



# Comparative study of two spinous process (SP) osteotomy techniques for posterior decompression surgery in lumbar spinal stenosis: SP base versus splitting osteotomy

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## Abstract

**Purpose** To compare the postoperative clinical and radiological outcomes of the SP base osteotomy versus SP splitting techniques for PD for treating LSS.

**Methods** Of 139 patients who underwent PD surgery for LSS, 97 who met the study criteria were enrolled in the study. Group A comprised 53 patients who underwent SP base osteotomy, and group B included 44 patients who underwent SP splitting osteotomy. The primary study endpoint was intensity of lower back pain (LBP) and pain radiation to the lower extremities measured with the visual analogue scale (VAS). Secondary endpoints included (1) clinical outcomes assessed using Oswestry disability index and 12-short health form questionnaire; (2) surgical outcomes; and (3) procedure-related complications.

**Results** LBP was more or less greater in SP base osteotomy group than in SP splitting osteotomy group at postoperative 1 week and 1 year ( $P = 0.04$  and  $0.03$ ), but radiating pain was no significant difference between the groups throughout the 1-year follow-up period. One year after the surgery, the fusion rate at the osteotomized site was significantly greater in SP splitting osteotomy group (77%) than in SP base osteotomy group (55%) ( $P = 0.03$ ). Clinical outcomes, surgical outcomes, and complications did not differ significantly between groups during follow-up times.

**Conclusions** The two SP osteotomy techniques offer excellent clinical and radiological outcomes at least for the first year after the surgery. In fusion rate at the osteotomized SP site, the SP splitting technique was superior to the SP base osteotomy technique.

**Graphical abstract** These slides can be retrieved under Electronic Supplementary Material.

The graphical abstract consists of three slides from the Spine Journal. The first slide, titled 'Key points', lists: 1. Spinal stenosis, 2. Posterior decompression, 3. Spinous process (SP) osteotomy, 4. SP Base osteotomy, and 5. SP Splitting osteotomy. The second slide shows two diagrams: 'SP base osteotomy' and 'SP splitting osteotomy', each with sub-diagrams A, B, and C. The third slide, titled 'Take Home Messages', contains three points: 1. Among SP osteotomy techniques for posterior decompression surgery in lumbar spinal stenosis, SP base osteotomy and SP splitting osteotomy was mainly utilized. However, no study has compared the outcomes of the two SP osteotomy techniques thoroughly. 2. In conclusion, the 2 SP osteotomy technique offer excellent clinical and radiological outcomes at least for the first year after the surgery. 3. In fusion rate at the osteotomized site of SP, SP splitting technique was superior to SP base osteotomy technique.

**Keywords** Spinal stenosis · Posterior decompression · Spinous process · Base osteotomy · Splitting osteotomy

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Extended author information available on the last page of the article

## Introduction

Posterior decompression (PD) surgery is a standard procedure for treating lumbar spinal stenosis (LSS), and sufficient clinical and radiological improvements are achieved with

this procedure [1–4], but it is also associated with significant drawbacks related to the detachment and injury of the back muscles [1, 2, 5–7]. These complications can lead to persistent postoperative back pain, segmental instability, and failed back surgery syndrome, and in some cases, additional surgery is required [1, 2, 7–9]. Consequently, spine surgeons have sought new methods for performing PD surgery such as spinous process (SP) osteotomy techniques that preserve the back muscles with increasing surgical exposure.

To minimize back muscle injury during PD surgery, several SP osteotomy techniques have been developed, with the main differences being the location of the SP osteotomy and the degree of back muscle preservation [1, 4, 5, 10–20]. One of the most widely performed techniques is SP base osteotomy, presented by Fraser RD et al. [15] in 1993 and Weiner et al. [16] in 1999, which involves osteotomy at the SP base after detachment of unilateral back muscles, enabling sufficient bilateral decompression; however, this procedure is also associated with back muscle injury to some extent. Another procedure is the SP splitting technique, introduced by Watanabe et al. [11] in 2005, which involves a split longitudinally from the SP dorsal surface without back muscle detachment, but this procedure is also associated with some risks, including inadequate osteotomy and supraspinatus ligament injury. Furthermore, this procedure is technically demanding. The use of either of these two SP osteotomy techniques for PD for the treatment of LSS relies on the preference of surgeons, which is usually based on positive results reported for these procedures in the literature. However, to our knowledge, no study has compared the postoperative clinical and radiological outcomes of these two SP osteotomy techniques for LSS. Herein, we used a retrospective comparative study design to evaluate the clinical and radiological outcomes of the SP base osteotomy technique and SP splitting osteotomy technique for PD for treating LSS.

## Methods

### Patients

This retrospective comparative study evaluated the postoperative clinical and radiological outcomes of the SP base and SP splitting osteotomy techniques during PD for treating LSS. The institutional review board of the corresponding author's hospital approved our study. Between January 2007 and March 2016, 139 patients underwent SP base or splitting osteotomy technique in PD surgery. Until May 2011, SP base osteotomy technique was performed whenever posterior decompressive surgery was needed for LSS. However, starting June 2011, the surgeons used SP splitting osteotomy as preferred technique, because of their confidence about the SP splitting osteotomy.

LSS was diagnosed according to the following criteria: (1) obvious clinical manifestations, such as lower back pain (LBP) and claudication, in patients who routinely had simple radiographs taken of the lumbar spine, including anteroposterior, lateral, dual oblique, and dynamic (flexion and extension) images; (2) confirmed pathological presence of LSS and exclusion of other spinal pathologies, such as infection or tumor, by computed tomography (CT) and magnetic resonance imaging (MRI) of the lumbar spine.

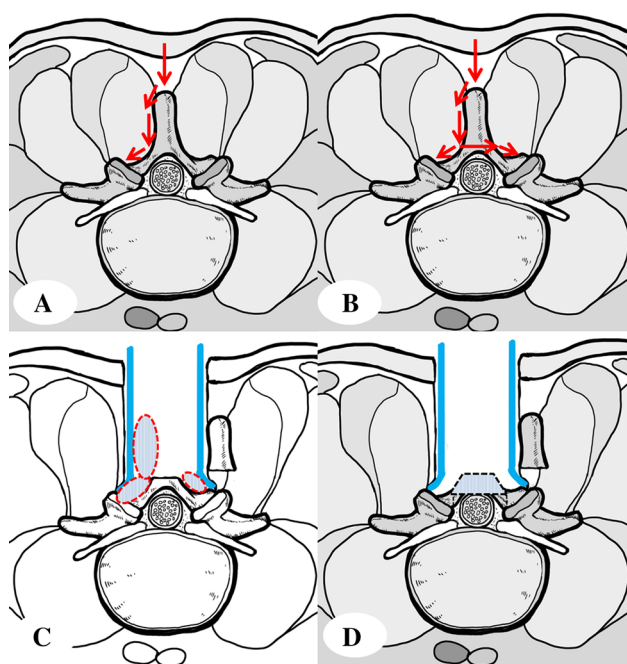
All enrolled patients met the study inclusion and exclusion criteria. Inclusion criteria were as follows: (1) a diagnosis of LSS on the basis of radiographs, CT, and/or MRI of the lumbar spine that was consistent with the clinical manifestations described above; (2) failure of conservative treatment after at least 6 months of treatment that included medication, physical treatment, rehabilitation, and injection treatments; (3) age between 40 and 80 years old; (4) the use of one of the two osteotomy techniques for PD; and (5) completion of follow-up for at least 1 year after the surgery. Patients who met any of the following criteria were excluded as follows: (1) lumbar spine fracture, infection, or tumor; (2) postoperative follow-up period of less than 1 year; (3) abnormal muscle activity or ambulation, such as that caused by parkinsonism or neuromuscular disease; (4) additional fusion and/or instrumentation surgery; and (5) inaccurate or missing data on pre or postoperative questionnaires.

Based on our study criteria and policy, we reviewed retrospectively our patients who underwent PD surgery during reference period. Finally, among a total of 139 patients who underwent PD surgery for LSS, 97 patients who underwent PD surgery with either the SP base or SP splitting osteotomy techniques and met the study criteria were enrolled in our study. Group A comprised 53 patients who underwent SP base osteotomy, and group B included 44 patients who underwent SP splitting osteotomy.

### Surgical techniques and postoperative protocol

All surgical procedures were performed by two orthopedic professors (spine specialist; M.-W. Ahn and G. W. Lee) who applied the same procedures and techniques. Surgery was performed by making a standard posterior midline skin incision at the operative segment.

In the SP base osteotomy group, the unilateral back muscle from the more affected side (left versus right) was detached from the SP, and the surgeon performed osteotomy at the SP base using a curved osteotome. A minimal portion of the bilateral back muscle from the lamina was also detached. The osteotomized SP was retracted to perform the PD procedure, including a partial laminectomy, ligamentum flavum excision, and medial facetectomy, when necessary. After decompression, the retracted SP was repositioned to its preoperative location with no fixation (Fig. 1).



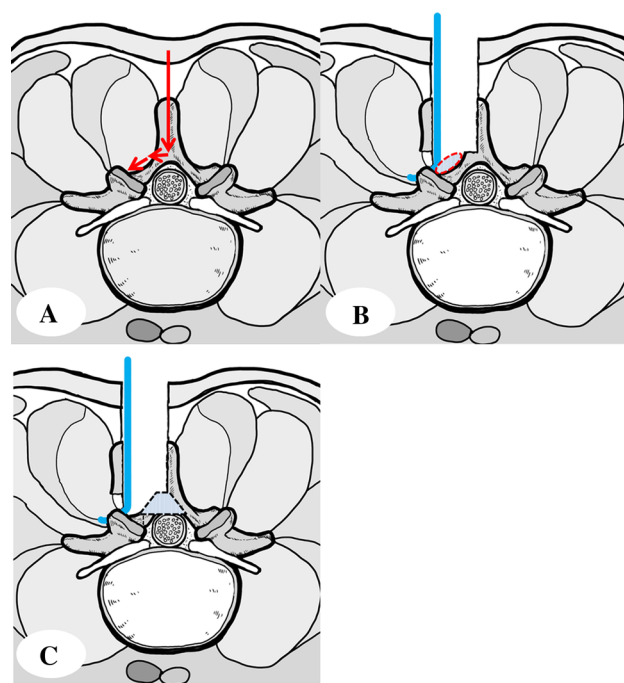
**Fig. 1** SP base osteotomy. **a** After skin incision, back muscles at the affected side were detached unilaterally from the SP. **b** SP base was osteotomized with a curved osteotome, and then retracted contralaterally. **c** Only small portion of the bilateral back muscles (area with red dotted line) was detached from the lamina and spinous process. **d** After then, PD procedure, including a partial laminectomy, ligamentum flavum excision, and medial facetectomy if necessary, was performed

In the SP splitting group, after the skin incision was made, the dorsal surface of the affected SP was exposed and split longitudinally using a surgical oscillating saw. The surgeon then fractured the base of the split SP on the symptomatic side and retracted it using a self-retractor. The PD procedure was carried out in a similar manner as described above for the SP base osteotomy. To allow decompression to be performed on the contralateral side, the SP base and the contralateral lamina were decancellated followed by resection of the ligamentum flavum. Contralateral medial facetectomy was performed when necessary. After sufficient decompression was achieved, the retracted SP was repositioned, and a Vicryl 1-0 suture was used for attachment (Fig. 2).

All patients were permitted to ambulate on the first day after surgery, and lumbo-sacral orthosis was maintained for 1 month after surgery. Patients were not permitted to sit for long periods of time during the first month after the surgery. After 3 months, patients were allowed to resume normal activities, including heavy lifting.

### Outcome measures

The primary post-treatment outcome measure was intensity of LBP and pain radiation to the lower extremities measured



**Fig. 2** SP splitting osteotomy. **a** After skin incision, the dorsal surface of the affected SP was exposed and split longitudinally using a surgical oscillating saw. **b** The base of the split SP on the symptomatic side was fractured and retracted using a self-retractor. A minimal portion of the back muscle (area with red dotted line) was detached from the lamina. **c** After then, PD procedure was carried out in a similar manner. To perform on the contralateral side, the SP base and the contralateral lamina were decancellated followed by resection of the ligamentum flavum

with the Visual Analogue Scale (VAS). The VAS score was obtained preoperatively, weekly for the first month after surgery, and then at 3, 6, and 12 months postoperatively. Patients were instructed to mark a horizontally oriented 10-point VAS ranging from “no pain; 0 points” at the far left to “greatest pain; 10 points” at the far right. Patients were not allowed to review their previous scores.

Secondary endpoints included clinical and radiological outcomes, surgical outcomes, and procedure-related complications. We evaluated the clinical outcomes with the Oswestry disability index (ODI) and a 12-item short form health survey (SF-12), and scores were obtained preoperatively and at 3, 6, and 12 months postoperatively. The SF-12 questionnaire responses, which consisted of physical component summary (PCS) scores and mental component summary (MCS) scores, were recorded and evaluated separately. The radiological outcome, i.e., the union status of the osteotomized SP site, was determined from radiographs (anteroposterior, lateral, dual oblique views, and flexion and extension dynamic images) at the 1-year postoperative time point. Healing at the osteotomy site was defined as the verification of a definite continuity at

the osteotomized site and no motion observed on dynamic radiographs, while nonunion was defined as no observation of a definite continuity on simple radiographs, definite motion observed on dynamic radiographs, or an inconclusive state. The healing status was verified by complete agreement of three orthopedic spine surgeons who were not involved in patient treatment and who was blinded to the patients' clinical information performed all measurements. Additionally, any problems or complications during the surgery or the follow-up period were thoroughly recorded.

## Statistical analyses

We used independent Student *t* tests, one-way or repeated measured analysis of variance (ANOVA) test for continuous variables and Fisher's exact tests for proportional variables. GraphPad Prism program (version 7.01 Graph Pad Software, Inc., San Diego, USA) was used for all statistical analyses, and a two-sided *P* value < 0.05 was considered statistically significant.

## Results

### Population

A total of 97 patients who underwent PD surgery with either the SP base (53 patients) or SP splitting osteotomy (44 patients) techniques and met the study criteria were enrolled in our study (Fig. 3). Demographic data are summarized in Table 1.

**Table 1** Demographic data of enrolled patients

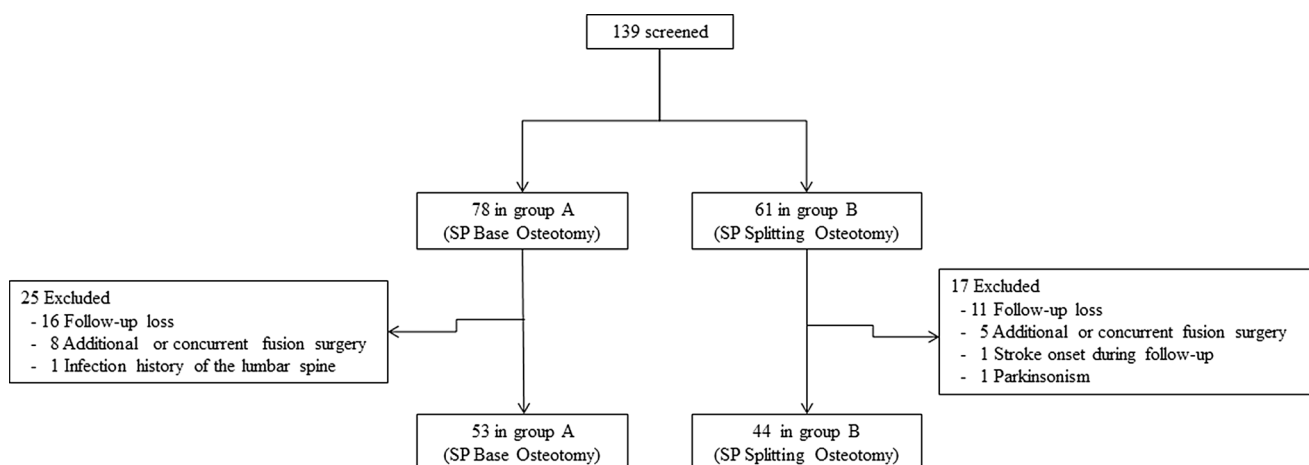
	Group A	Group B	<i>P</i>
<i>N</i>	53	44	–
Age (year)	62.1 ± 9.8	66.3 ± 7.2	0.53
Sex (male/female)	24/29	18/26	0.69
Height (cm)	167.4 ± 15.9	168.1 ± 19.3	0.84
Weight (kg)	66.3 ± 7.2	66.8 ± 8.0	0.91
BMI (kg/m <sup>2</sup> )	27.1 ± 9.2	26.9 ± 8.9	0.88
Smoking (%)	18 (40)	11 (25)	0.38
Medical illness			–
DM	11	10	
HTN	9	13	
Kidney disease	4	3	
Operative segment			–
L4–L5	32 (60%)	25 (57%)	
L5–S1	10 (19%)	11 (25%)	
L3–L5	7 (13%)	5 (11%)	
L4–S1	4 (8%)	3 (7%)	

Group A, SP base osteotomy; Group B, SP splitting osteotomy. Values in data cells represent mean ± SD (standard deviation) or number of patients

*BMI* body mass index, *DM* diabetes mellitus, *HTN* hypertension

### Primary endpoint (pain intensity)

The preoperative VAS score for LBP was 8.3 in group A and 8.5 in group B (*P* = 0.84). In group A, the mean VAS score improved to 4.9 at 3 months, 3.1 at 6 months, and 2.6 at 1 year after the surgery. In group B, the mean VAS score improved to 4.1 at 3 months, 2.7 at 6 months, and 1.9 at 1 year after the surgery. One week and 1 year postoperatively, there was a significant difference between the two groups (*P* = 0.04 and 0.03, respectively), although there



**Fig. 3** Flow diagram of enrolled patients

were no significant differences between the groups at other follow-up times (Fig. 4a).

The preoperative VAS score for radiating pain to the lower extremities was 6.3 in group A and 6.1 in group B ( $P = 0.83$ ). In group A, the mean VAS score improved to 2.2 at 3 months, 1.8 at 6 months, and 1.7 at 1 year after the surgery. In group B, the mean VAS score improved to 2.1 at 3 months, 1.8 at 6 months, and 1.9 at 1 year after the surgery. There were no significant differences between the groups throughout the 1-year follow-up period (Fig. 4b).

**Secondary endpoints**

The mean ODI score improved from  $39.7 \pm 8.2$  preoperatively to  $16.1 \pm 7.9$  at 1 year after the surgery in group A, and from  $38.5 \pm 10.4$  preoperatively to  $14.7 \pm 9.1$  at 1 year after the surgery in group B. There were no significant differences between the groups throughout the 1-year follow-up period.

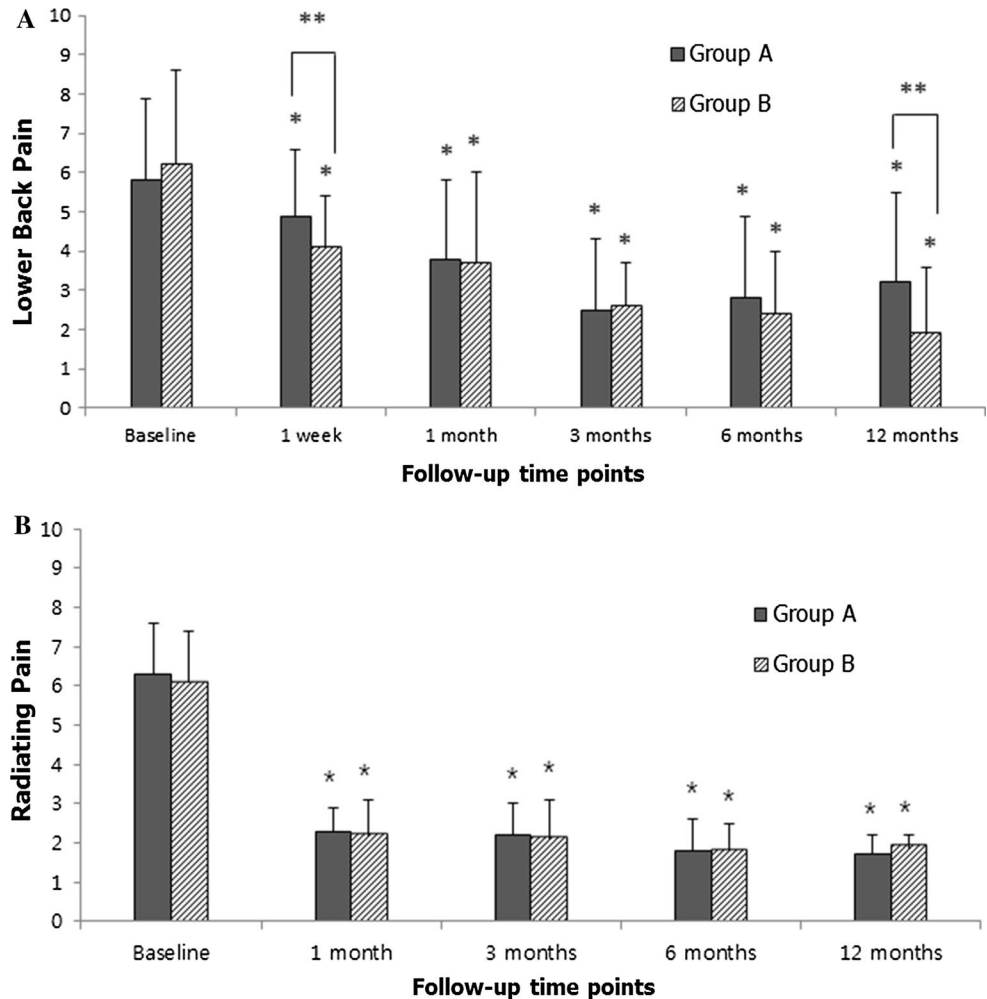
With regard to the SF-12 questions, the mean PCS score improved from  $21.8 \pm 6.9$  preoperatively to  $40.7 \pm 8.3$

1 year after the surgery in group A, and from  $22.6 \pm 9.1$  preoperatively to  $42.5 \pm 10.4$  1 year after the surgery in group B; there were no significant differences between the groups at any of the follow-up times. The mean MCS scores also improved from  $29.2 \pm 9.7$  preoperatively to  $43.3 \pm 8.4$  1 year after the surgery in group A and from  $30.3 \pm 10.1$  preoperatively to  $45.7 \pm 9.2$  1 year after the surgery in group B; there were no significant differences between the groups at any of the follow-up times.

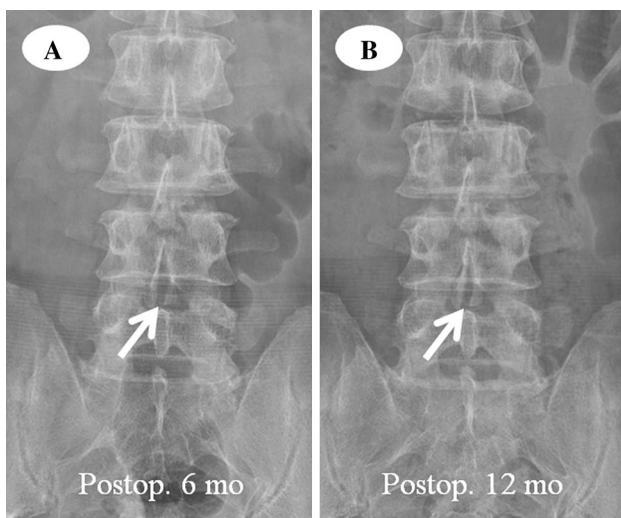
One year after the surgery, radiographs showed that the healing at the osteotomized site was significantly greater in group B (34/44, 77%) than in group A (29/53, 55%) ( $P = 0.03$ ) (Figs. 5, 6).

Surgical outcomes, such as estimated operative time, estimated blood loss, and length of hospital stay, did not differ significantly between the groups. Additionally, the complication rates during surgery or at the follow-up times were similar between the groups. One patient in group A developed a superficial infection that was managed with debridement and additional medication, and no further complications occurred. Dural injury occurred in two

**Fig. 4 a** Mean VAS in lower back pain by time points. **b** Mean VAS in radiating pain to the lower extremity by time points. Error bars represent standard deviations. Asterisk indicates that there was a significant difference between the VAS scores at preoperative and each follow-up time. Double asterisk indicates that there was a significant difference between the two groups







**Fig. 5** Nonunion case of SP splitting technique. **a** Postoperative 6 months radiograph shows definite discontinuity (white arrow) of SP osteotomized site. **b** In postoperative 1 year, the discontinuity space is slightly reduced, but still observed obviously (white arrow)

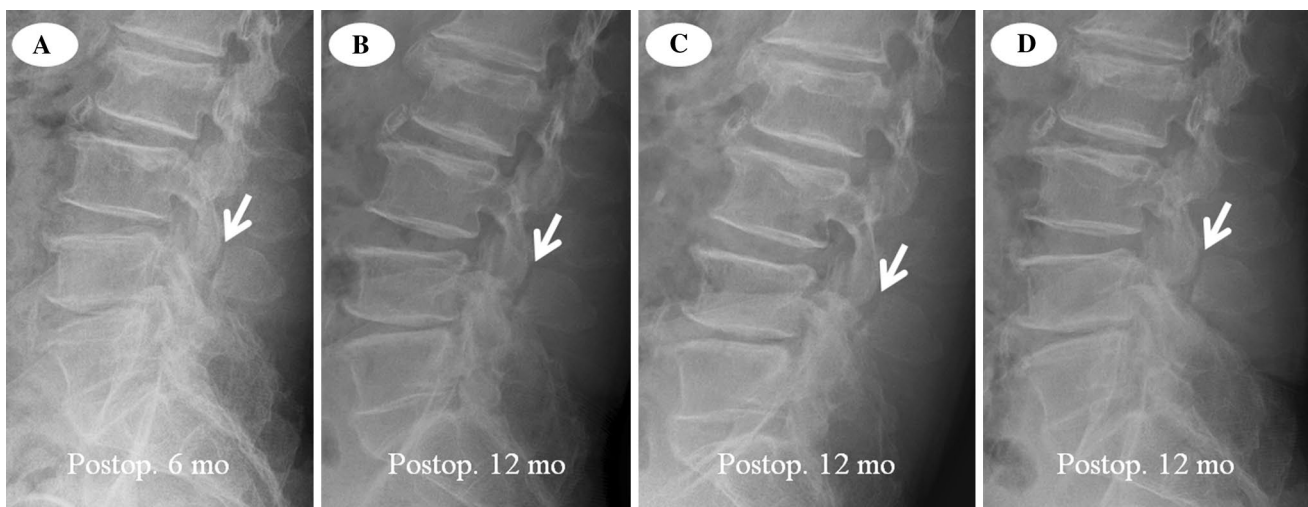
patients (one in each group) during procedure, but not during the osteotomy. The surgeon was able to repair the injured dura with a silk suture in a patient of SP base osteotomy group. The injured dura in a patient of SP splitting osteotomy group could not be repaired due to the relatively narrow surgical field, and the surgeon overlaid the dura with fat tissue and a synthetic dural sealant product. The two patients who experienced dural injuries did not have related postoperative complications. No other surgical

complications were observed during the surgery or the follow-up period.

## Discussion

Conventional PD surgery for LSS is associated with an increased risk of back muscle injury, which can cause persistent back pain, segmental instability, and failed back surgery syndrome, and can sometimes require additional surgery [1, 2, 6–10, 18, 19, 21]. Therefore, spine surgeons have explored new methods, such as SP osteotomy techniques, to minimize muscle injury with enabling wider visualization of surgical field during PD [1, 2, 10–21]. Surgeons have incorporated various SP osteotomy techniques; among the most widely used are SP base osteotomy and SP splitting osteotomy [11, 15, 16]. Numerous studies have demonstrated that each of these osteotomy techniques can yield excellent postoperative clinical and radiological outcomes, but a comparative study of the two osteotomy techniques has not been reported.

Herein, we aimed to compare the clinical, radiological, and surgical outcomes of these two SP osteotomy techniques in LSS patients over a follow-up period of 1 year. With both techniques, significant improvements in the pain intensity of the lower back and lower extremities, which was the primary outcome measure, were achieved 1 year postoperatively. The SP splitting technique was significantly more effective than SP base osteotomy in LBP intensity 1 week and 1 year after the surgery, as depicted at Fig. 4a. We suggest that SP base osteotomy may be less effective in reducing early postoperative LBP intensity than is SP splitting osteotomy, because



**Fig. 6** Nonunion case of SP base osteotomy technique. **a** Postoperative 6 months radiograph reveals definite discontinuity (white arrow) of SP osteotomized site. **b** In postoperative 1 year, the discontinuity gap (white arrow) is still observed obviously. In lateral extension (**c**)

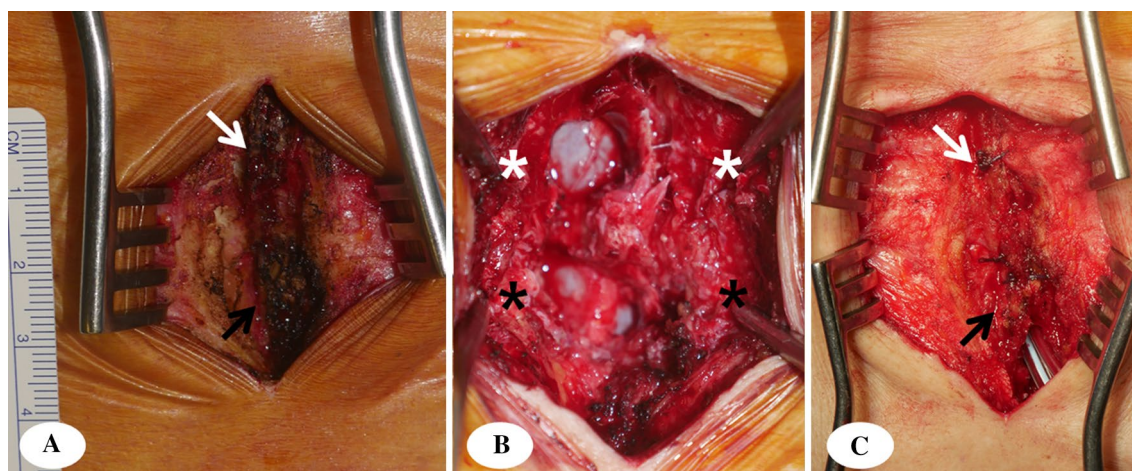
and flexion (**d**) radiographs at postoperative 1 year, the osteotomized site (white arrow) has definite motion with bony gap and sclerotic margin

SP base osteotomy requires a relatively longer skin incision for PD and involves greater muscle injury and dissection as compared to the SP splitting technique, as described in Figs. 1, 2 and 7. However, skin and muscle injuries heal spontaneously over time, and this could be a reason for the similar LBP intensity between the two groups 1 month postoperatively.

The secondary endpoints of our study were clinical outcomes, radiological outcomes, surgical outcomes, and complications. Clinical outcomes were measured with the ODI and SF-12 scales, and the two clinical parameters were similar between the two groups throughout the 1 year follow-up period, similar to previous study [20]. That is, PD surgery, regardless of the osteotomy method used, produced sufficient canal decompression and excellent improvement of the clinical outcomes, such as LBP and claudication, in patients with LSS. Radiological outcomes were determined according to the healing status at the osteotomized SP site. The healing rate was significantly greater in the SP splitting osteotomy group than in the SP base osteotomy group (77 versus 55%;  $P = 0.03$ ). Several articles have demonstrated that nonunion status at the operative segment could be related to poor outcomes, including pain intensity and functional status. In this regard, we presumed that the more LBP in SP base osteotomy group at postoperative 1 year could be caused by the lower union rate as compared to SP splitting osteotomy group, and the higher union rate of SP splitting technique could be a strong point to predict postoperative outcomes. However, the healing achievement was not significantly related to postoperative clinical outcomes based on ODI and SF-12. There are two possible explanations for this: (1) SP fracture did not significantly influence related outcomes if the back muscles and posterior

ligamentous complex surrounding the SP were relatively preserved, and (2) we were not able to confidently confirm the union status because we reviewed it with simple radiographs, which may not have been detailed enough. Furthermore, although we could not sufficiently verify fusion in this study, we attempted to mitigate the measurement error using three independent observers and their complete agreement to evaluate radiographic images and using dynamic flexion and extension radiographs as well.

Ours is a unique study to analyze and compare the postoperative clinico-radiological outcomes of two widely used SP osteotomy techniques to minimize back muscle injury due to PD. Although several SP osteotomy techniques have been introduced to minimize back muscle injury, these techniques have rarely been compared with regard to postoperative outcomes [19]; this lack of comparative data on the technique benefits might result in lesser adoption of these techniques by surgeons. Thus, this study helps spine surgeons evaluate the technique benefits and could be a cornerstone for further studies. Our study, however, has several inherent limitations. First, we used a retrospective design with a relatively small sample size and a short follow-up period of 1 year. Further studies with a prospective randomized design, larger sample size, and longer follow-up times are necessary to determine the optimal SP osteotomy technique that will provide the best postoperative outcomes. Second, to evaluate radiological outcomes, we used simple radiographs to define the healing status of the osteotomized SP site, because they were retrospectively available, were less costly, and did not involve subjecting patients to superfluous radiation exposure; further, more complicated imaging seemed unnecessary for patients with no complaints. We are aware that CT



**Fig. 7** Intraoperative photographs of SP splitting osteotomy in lumbar spinal stenosis at L3–4–5 levels. **a** Dorsal surfaces of spinous processes of L3 (white arrow) and L4 (black arrow) were exposed. **b** The spinous processes were longitudinally splitted and retracted bilaterally (L3, white asterisk; L4, black asterisk), and posterior decompression could be performed sufficiently. **c** Bilaterally retracted spinous processes of L3 (white arrow) and L4 (black arrow) were repositioned and sutured

ally (L3, white asterisk; L4, black asterisk), and posterior decompression could be performed sufficiently. **c** Bilaterally retracted spinous processes of L3 (white arrow) and L4 (black arrow) were repositioned and sutured

is more accurate for detecting fusion status. To compensate for the detection error associated with simple radiographic images, we also used dynamic flexion and extension radiographs. Since the dynamic radiographs were taken with the patient in the flexion and extension positions with the back muscles in contracture, better visualization of the osteotomized site was achieved both directly and indirectly, aiding in accurate verification. Nevertheless, the simple and dynamic radiographs cannot make assertions regarding the fusion status at the osteotomized site of SP, which can be significant limitation of the current study. Third, in spite of muscle-preserving surgery, the number of surgical segments should be significantly correlated to the postoperative pain, functional status, or the amount of muscle injury, by previous report [22]. In our study, we could not evaluate the differences according to the number of surgical segments, due to relatively small sample size. Finally, although we compared the postoperative outcomes between the two SP osteotomy techniques for PD, but we did not compare the outcomes with those of conventional PD surgery, which would be important for understanding the significance of back muscle preservation. Thus, further studies comparing conventional PD surgery with SP osteotomy technique for PD are necessary, with larger sample size and longer follow-up period.

## Conclusion

This retrospective comparative study is the first, to our knowledge, to compare the postoperative outcomes of two widely performed SP osteotomy techniques for minimizing back muscle injury during PD for treating LSS. For both techniques, the intensity of LBP and pain in the lower extremities improved significantly 1 year after the surgery. However, in terms of LBP intensity, the SP splitting technique offered more or less greater pain improvement than did the SP base osteotomy 1 week and 1 year after the surgery. Clinical outcomes based on the ODI and SF-12 were similar between the groups. The healing rate at the osteotomized SP site was greater in the SP splitting group than in the SP base osteotomy group. Surgical outcomes and procedure-related complications were also similar between the groups.

Based on the outcomes of this study, we conclude that the two SP osteotomy techniques offer excellent clinical and radiological outcomes at least for the first year after the surgery. In terms of fusion rate at the osteotomized SP site, the SP splitting technique was superior to the SP base osteotomy technique.

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## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no competing interests.

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