. This combination technique can sufficiently decompress the affected nerve root and preserve the facet joint and pars interarticularis. Although postoperative residual leg pain was observed in two patients, it disappeared after additional decompression surgery. Thus, all the patients with DLFS were successfully treated with decompression surgery. The short-term clinical outcomes were good or excellent in 60.9% patients. Hallett et al. [6] performed a randomized clinical trial of patients with foraminal stenosis without instability due to degenerative disc disease. They reported no differences in the clinical outcomes of decompression and additional fusion. Ozeki et al. [12] reported that short-term clinical results after microscopic decompression via the intrapedicular approach were satisfactory with an average JOA score recovery rate of 62.1%. Other studies on foraminal stenosis without instability have also suggested that sufficient decompression can produce satisfactory clinical outcomes even without spinal fusion [1, 10, 12, 13]. The present study, even including patients with DLS, showed similar satisfactory clinical outcomes after decompression surgery alone.

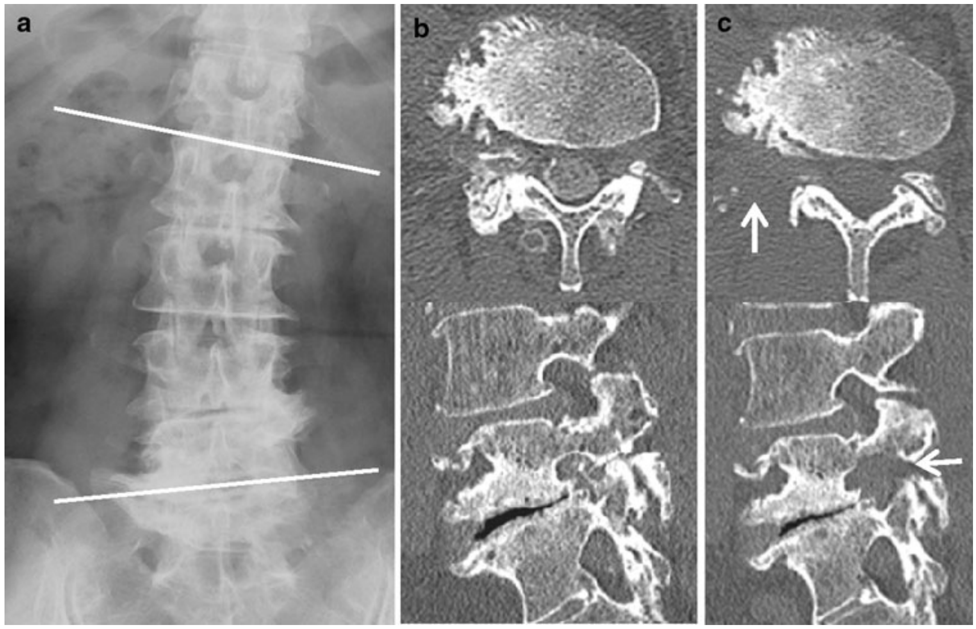


**Fig. 4** Case representation. A 76-year-old woman with right L4–L5 foraminal stenosis underwent microscopic lumbar foraminotomy and additional partial pediculectomy at the left L4 and medial facetectomy at L3–L4. **a** Preoperative radiogram shows a 15° Cobb angle. **b** Preoperative axial (*above*) and sagittal (*below*) CT scan shows the right L4–L5 foraminal stenosis. **c** Postoperative axial (*above*) and sagittal (*below*) CT scan shows minimal resection at the intervertebral foramen and expanded intervertebral foramen by partial pediculectomy (*arrows*)

Recurrent radiculopathy is a serious problem following symptom improvement after decompression surgery. Chang et al. [3] reported that the incidence of residual or recurrent leg pain after decompression surgery was 21.7% in patients with foraminal stenosis, including foraminal disc herniation. In this study, the recurrence rate was 19.6%. Thus, the recurrence rates were similar despite different study populations. In our study, 89% patients with recurrent radiculopathy were those who had DLS. Among the patients with DLS, the Cobb angle difference between the standing and supine positions was significantly greater in the patients with recurrent radiculopathy than in those without it. The ROM of the affected level in lateral bending also tended to be higher in patients with recurrent radiculopathy than in those without it, whereas sagittal ROM did not differ between the two groups. These results suggest that the instability of the coronal curve affects the clinical outcomes of the surgical procedure. Hypermobility of the affected level, combined with scar tissue, may irritate the nerve root and cause recurrence. To prevent recurrent radiculopathy, sufficient decompression should be performed considering the dynamic instability, especially in patients with both DLS and its coronal instability.

Although the present study showed that the average outcomes of patients with DLS treated with decompression surgery were unsatisfactory, we believe that our foraminotomy technique can be applied to some patients with DLS because of the following reasons. First, it has been reported that fusion surgery for DLS has a relatively high complication rate than for other degenerative diseases such as spondylolisthesis [2, 4, 19]. Therefore, for patients who are poor candidates for massive spinal reconstruction surgery because of their general condition, our decompression technique is a treatment option. Second, DLS with a rigid curve may also be an indication for our decompression technique. The present study results showed that the patients with <3° Cobb angle difference between the supine and standing positions had no recurrence, and 70% patients achieved good or excellent outcomes. DLS with coronal instability may be an indication for fusion surgery, but it cannot be exactly determined from the present results. This study only showed the short-term outcomes and postoperative radiologic evaluation was performed only on the basis of the anteroposterior lumbar radiograms, with no total spine or pelvic radiograms. Further studies focusing on long-term follow-up, spinal balance, and influence of the pelvis will further clarify the conditions indicating decompression surgery.

## Conclusion

Less-invasive microscopic lumbar foraminotomy produced satisfactory clinical outcomes in 60.9% patients with DLFS, including even those with DLS. However, the outcomes of some patients with DLS were not equivalent to those of the patients without DLS. Radiological evaluation indicated that coronal instability might affect the clinical outcomes.

**Conflict of interest** No funds or grants were received in support of this work.

## References

1. Baba H, Uchida K, Maezawa Y, Furusawa N, Okumura Y, Imura S (1996) Microsurgical nerve root canal widening without fusion for lumbosacral intervertebral foraminal stenosis: technical notes and early results. Spinal Cord 34:644–650

2. Bono CM, Lee CK (2005) The influence of subdiagnosis on radiographic and clinical outcomes after lumbar fusion for degenerative disc disorders: an analysis of the literature from two decades. Spine (Phila Pa 1976) 30:227–234
3. Chang SB, Lee SH, Ahn Y, Kim JM (2006) Risk factor for unsatisfactory outcome after lumbar foraminal and far lateral microdecompression. Spine (Phila Pa 1976) 31:1163–1167
4. Cho KJ, Suk SI, Park SR, Kim JH, Kim SS, Choi WK, Lee KY, Lee SR (2007) Complications in posterior fusion and instrumentation for degenerative lumbar scoliosis. Spine (Phila Pa 1976) 32:2232–2237
5. Epstein NE (2002) Foraminal and far lateral lumbar disc herniations: surgical alternatives and outcome measures. Spinal Cord 40:491–500
6. Hallett A, Huntley JS, Gibson JN (2007) Foraminal stenosis and single-level degenerative disc disease: a randomized controlled trial comparing decompression with decompression and instrumented fusion. Spine (Phila Pa 1976) 32:1375–1380
7. Hirabayashi K, Watanabe K, Wakano K, Suzuki N, Satomi K, Ishii Y (1983) Expansive open-door laminoplasty for cervical spinal stenotic myelopathy. Spine (Phila Pa 1976) 8:693–699
8. Jenis LG, An HS (2000) Spine update: lumbar foraminal stenosis. Spine (Phila Pa 1976) 25:389–394
9. Jenis LG, An HS, Gordin R (2001) Foraminal stenosis of the lumbar spine: a review of 65 surgical cases. Am J Orthop 30:205–211
10. Kunogi J, Hasue M (1991) Diagnosis and operative treatment of intraforaminal and extraforaminal nerve root compression. Spine (Phila Pa 1976) 16:1312–1320
11. Nathan H, Weizenbluth M, Halperin N (1982) The lumbosacral ligament (LSL), with special emphasis on the “lumbosacral tunnel” and the entrapment of the 5th lumbar nerve. Int Orthop 6:197–202
12. Ozeki N, Aota Y, Uesugi M, Kaneko K, Mihara H, Niimura T, Saito T (2008) Clinical results of intrapedicular partial pediculectomy for lumbar foraminal stenosis. J Spinal Disord Tech 21:324–327
13. Park YK, Kim JH, Chung HS, Suh JK (2003) Microsurgical midline approach for the decompression of extraforaminal stenosis in L5–S1. J Neurosurg 98:264–270
14. Porter RW, Hibbert C, Evans C (1984) The natural history of root entrapment syndrome. Spine (Phila Pa 1976) 9:418–421
15. Sheehan JM, Helm GA, Kallmes DF, Bogaev CA, Jane JA (1997) Partial pediculectomy in the treatment of lumbar spinal stenosis: technical note. Neurosurgery 41:308–310
16. Weidenbaum M (2006) Considerations for focused surgical intervention in the presence of adult spinal deformity. Spine (Phila Pa 1976) 31:S139–S143
17. Weiner BK, Fraser RD (1997) Foraminal injection for lateral lumbar disc herniation. J Bone Joint Surg Br 79:804–807
18. Wiltse LL, Guyer RD, Spencer CW, Glenn WV, Porter IS (1984) Alar transverse process impingement of the L5 spinal nerve: the far-out syndrome. Spine (Phila Pa 1976) 9:31–41
19. Wu CH, Wong CB, Chen LH, Niu CC, Tsai TT, Chen WJ (2008) Instrumented posterior lumbar interbody fusion for patients with degenerative lumbar scoliosis. J Spinal Disord Tech 21:310–315