Comparison of Modified Marmot Surgery and Lumbar Spinous Process Splitting Laminectomy in Lumbar Spinal Stenosis: Two-Year Outcomes

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Abstract:

Introduction: Compared with the conventional posterior lumbar decompression surgery, the spinous process splitting approach for lumbar spinal stenosis is less invasive. There are currently two types of the spinous process splitting approach that are performed. First is the lumbar spinous process splitting laminectomy (LSPSL), which involves the detachment of the spinous process from the lamina. Second is the modified Marmot method, which involves leaning of the spinous process without detachment from the lamina. To the best of our knowledge, this is the first study comparing the 2-year surgical outcomes of the modified Marmot method and LSPSL in cases of lumbar spinal canal stenosis.

Methods: We recruited 69 patients who underwent decompression surgery. A total of 32 patients underwent the modified Marmot method (M group), and 37 patients underwent LSPSL (S group). We compared the clinical results, laboratory data of surgical invasion, wound pain, and safety.

Results: No significant difference was observed in terms of the demographic data and operative time between the two groups. The number of decompressed segments and intraoperative and postoperative blood loss volume in the M group were greater than that in the S group. In the S group, the postoperative Japanese Orthopedic Association scores and recovery rates were significantly greater compared with those in the M group. Perioperative complications did not significantly differ between the two groups. On postoperative day 1, the Postoperative Visual Analog Scale scores at rest in the M group were lower than those in the S group.

Conclusions: In clinical practice, we believe that posterior lumbar decompression surgery is safe, effective, and minimally invasive. Although the modified Marmot method may be less invasive and result in the reduction of wound pain during early postoperative periods, the clinical results did not exhibit greater long-term improvements with regard to surgical complications and neurological improvement, when compared with LSPSL.

Keywords:

Activities of daily living, body mass index, failed back surgery syndrome, low back pain, lumbar spinous process splitting laminectomy, lumbar spinal stenosis, decompression, modified Marmot method

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Introduction

Numerous spine surgeons have performed multilevel subarticular fenestration during decompression surgeries for lumbar spinal stenosis (LSS)[1)]. However, some studies have reported that conventional lumbar surgery leads to postoperative paraspinal muscle atrophy due to intraoperative muscle injury and denervation[2,3)]. The spinous process splitting approach is a minimally invasive decompression surgery for LSS.

We currently perform two types of the spinous process splitting approach. The first approach involves the detachment of the spinous process from the lamina after spinous process splitting as well as suturing of the spinous process

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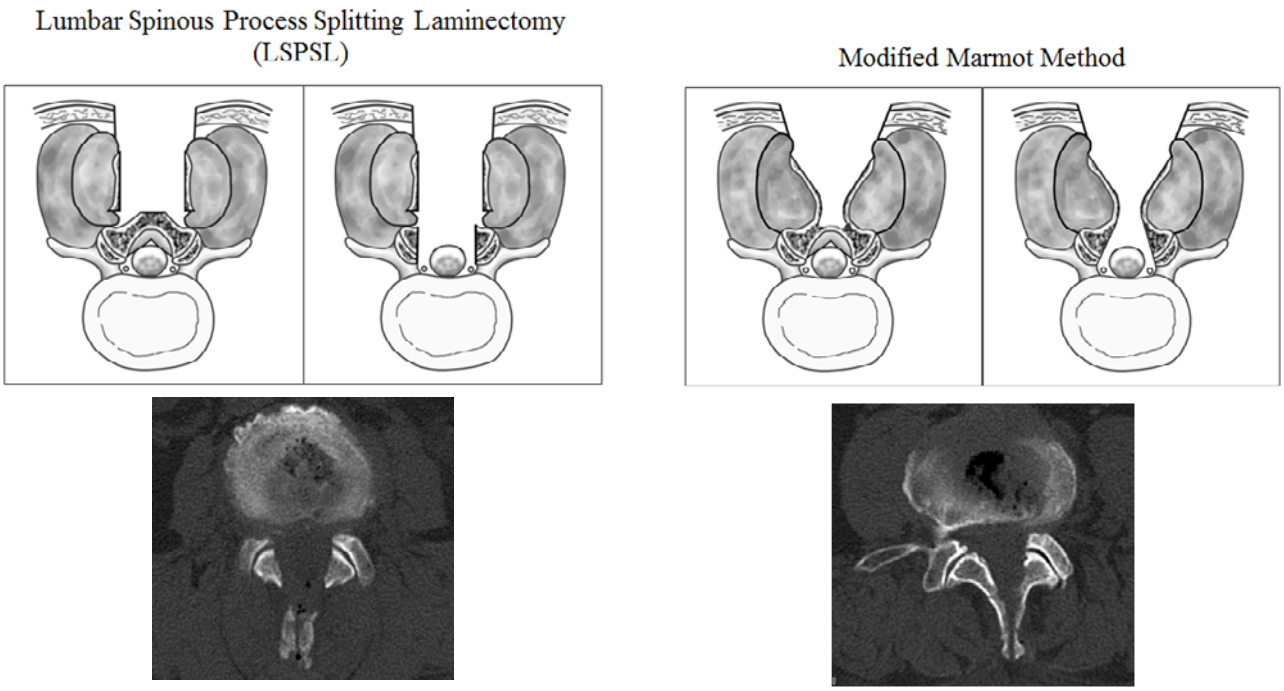

Figure 1. Lumbar spinous process splitting laminectomy and modified Marmot method.

after laminectomy; this approach is called lumbar spinous process splitting laminectomy (LSPSL)[4]. The second approach involves leaning of the spinous process after splitting without detachment from the lamina and execution of decompression obliquely to preserve the dorsal cortex of the lamina; this approach is called the modified Marmot method[5]. The schemas of these two approaches are presented in Fig. 1.

It has been reported that some types of the spinous process splitting approach for LSS are less invasive than the conventional posterior lumbar decompression surgery[4-12]. This is because the spinous process splitting approach preserves the attachment of the paraspinal muscles and ligaments. A comparison of the surgical outcomes after the application of the modified Marmot method and after LSPSL has not yet been performed. Thus, this study aimed to compare the clinical outcomes between LSS patients who underwent the modified Marmot and those who underwent LSPSL.

Materials and Methods

Study design

This study is a retrospective cohort study and was approved by our Institutional Ethics Committee. Informed consent was obtained from the participants.

Inclusion and exclusion criteria

The present study recruited patients who were diagnosed with LSS and considered eligible for surgical treatment. Patients with LSS who underwent decompression surgery between October 2014 and April 2017 were included. The inclusion criteria were (i) patients older than 20 years, (ii) patients with symptomatic LSS with one or more clinical signs or related symptoms of the cauda equine syndrome or radiculopathy, and (iii) patients with imaging findings of lumbar spinal canal stenosis, failure of conservative treatment, and no previous surgery for LSS. The exclusion criteria were (i) previous spine surgery, trauma, and spondylolisthesis requiring spinal fusion surgery. In this study, a minimum 2-year follow-up of operatively treated patients with LSS was conducted.

A total of 81 consecutive patients with LSS were recruited in this study. After excluding 12 patients who were lost to follow-up, the clinical data (follow-up ratio: 85%) of 69 patients were analyzed. The patients were divided into two groups: 32 patients underwent the modified Marmot method (M group), and 37 underwent LSPSL (S group). All surgical procedures were performed by spine specialists. Although the number of decompressed segments was discussed in a spine team conference before surgery, the number was finally determined by the chief surgeon based on symptoms and radiological findings. Acetaminophen was administered by infusion until 24 h following surgery, and then, acetaminophen or non-steroidal anti-inflammatory drugs (NSAIDs) were administered orally according to the complaint of wound pain. Moreover, regular oral administration was not performed. Both groups were included in the same rehabilitation program following surgery.

Surgeons

In this study, four spinal surgeons who had at least 5 years of clinical experience and were certified orthopedic specialists in Japan performed all surgeries. Two of them performed LSPSL, and the other two performed the modi-

Table 1. Demographic and Perioperative Data.

	S group	M group	*P*-value
Number of patients	37	32	
Sex (male/female)	1.6:1	1.3:1	0.62
Age (years)	69.0 (61.0–73.5)	72.5 (64.5–78.0)	0.06
BMI (kg/m^2)	24.7 (21.5–26.9)	24.0 (22.2–25.9)	0.55
ASA PS	2 (2–3)	2 (2–3)	0.32
Decompression segments	2.1 (1.8,2.4)	2.9 (2.6,3.2)	<0.05
Operative time (min)	157 (120.5–195.5)	151 (138.3–184.0)	0.69
Intraoperative blood loss (mL)	50 (0.0–130.0)	100 (38.3–243.8)	<0.05
Days of drainage (days)	1 (1–1)	1 (1–1)	0.57
Postoperative blood loss (mL)	168 (91.5–224)	195 (142.5–300)	<0.05

BMI: Body mass index
ASA PS: American Society of Anesthesiologists Physical Status
S group: Lumbar spinous process splitting laminectomy group
M group: Modified marmot method group

fied Marmot method.

Measurement

Both groups were evaluated and compared according to four types of outcomes. First, the clinical outcomes of neurologic deficits and activities of daily living were measured. The Japanese Orthopedic Association (JOA) score and Oswestry Disability Index (ODI) score were calculated preoperatively and at 3, 6, 12, and 24 months postoperatively. In addition, the recovery rate was calculated using the JOA score. Second, we measured the degree of surgical invasion, which was determined by operative time and intraoperative and postoperative blood loss. The levels of serum C-reactive protein and creatine phosphokinase were measured on postoperative days 1, 4, and 7. Third, we assessed the wound pain using the Visual Analog Scale (VAS) on postoperative days 1, 4, 7, and 14. Fourth, we assessed the safety in terms of perioperative complications.

Statistical analyses

Statistical analyses were conducted using SPSS version 24.0 (SPSS Japan Inc., Tokyo, Japan) and easy R(EZR) (Saitama Medical Center, Jichi Medical University, Saitama, Japan). The Shapiro-Wilk test was first conducted to determine the normality of data. The nonparametric variables were analyzed using the Mann-Whitney U test and Kruskal-Wallis test with the Steel-Dwass *post hoc* test. The parametric variables were analyzed using Student's t-test and one-way ANOVA with Tukey's *post hoc* test. Frequency analyses were conducted using the chi-squared test and Fisher's exact probability test. All *P*-values<0.05 were considered statistically significant.

Power analysis

A *post hoc* power analysis was conducted to determine the number of samples required to detect a significant difference between the JOA scores. This analysis assumed a mean difference of 3 (sigma, 5.1) in the JOA score. To achieve a power of 0.80 with an alpha of 0.05 using two-tailed t-tests, a sample size of 46 was required for the JOA score.

Results

In this study, a total of 69 patients were enrolled: 32 patients in the M group and 37 patients in the S group. The demographic and perioperative data are presented in Table 1. The median age was 72.5 years in the M group and 69.0 years in the S group (p=0.06). The male-to-female ratio was 1.3:1 in the M group and 1.6:1 in the S group (p=0.62). In addition, the median body mass index was 24.0 in the M group and 24.7 in the S group (p=0.55). In both groups (p=0.32), the median American Society of Anesthesiologists Physical Status (ASA PS) was 2. No significant difference was observed in the demographic data between the two groups. Moreover, the operative time did not significantly differ between the two groups (p=0.69). In the M group, the intraoperative and postoperative blood loss volume was significantly larger compared with that in the S group (p<0.05). The median postoperative drainage days was 1 in both groups (p=0.57). The number of decompressed segments in the M group was significantly higher than that in the S group (p<0.05). The postoperative clinical outcomes are presented in Table 2. In both groups, following surgery, the JOA score and ODI score significantly improved at each time point compared with the preoperative scores. The preoperative JOA scores did not significantly differ between the two groups. The JOA scores at 6 and 24 months postoperatively and the recovery rates at 6, 12, and 24 months postoperatively in the S group were significantly greater than those in the M group. The ODI scores at each time point did not significantly differ between the two groups. The laboratory data of surgical invasion are presented in Table 3. Except for C-reactive protein on postoperative day 1, the laboratory parameters did not significantly differ between the two groups at each time point. Table 4 presents a description of postoperative wound pain. The VAS score at rest

Table 2. JOA Scores and ODI of Clinical Outcomes.

	S group	M group	*P*-value
JOA score (points)			
Preoperative	14 (11–17)	14.5 (10.3–19)	0.99
3 months	25 (22–26)	21.5 (17–25.8)	0.21
6 months	25 (22–27)	21.5 (17–25)	<0.05
12 months	25 (22–27)	21.5 (18.3–26.8)	0.06
24 months	25 (23–26.5)	20 (15.3–25.8)	<0.05
Recovery rate (%)			
3 months	70.6 (48.5–77.9)	62.1 (30.8–79.2)	0.18
6 months	66.7 (58.6–87.1)	50 (32.2–69.7)	<0.05
12 months	71.7 (56.3–85.4)	50 (33.3–77.7)	<0.05
24 months	66.7 (58.9–77.5)	37.2 (10.6–69.9)	<0.05
ODI (%)			
Preoperative	45 (37.5–62.5)	52 (31–59.5)	0.95
3 months	22.3 (14.5–36.6)	30 (13.4–51.2)	0.38
6 months	20 (8–40)	36 (22.3–54.5)	0.07
12 months	20 (10–42.3)	28.9 (17.0–37.8)	0.47
24 months	24.5 (8.9–35.6)	40.1 (22.2–61.9)	0.08

JOA score: Japanese Orthopaedic Association score
ODI: Oswestry Disability Index
S group: Lumbar spinous process splitting laminectomy group
M group: Modified marmot method group

Table 3. Laboratory Data for Surgical Invasion.

	S group	M group	*P*-value
CRP (mg/dL)			
Preoperative	0.1 (0–0.1)	0 (0–0.1)	0.76
POD 1	1.0 (0.5–1.4)	1.5 (0.8–2.4)	<0.05
POD 4	3.3 (2.0–6.4)	4.7 (3.0–8.1)	0.24
POD 7	0.9 (0.6–1.7)	1.2 (0.8–1.7)	0.29
CPK (IU/L)			
Preoperative	136.5 (79.8–196.5)	122 (84–173.8)	0.78
POD 1	159 (104–220.5)	155 (108.3–270.5)	0.93
POD 4	112 (64.5–164)	108.5 (75.3–184)	0.49
POD 7	75 (40–116.5)	67 (42–122)	0.95

POD: Postoperative day; CRP: C-reactive protein; CPK: Creatine phosphokinase
S group: Lumbar spinous process splitting laminectomy group
M group: Modified marmot method group

at postoperative day 1 in the M group was significantly less than that in the S group ($p<0.05$). At other time points, the postoperative VAS score did not differ between the two groups. With regard to the complications, the M group had one case of hematoma and three cases of dural tears, and the S group had one case of hematoma, one case of surgical site infection, and one case of dural tear. These complications did not significantly differ between the two groups.

Discussion

Spine surgeons are familiar with the conventional bilateral fenestration reported by Lin et al. in 1982[13]. This procedure can preserve the posterior ligaments and facet joints. However, it requires the detachment of the paraspinal muscles from the spine, which causes muscle damage and denervation. Muscle damage and denervation, in turn, may lead to postoperative muscle atrophy, residual low back pain, and failed back surgery syndrome (FBSS)[2,3,14]. Therefore, numerous less-invasive surgeries have been reported, such as bilateral decompression *via* the unilateral approach, microdecompression, and microendoscopic posterior decompression[15-17]. However, such procedures may cause at least unilateral paraspinal muscle damage. To overcome this drawback, LSPSL was reported by Watanabe et al. in 2005[4]. This approach can prevent intraoperative paraspinal muscle damage and postoperative muscle atrophy bilaterally. In addition, the modified Marmot method was reported by Kawakami et al. in 2013[5]. This approach can prevent floating of the spinous process complex, which might affect the physiological function of the paravertebral muscle.

Table 4. Postoperative Wound Pain Assessed by the Visual Analogue Scale.

	S group	M group	*P*-value
Pain at rest			
POD 1	4.5 (3.0–5.6)	2.0 (0.8–4.3)	<0.05
POD 4	1.6 (1.0–2.0)	2.0 (0.0–3.8)	0.75
POD 7	0.9 (0.0–2.0)	2.0 (0.2–4.0)	0.06
POD 14	0.7 (0.0–1.3)	1.4 (0.0–4.3)	0.47
Pain with movement			
POD 1	5.7 (2.5–7.2)	5.5 (4.8–7.0)	0.70
POD 4	4.5 (1.5–7.0)	4.0 (2.9–7.0)	0.61
POD 7	2.0 (1.0–6.0)	3.0 (1.0–5.0)	0.71
POD 14	1.5 (0.0–4.5)	2.0 (0.0–5.9)	0.98

POD: Postoperative day
S group: Lumbar spinous process splitting laminectomy group
M group: Modified marmot method group

LSPSL is an easy approach and provides a wide view because the spinous process is detached from the lamina and is spread on both sides. Conversely, the modified Marmot method is a difficult approach and provides a narrow view because the spinous processes are leaned without being detached from the lamina. We expect the modified Marmot method to reduce paraspinal muscle damage and postoperative pain as this procedure preserves the paraspinal muscles and spinous processes. Indeed, the VAS score at rest on postoperative day 1 in the M group was significantly less than that in the S group.

However, in this study, the JOA scores at 6 and 24 months postoperatively and the recovery rates at 6, 12, and 24 months postoperatively in the S group were significantly greater than those in the M group. We speculated a few key factors. First, the JOA scores and recovery rates following surgery were low in the M group with intraoperative dural tears. Saxler et al. reported that the long-term results of surgery complicated by dural injury were worse than those of surgery not complicated by dural injury[18]. Second, the ef-

fects of foraminal stenosis following central decompression surgery may have occurred in the M group. This is because the narrow view can cause incomplete decompression, especially in lateral recess, and a large number of decompressed segments in the M group, which might result in insufficient improvement. Most laboratory data did not differ between the groups. The results indicated that both surgical procedures were minimally invasive. The VAS score at rest at postoperative day 1 in the M group was significantly less than that in the S group. Therefore, the modified Marmot method may reduce postoperative pain. However, it was feared that the modified Marmot method might cause numerous complications due to the narrow view and technical difficulties. Although no statistically significant difference was observed in perioperative complications between the two groups, the ratio of dural tears in the M group was 9.4% (3/32 cases). This ratio was higher than that in previous reports[19,20]. We consider that the method used in the M group required a highly technical skill.

This study had some limitations, such as the retrospective study design, the small number of enrolled cases, the different numbers of decompressed segments between the groups, and a lack of radiological analysis of the paraspinal muscles. To explore the efficacy of these surgical procedures in spine surgery, further research is required.

In conclusion, the clinical results of the modified Marmot method for LSS were not better than those of LSPSL in this study. Although the modified Marmot method potentially reduces wound pain during the early postoperative period, it is a difficult approach and provides a narrow view. Therefore, LSPSL can be considered a more reasonable method for LSS.

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

Ethical Approval: This study was approved by Nara Medical university Institutional Ethics Committee (approval number: 1930).

Author Contributions: Hideki Shigematsu: the conception of the work

Keisuke Masuda: the design of the work, drafting the work

Masato Tanaka: the acquisition of data

Sachiko Kawasaki: the acquisition of data

Yuma Suga: the acquisition of data

Yusuke Yamamoto: the analysis of data

Eiichiro Iwata: the acquisition of data

Yasuhito Tanaka: the interpretation of the data

Informed Consent: Informed consent was obtained from the participants.

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