Clinical Outcomes and Postoperative Radiographic Assessment of Osteoplastic Hemilaminectomy in the Treatment of Lumbar Foraminal Nerve Root Compression

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Abstract:

Introduction: Osteoplastic hemilaminectomy for the treatment of lumbar foraminal nerve root compression is a safe technique as the exiting nerve root can be directly observed during neuroforaminal decompression without spinal fusion. Moreover, this procedure allows anatomical reconstruction of the posterior elements. However, there might be a potential risk for the progression of lumbar segmental instability after performing this procedure. This study aimed to review the radiographic and clinical outcomes of osteoplastic hemilaminectomy for the treatment of lumbar foraminal nerve root compression.

Methods: We retrospectively reviewed 51 patients who underwent osteoplastic hemilaminectomy with a minimum follow-up of 2 years. The clinical outcomes were evaluated using the visual analog scale (VAS) for low back pain, leg pain, and numbness and the Japanese Orthopaedic Association (JOA) score. Lumbar segmental instability was evaluated as a radiographic assessment using functional radiography. The mean follow-up period was 65 months.

Results: The preoperative VASs for low back pain, leg pain, and numbness were 46±31, 72±26, and 43±34, respectively, which were improved to 24±23, 19±23, and 19±23, respectively. The JOA score was also improved from 14±5 to 22±4. Three patients (5.9%) were reoperated due to recurrent disc herniation within 2 years following surgery. In addition, three patients (5.9%) developed postoperative lumbar segmental instability but did not require additional surgery.

Conclusions: The current study revealed that 94.1% of the patients who underwent osteoplastic hemilaminectomy achieved a significant improvement in the clinical outcomes and did not require additional surgery within 2 years following the procedure. Over a 5-year follow-up on average, 5.9% of the subjects developed postoperative lumbar segmental instability; however, they have maintained acceptable clinical conditions.

Keywords:
osteoplastic hemilaminectomy, lumbar foraminal nerve root compression, lumbar segmental instability

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Introduction

In the treatment of lumbar foraminal nerve root compression, neuroforaminal decompression is important in order to achieve favorable clinical outcomes. Facetectomy and intervertebral foraminotomy are acceptable procedures for adequate decompression. However, they could result in an unfortunate structural disruption and also require subsequent spinal fusion.

In recent years, microendoscopic and percutaneous endoscopic foraminotomy has become one of the treatment options for lumbar foraminal nerve root compression. Although this procedure is less invasive and is expected to preserve most of the facet joint and pars interarticularis of the lamina, operators need to have sufficient skills to perform the procedure; otherwise, nerve root injury, insufficient neuroforaminal decompression, and excessive facetectomy may occur according to narrow and inexperienced in operative field.

Osteoplastic laminectomy is a traditional decompressive

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surgical procedure of the lumbar spine. In 1952, osteoplastic laminectomy was established by Kondo in Japan[1] and was considered as one of the standard procedures for the treatment of lumbar disc herniation and lumbar canal stenosis[2,3]. In 1991, Kunogi employed osteoplastic hemilaminectomy for intraforaminal and extraforaminal root compressions[4]. This procedure is a safe technique by directly observing exiting nerve root during neuroforaminal decompression due to temporary excised hemilamina by cutting spinous process and pars interarticularis. In addition, it enables the reconstruction of the posterior-stabilized structures by recapping the excised hemilamina to the original position. However, only a few studies have investigated the long-term clinical and radiographic outcomes of this technique. Thus, whether osteoplastic hemilaminectomy poses a potential risk for the progression of lumbar segmental instability and maintains a good clinically recorded long-term outcome remain unclear. This study aimed to review the radiographic and clinical outcomes of osteoplastic hemilaminectomy in the treatment of lumbar foraminal nerve root compression with a minimum follow-up of 2 years.

Materials and Methods

This study was approved by the institutional review board of our institution. A total of 78 consecutive patients who underwent osteoplastic hemilaminectomy for lumbar foraminal nerve root compression between August 2000 and July 2017 in our hospital were retrospectively reviewed. Of the 78 patients, 51 (male, 25; female, 26; mean age, 59 [range: 26-81 years]) had sufficient clinical and radiographic data for analysis. The mean follow-up period was 65 months (24-156 months). All the patients had radiculopathy that was resistant to nonoperative treatments, including prescription of painkillers, physiotherapy, and nerve root injection. The preoperative diagnoses were based on neurological examination, selective nerve root injection, and magnetic resonance (MR) imaging. A decrease in or disappearance of perineural fat tissue surrounding the nerve root at the parasagittal MR images was the most suggestive finding of the foraminal lesions[5]. Computed tomographic (CT) discography was conducted as an additional imaging examination as it was difficult to make a definitive diagnosis using the MR images. The pathologies included single-level foraminal disc herniation in 44 patients, extraforaminal disc herniation in 4 patients, and foraminal stenosis in 3 patients. Preoperative surgical intervertebral disc degeneration was classified using the Pfirrmann grading system[6]. The prevalence of mild disc degeneration (grade III) was 29.4% (15/51 patients); moderate disc degeneration (grade IV), 68.6% (35/51 patients); and significant disc degeneration (grade V), 2.0% (1/51 patients), respectively.

The clinical outcomes were evaluated using visual analog scales (VAS) (0-100) for low back pain, leg pain, and leg numbness, as well as the Japanese Orthopaedic Association (JOA) score (−6-29) preoperatively and at the final follow-up[7]. The improvement in the JOA score was calculated as follows: (postoperative score-preoperative score) / (29-preoperative score)×100%. All the patients underwent single-level osteoplastic hemilaminectomy (L2 in 6 patients, L3 in 12 patients, L4 in 20 patients, and L5 in 13 patients). Four patients who were found to have adjacent spinal canal stenosis in the MR images underwent medial facetectomy following osteoplastic hemilaminectomy. The Wilcoxon signed-rank test was employed for statistical comparison, and $P<0.01$ indicated statistical significance.

The radiographic outcomes were evaluated *via* functional radiography preoperatively and at the final follow-up. The radiographic parameters that were assessed included the amount of translation, angular motion, and lateral disc space height. Translation was measured at the posterior aspect of the vertebral bodies, and the difference between flexion and extension was utilized. Angulation was measured as the difference in the disc space angle between flexion and extension. In addition, the lateral disc space height was measured at the middle disc space on the standing lateral radiograph. Based on the previous reports, lumbar segmental instability was defined as a translation difference of ≥4 mm or ≥5° posterior spreading in flexion position[8-10]. We also investigated the union rates of the spinous process and pars interarticularis *via* multiplanar reconstruction CT scan 2 years following surgery. Bone union was defined according to the osseous continuity between the osteoplastic lamina and host bone. The Wilcoxon signed-rank test was employed for statistical comparison, and $P<0.01$ indicated statistical significance.

Surgical technique

The midline posterior is exposed. Subperiosteal exposure of the spinous process and hemilamina is performed bases of the transverse process. The pars interarticularis and spinous process were cut using a stainless-steel threadwire saw, and the hemilamina is detached (Fig. 1). The facet joint capsules are cut using a scalpel. The use of an electrical scalpel should be avoided to prevent injury to the facet joint capsules. The medial and upper portions of the superior articular process and the ligamentum flavum are resected to obtain a better view of the foramen as required. In this procedure, it is important to cut the pars interarticularis as proximally as possible to directly observe the exiting nerve root. After herniotomy and neuroforaminal decompression, the excised hemilamina is reconstructed to the original position by being fixed to the spinous process with two poly-L-lactic acid screws (Fig. 2). The facet joint capsules are repaired with a non-absorbable suture. The patients are allowed to ambulate using orthosis the day after surgery. An orthosis is used for 2 to 4 months postoperatively during the bone healing process.

Results

Clinical outcomes

The mean operation time was 110 min (range: 68-180 min), and the mean intraoperative estimated blood loss was 73 mL (range: 10-350 mL). No major complications, such as dural tear, nerve root injury, and/or cauda equina deficit, were observed. The preoperative VASs for low back pain, leg pain, and numbness were 46±31, 72±26, and 43±34, respectively, which were improved to 24±23, 19±23, and 19±23, respectively, at the final follow-up. The individual differences of the VASs for low back pain, leg pain, and numbness were statistically significant in the Wilcoxon signed-rank test ($P<0.01$) (Fig. 3). The JOA score also improved from 14±5 to 22±4; the difference was statistically significant in the Wilcoxon signed-rank test ($P<0.01$) (Fig. 4). The improvement in the JOA score was 56.0%. Six patients (11.8%) were reoperated due to relapsed ipsilateral radiculopathy caused by recurrent disc herniation in three and foraminal stenosis in three (Table 1). Although reoperations for recurrent disc herniation were performed within 2 years following surgery, reoperations for foraminal stenosis were performed after more than 6 years. All the patients who required additional surgeries underwent transforaminal lumbar interbody fusion (TLIF), following adequate neuroforaminal decompression.

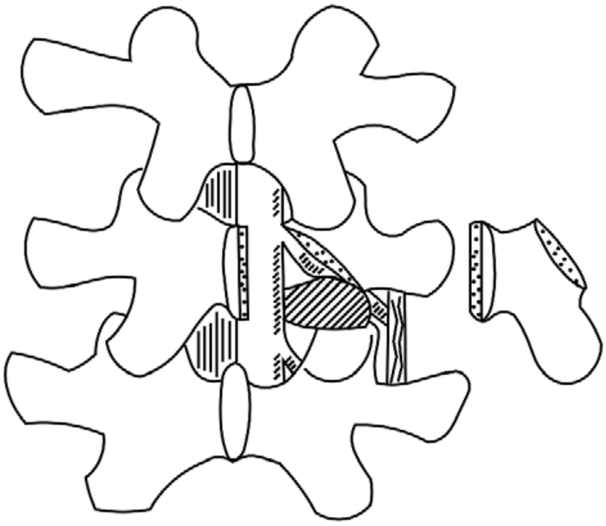

Figure 1. Cutting of the pars interarticularis and spinous process using a T-saw and detachment of the hemilamina.

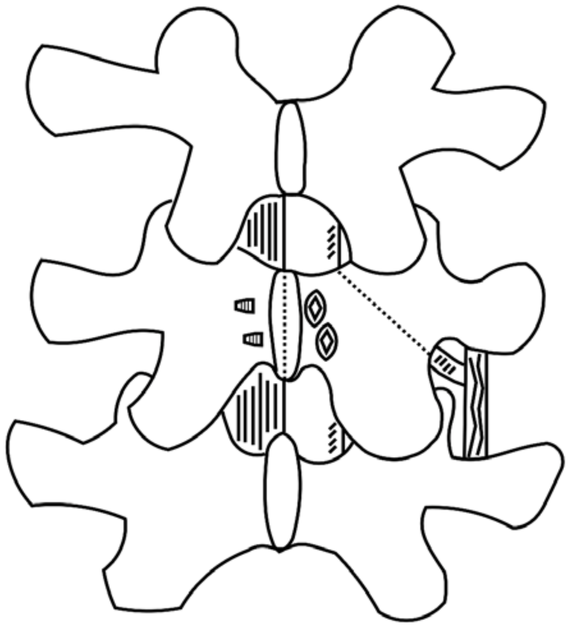

Figure 2. The excised hemilamina is reconstructed to the original position by being fixed to the spinous process with two poly-L-lactic acid screws.

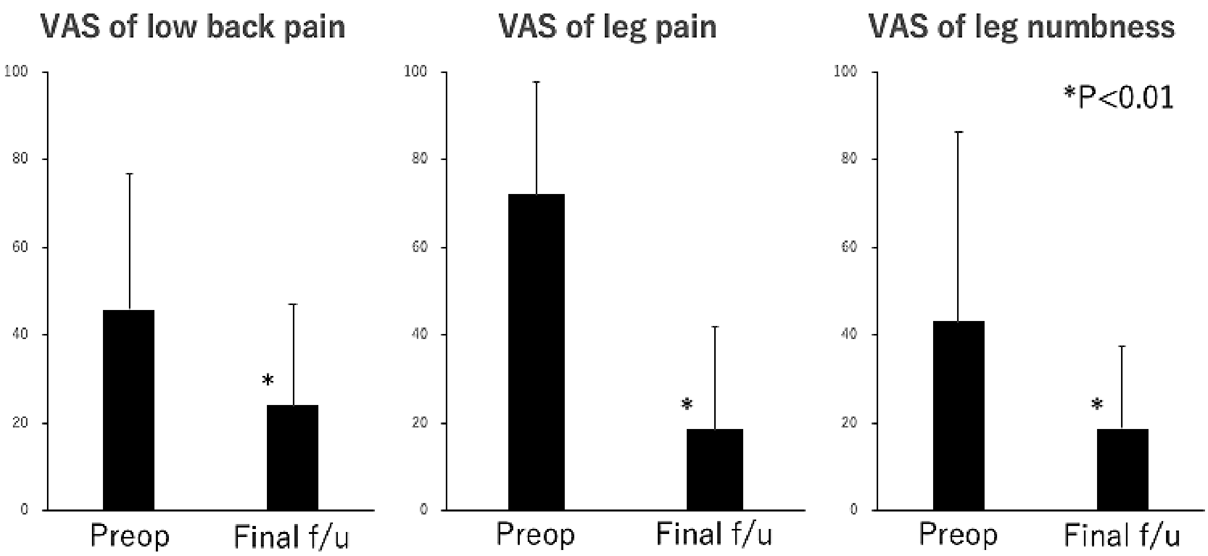

Figure 3. The preoperative visual analog scales (VASs) for low back pain, leg pain, and numbness were 46±31, 72±26, and 43±34, respectively, and significantly improved to 24±23, 19±23, and 19±23, respectively, at the final follow-up ($P<0.01$ in the Wilcoxon signed-rank test).

Radiographic assessment

The mean preoperative amount of translation was 0.4 mm (range: 0-3.7 mm), the angular motion was 8.1° (range: 1.9°-24.8°), and the lateral disc height was 9.0 mm (range: 4.4-12.9 mm). The mean postoperative amount of translation was 0.6 mm (range: 0-5 mm), the angular motion was 7.6° (range: 0.7°-15.9°), and the lateral disc height was 7.6 mm (range: 4.1-11.3 mm) at the final follow-up. No significant differences were observed between the preoperative and postoperative amounts of translation and angular motion in the Wilcoxon signed-rank test (*P*=0.126 and 0.890, respectively). However, the postoperative lateral disc height was significantly lower than the preoperative lateral disc height in the Wilcoxon signed-rank test (*P*<0.01) (Table 2). All the patients had no segmental instability in the preoperative functional radiography. Postoperative segmental instability at the operated level eventually occurred in three patients (5.9%) at the final follow-up (Table 3). Although two patients developed a translation difference of ≥4 mm (Fig. 5) and one patient developed a ≥5° posterior spreading in flexion position (Fig. 6), these patients did not require additional surgery. Radiographic bone union of the spinous process was achieved in 50 patients (98.0%), whereas bone union of the pars interarticularis was achieved in 31 patients (64.7%) in the CT scan 2 years following surgery. Patients with non-union of the pars interarticularis have also maintained acceptable clinical conditions (JOA score: 23/29, VAS for low back pain: 18/100, VAS for leg pain: 13/100, and VAS for leg numbness: 12/100) at the final follow-up. Three patients with postoperative segmental instability achieved bone unions of the pars interarticularis as well as the spinous process.

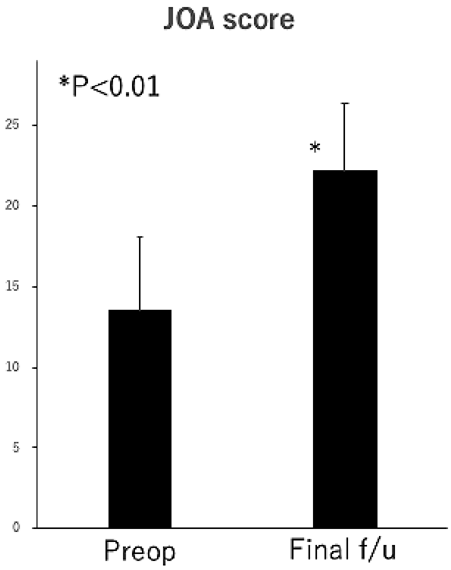

Figure 4. The Japanese Orthopaedic Association (JOA) score was 14±5 preoperatively and significantly improved to 22±4 at the final follow-up (*P*<0.01 in the Wilcoxon signed-rank test).

Discussion

In 1905, Bickham first introduced osteoplastic resection and laminectomy as new techniques for the exposure of the spinal cord and canal, which afforded anatomical reconstruction of the posterior elements[11]. In Japan, osteoplastic

Table 1. Patients who Required Additional Surgery.

	Age	Gender	Primary diagnosis	Second diagnosis	Time between primary and additional surgery (month)
1	42	Male	L4/5 FDH	L3/4 recurrent FDH	13
2	63	Female	L3/4 FDH	L3/4 FS	97
3	66	Male	L4/5 FS	L4/5 FS	77
4	64	Female	L5/S FDH	L5/S FS	79
5	46	Male	L5/S EFDH	L5/S recurrent EFDH	11
6	65	Male	L4/5 FDH	L4/5 recurrent FDH	6

FDH: Foraminal disc herniation
FS: Foraminal stenosis
EFDH: Extraforaminal disc herniation

Table 2. Radiographic Assessment.

	Preoperatively	Final follow-up	*P*-value
Amount of translation (mm)	0.4±2.0	0.6±2.4	*P*=0.126
Angular motion (°)	8.1±4.3	7.6±3.6	*P*=0.890
Lateral disc height (mm)	9.0±1.9	7.6±1.8	*P*<0.01[a]

[a] Statistically significant.

Table 3. Radiographic and Clinical Outcomes of Patients who Developed Postoperative Segmental Instability.

	Age	Gender	Diagnosis	Amount of translation (mm)		Angular motion		Disc angle in flexion		Lateral disc height (mm)		VAS of low back pain		VAS of leg pain		VAS of leg numbness		JOA score	
				Preop	Ff/u	Preop	Ff/u	Preop	Ff/u	Preop	Ff/u	Preop	Ff/u	Preop	Ff/u	Preop	Ff/u	Preop	Ff/u
1	63	Female	L5/S EFDH	0	5	12.6°	7.8°	2.2°	3.6°	10.2	7.6	48	35	98	14	31	14	6	22
2	79	Female	L4/5 FDH	2	2	1.9°	8.8°	0.5°	−5.5°	10.3	9.3	52	55	85	35	43	24	12	17
3	56	Female	L3/4 FDH	0	4	11.9°	8.6°	−1.4°	−0.6°	9.4	9.4	60	30	100	0	0	0	12	27

VAS: Visual analog scale, JOA: Japanese Orthopaedic Association

Preop: Preoperative, Ff/u: Final follow-up

FDH: Foraminal disc herniation, EFDH: Extraforaminal disc herniation

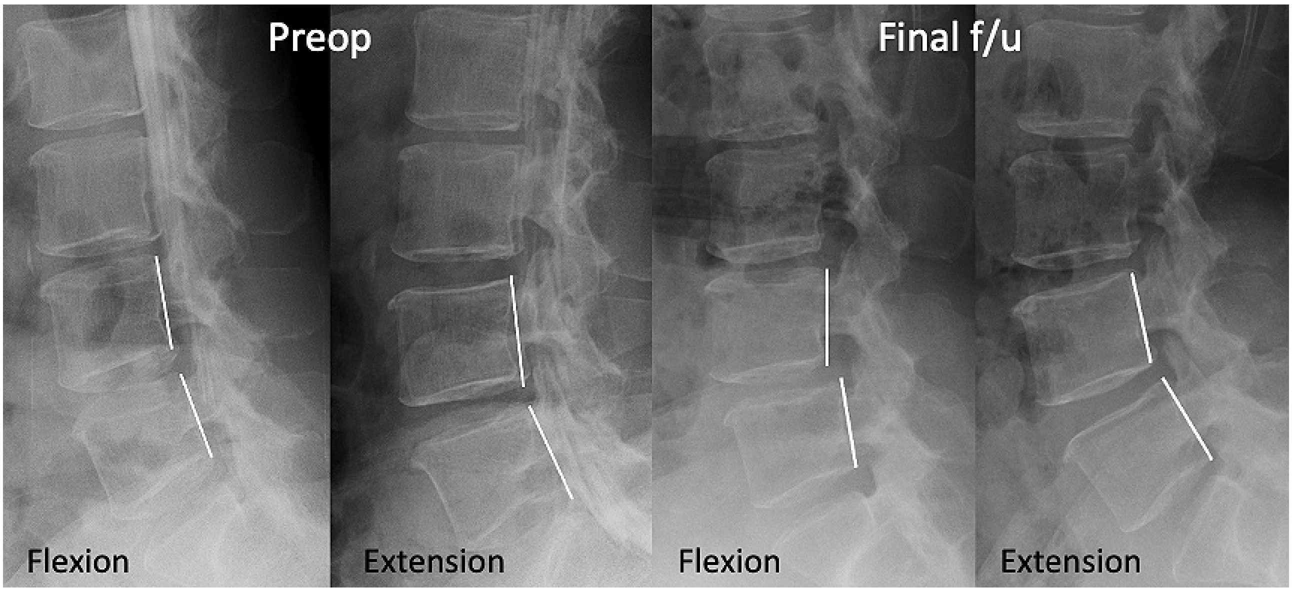

Figure 5. A case of postoperative anterolisthesis. This is a 56-year-old female who had undergone L4 osteoplastic hemilaminectomy. She did not have spondylolisthesis preoperatively. After 36 months, she developed a translation difference of 4 mm as observed on the lateral flexion and extension radiographs.

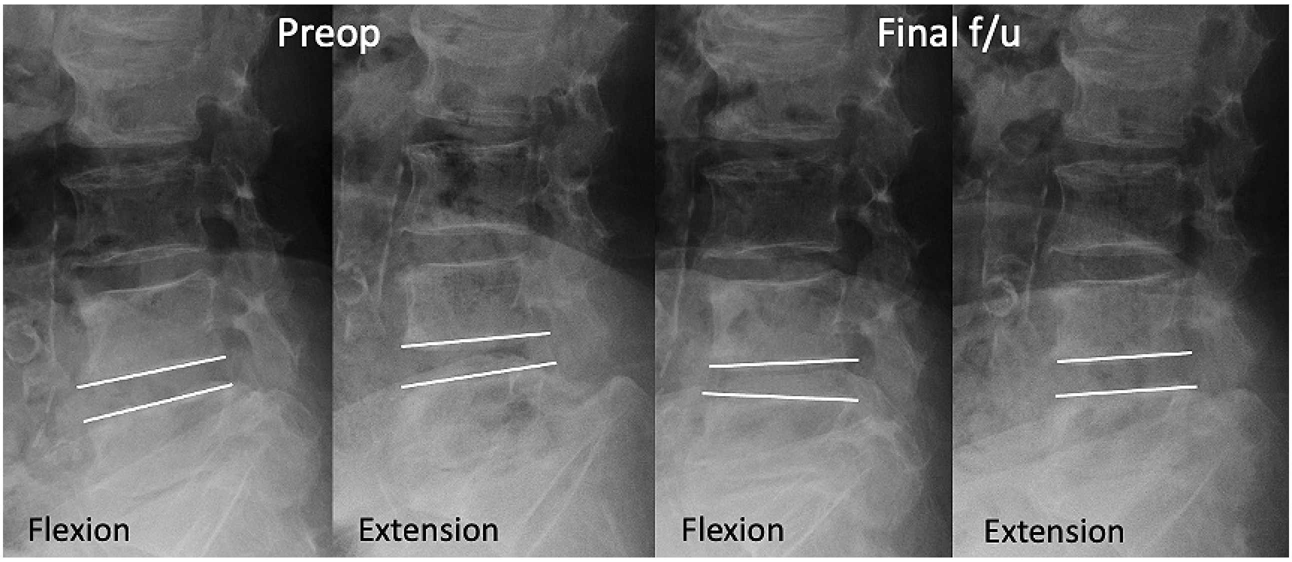

Figure 6. A case of postoperative segmental kyphosis. This is a 79-year-old female who had undergone L4 osteoplastic hemilaminectomy. She had kept segmental lordosis preoperatively. After 42 months, she developed a 5.5° posterior spreading as observed on the lateral flexion radiograph.

laminectomy for lumbar disc herniation was developed by Kondo in 1952[1]. Thereafter, osteoplastic laminectomy has been applied in several spinal pathologies, including lumbar spinal stenosis, foraminal nerve root compression, and spinal cord tumor successively[3,4,12]. Osteoplastic hemilaminectomy was introduced to our institution for lumbar foraminal nerve root decompression in 1998. One advantage of this technique is that it allows a comprehensive view of the exiting nerve root throughout the intraforaminal and extraforaminal zones and the preservation of most of the facet joint and pars interarticularis of the lamina. Li et al investigated the biological sequence of the reconstructed posterior elements in the lumbar spine of rabbits[13]. They revealed that osteoplastic laminectomy could prevent postoperative instability of the lumbar spine through the biological reconstruction of the posterior elements. Kunogi et al. reported that osteoplastic hemilaminectomy provided good clinical pain relief for foraminal nerve root compression[4]; however, they did not refer to the lumbar segmental instability after this procedure.

In our study, of the 48 patients who were diagnosed with extra- or intraforaminal disc herniation, 3 (6.2 %) were reoperated due to recurrent disc herniation. It has been reported that the reoperation rate for lumbar disc herniation with standard open discectomy is in the range of 6%-24%[14-17]. Thus, it seems that we have obtained a comparable reoperation rate for lumbar disc herniation by this procedure.

Recently, several studies have investigated the efficacy of minimally invasive surgery using microendoscope and percutaneous endoscope for the treatment of extraforaminal disc herniation and foraminal stenosis[18-22]. Ahn et al. reported that percutaneous endoscopic lumbar foraminotomy is a safe and effective technique for lumbar foraminal stenosis; however, there may be a learning curve for this technique, and the use of drill and punches under endoscopic control is unfamiliar to most spine surgeons[22]. Enyo et al. studied how much of the facet joint and the pars interarticularis can be removed in microendoscopic lateral decompression for lumbar foraminal stenosis in a biomechanical study[23]. They reported that the removal of no >50% of the facet joint or the lateral part of the pars interarticularis to prevent postoperative instability when using microendoscopic lateral decompression for lumbar foraminal stenosis would seem judicious. Considering these previous studies, it is likely that decision making of appropriate decompressive area is difficult if not operators must become skilled at the procedure. However, osteoplastic hemilaminectomy could provide familiar and comprehensive view of the exiting nerve root throughout the intraforaminal and extraforaminal zones. In our case series, no major complications, such as dural tear, nerve root injury, and excessive facetectomy, were observed.

Lumbar segmental instability at the operated level occurred in three patients (5.9%) at the final follow-up; however, these patients have maintained acceptable clinical conditions without additional surgeries. Thus, there was no association between postoperative segmental instability and deterioration of clinical conditions requiring additional surgery. However, of the 51 patients, 3 (5.9%) without segmental instability eventually underwent TLIF due to foraminal stenosis at the operated level more than 6 years after primary surgery. In our radiographic assessment, postoperative disc height significantly decreased. A decrease in disc height and even minimal postoperative instability might affect the pathologic condition of the nerve root at the foraminal zone in the long term. Hence, a rigid spinal fusion is recommended following adequate decompression at least in cases such as degenerative spondylolisthesis and degenerative lumbar scoliosis exhibiting preoperative instability associated with foraminal nerve root compression.

Little has been reported on degenerative changes and segmental instability following endoscopic surgeries for lumbar foraminal lesions. Yoshimoto et al. reported revision cases of microendoscopic decompression for lumbar foraminal stenosis at the 66.3-month follow-up on average[24]. In their case series, TLIF for the recurrence of foraminal stenosis at the same level was performed in two patients (10.0%) due to the progression of degenerative lumbar scoliosis and bone regrowth of the pedicle. Benzakour also reported that the reoperation rate following mini-open discectomy for lumbar disc herniation at the same level was 10.7% (recurrent disc herniation: 4.1%, segmental instability: 1.6%, and degenerative indications including discopathy, foraminal stenosis, or spondylolisthesis: 4.9%) at the 15-year follow-up[25]. These studies suggested that degenerative changes could occur after not only osteoplastic hemilaminectomy but also standard discectomy or microendoscopic surgery. Taken together, it is highly probable that osteoplastic hemilaminectomy does not pose a great risk for progression of segmental instability and degenerative disease.

This study has several limitations. The most significant one is the lack of a control group in which patients with lumbar foraminal nerve root compression were treated with other surgical methods or conservative treatment. It was not confirmed whether osteoplastic hemilaminectomy itself accelerated the progression of postoperative segmental instability. In addition, two criticisms related to the small sample size and low follow-up rate may arise. Of the 78 patients with a minimum follow-up of 2 years, only 51 (65.4%) who had sufficient clinical and radiographic data for analysis could be surveyed. The main reason for the low follow-up rate was that some young patients with favorable postoperative course did not approve to undergo radiographic examinations 2 years following surgery despite of the requesting office visits. Although the follow-up rate was low, the mean follow-up period was 65 months, which was significantly longer than those of other previous studies[3,4,26]. Moreover, this investigation included postoperative radiographic outcomes of osteoplastic hemilaminectomy. Minimally invasive techniques, such as microendoscopic and percutaneous endoscopic lumbar foraminotomy, are attractive and useful for spine surgeons in some cases; however, surgical complications must be prevented as much as possible. We believe that osteoplastic hemilaminectomy is a classic procedure but is still one of the requisite treatment options for lumbar foraminal nerve root compression.

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

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Author Contributions: Masaru Tanaka wrote and prepared the manuscript with support from Masahiro Kanayama, Yukitoshi Shimamura, Tsutomu Endo, and Fumihiro Oha. Masahiro Kanayama conceived the original idea, and all of the authors conceived the study concept and study design. Hiroyuki Hara, Takeru Tsujimoto, and Yuichi Hasegawa carried out statistical analysis. Tomoyuki Hashimoto, Hidetoshi Nojiri, and Muneaki Ishijima supervised the research project. All authors participated in interpretation of the results and writing of the report, and approved the final version.

Ethical Approval: The Institutional Review Board of Hakodate Central General Hospital approved the protocol followed in this study (approval code: 2016-30)

Informed Consent: Informed consent was obtained by all participants in this study.

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