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Good Clinical Outcomes and Fusion Rate of Facet Fusion With a Percutaneous Pedicle Screw System for Degenerative Lumbar Spondylolisthesis

Minimally Invasive Evolution of Posterolateral Fusion

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Study Design. A retrospective clinical and radiographical study.

Objective. To assess the clinical outcomes and fusion rate of facet fusion (FF) for degenerative lumbar spondylolisthesis (DLS).

Summary of Background Data. On the basis of the long-term clinical and radiological follow-up studies of posterolateral fusion (PLF)—that is, intertransverse process fusion with pedicle screw instrumentation—for DLS, we recognized that FF alone would be sufficient for spinal fusion.

Methods. Eighty-eight patients who underwent FF for single-level DLS were retrospectively reviewed after at least 1 year of follow-up. The control group comprised 21 patients who underwent conventional PLF. The operative technique involved a 5-cm midline skin incision, bilateral laminar fenestration, and FF with autologous bone harvested from the spinous process. Percutaneous pedicle screws were then inserted through the fascia. The fusion rate of FF was evaluated using computed tomography, and the change in the range of motion at the fused level was assessed on flexion-extension lateral radiographs. The Japanese Orthopaedic Association Back Pain Evaluation Questionnaire was used to assess the therapeutic effectiveness of FF. The results of the Roland-Morris Disability Questionnaire and the visual analogue scales of low back pain, buttock and lower limb pain, and buttock and lower limb numbness were evaluated.

Results. The fusion rate was 88.6% (78/88 cases). Among 10 patients with inadequate fusion, the average range of motion significantly decreased from 14.4° preoperatively to 4.3° postoperatively. The Japanese Orthopaedic Association Back Pain Evaluation Questionnaire category scores demonstrated therapeutic effectiveness in 93.0% of the patients for walking ability and in 73.0% of the patients for low back pain. The average preoperative scores of the Roland-Morris Disability Questionnaire and the visual analogue scales of low back pain, buttock and lower limb pain, and buttock and lower limb numbness were significantly reduced postoperatively in the FF group.

Conclusion. FF achieved good clinical outcomes that were superior to those of conventional PLF with a comparable fusion rate. It is useful for managing DLS and is a minimally invasive evolution of PLF.

Key words: facet fusion, degenerative lumbar spondylolisthesis, minimally invasive surgery, percutaneous pedicle screw, posterolateral fusion, clinical results.

Level of Evidence: 3

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In our long-term clinical and radiological follow-up study of posterolateral fusion (PLF)—that is, intertransverse process fusion with pedicle screw instrumentation—for degenerative lumbar spondylolisthesis (DLS), we reported good clinical outcomes after PLF as *in situ* fusion, a low incidence of adjacent segment disease, and the lack of a need for slippage reduction.[1] There are many reports of satisfactory long-term outcomes after PLF,[2,3] with some authors reporting no significant differences in clinical outcomes and fusion rates between PLF and posterior lumbar interbody fusion and questioning the need for anterior support in short lumbar fusions.[4–6] The only drawback of PLF is its invasiveness into the paraspinal muscles, which is reportedly associated with unfavorable postoperative outcomes such as residual low back pain (LBP). After the study, we recognized that facet fusion (FF) alone would be sufficient for spinal fusion. We devised a new, simple, minimally invasive FF using a percutaneous pedicle screw (PPS) system for DLS. In this study, we assessed the clinical outcomes and fusion rate achieved with this procedure.

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MATERIALS AND METHODS

Patient Population

Eighty-eight of 90 consecutive patients (55 females, 33 males; average age, 68.4 yr; range, 49–91 yr) who underwent FF for single-level DLS between June 2009 and April 2013 were retrospectively reviewed after at least 1 year of follow-up. Two patients were lost to follow-up, and the follow-up rate was 97.8%. The slipped vertebra was L4 in 82 patients and L3 in 6 patients. The control group consisted of 21 patients (16 females, 5 males; average age, 63.5 yr; range, 38–85 yr) who underwent conventional PLF for single-level DLS. All patients included in this study presented with intractable radiculopathy and intermittent claudication even after several months of conservative treatment. Patients complaining of LBP alone preoperatively were excluded. The indications for lumbar fusion were (1) sagittal translation 8% or more on a flexion-extension lateral radiograph or (2) anterior wedging 5° or more on a flexion radiograph and a disc range of motion (ROM) 10° or more. When lumbar fusion was indicated, we did not perform other fusion approaches, such as interbody fusion or reduction of slippage, and all the patients were treated with FF regardless of the grade of spondylolisthesis.

Operative Technique

All operations were performed by 2 surgeons (T.M. and H.A.). FF was performed as follows. The spine was exposed by a 5-cm posterior midline skin incision and subperiosteal muscle dissection was performed laterally to the dorsal aspect of the facet joint. Cortical and cancerous bone was separately harvested with a small bone nibbler and curette from the spinous processes and laminae of the cephalad segment and the cephalad edge of the caudal segment (Figure 1A). The central canal and the lateral recess were decompressed by laminar fenestration and bilateral undercutting of the medial part of the facet joints (Figure 2). Thorough decortication of the facet joint was performed carefully to a depth and length of at least 1 cm with a 3-mm diamond burr (Figure 1B). Cancerous chips from the spinous process and laminae were pushed into the decorticated facet joint spaces first. Milled cortical bone was grafted into the remaining spaces. PPSs were then inserted through the fascia (Figure 3).

Postoperative Protocol

The patients were allowed to sit up in bed with a soft brace on the first postoperative day and were mobilized with physiotherapy after the removal of the drain and urinal catheter on the second postoperative day. The soft brace was worn for 3 months postoperatively. If a patient had osteoporosis, a hard brace was used for 3 months and the soft brace was used for another 3 months.

Outcome Measures

We evaluated the fusion rate using computed tomography, wherein fusion was assessed according to a comprehensive grading system for FF. Grade I was defined as complete bony continuity covering a whole facet joint (Figure 4A). Grade II was defined as partial bony continuity on a facet joint (Figure 4B). In grade III, bony continuity was not confirmed with certainty at any portion of a facet joint (Figure 4C). Grade IV was defined as obvious nonunion of an FF (Figure 4D). Unilateral or bilateral grade I or II fusion was considered adequate (Figure 3C), whereas grade III or IV fusion was considered inadequate. ROM at the fused level was measured on a flexion-extension lateral radiograph preoperatively and at the final follow-up. The therapeutic effectiveness of FF was assessed using the Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ) preoperatively and 1 year postoperatively as a clinical outcome.[7] The Roland-Morris Disability Questionnaire (RMDQ) and the visual analogue scales (VAS) of low back pain (LBP-VAS), buttock and lower limb pain (BLP-VAS), and buttock and lower limb numbness (BLN-VAS) were also recorded at the same time as the JOABPEQ. In addition, the surgical complication rate was reviewed. The control (PLF) group was evaluated using the RMDQ, LBP-VAS, BLP-VAS, and BLN-VAS. Clinical outcomes were compared between the FF and PLF groups.

Statistical Analysis

For statistical evaluation, the Wilcoxon signed-ranks test was used for differences between pre- and postoperative FF parameters and the nonparametric Mann-Whitney *U* test was used to test differences between the FF and PLF groups. The Fisher exact probability test was used for assessing the differences in therapeutic effectiveness, expressed as JOABPEQ categories, between the adequate and inadequate fusion groups. The level of significance was set at $P < 0.05$.

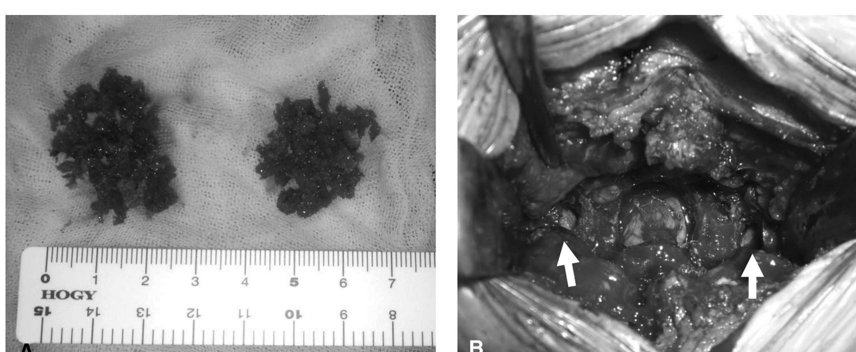

Figure 1. Operative images of minimally invasive facet fusion. **A,** Cancerous bones harvested from the spinous processes and laminae. **B,** Thorough decortication of the facet joint (arrows).

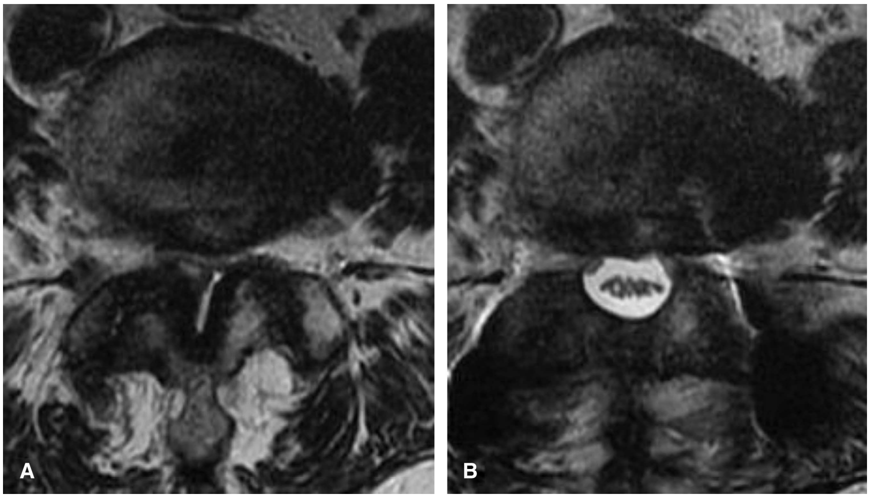

Figure 2. Magnetic resonance images at L4–L5 in a 63-year-old female. **A,** Preoperative axial image shows severe spinal canal stenosis. **B,** Postoperative axial image demonstrates adequate decompression of the dural tube after laminar fenestration and bilateral undercutting of the medial part of the facet joints.

Institutional Ethics Committee Approval

This study was approved by the Medical Ethical Committee of our hospital (#25-13).

RESULTS

Radiological Results

The average postoperative follow-up period was 31.0 (range, 12–55) months. The fusion rate was 88.6% (78/88 cases) at least on a unilateral facet and 86.4% (76/88 cases) on bilateral facets. At the final follow-up, all patients with adequate fusion on computed tomographic scan had no recognized motion at the fused level. Among 10 patients with inadequate fusion, the average ROM significantly decreased from 14.4° preoperatively to 4.3° postoperatively.

Clinical Outcomes

The JOABPEQ category scores demonstrated therapeutic effectiveness in 93.0% of the patients for walking ability, 73.0% of the patients for LBP, 60.0% of the patients for social life function, 36.9% of the patients for lumbar function, and 36.6% of the patients for mental health (Figure 5). Furthermore, therapy was effective even in the 10 patients with inadequate fusion (therapeutic effectiveness 100% for walking ability, 87.5% for LBP, 37.5% for social life function, 14.3% for lumbar function, and 12.5% for mental health). There was no significant difference in therapeutic effectiveness between the adequate and inadequate fusion groups for any category.

The average RMDQ value significantly decreased from 11.7 preoperatively to 4.7 postoperatively in the FF group ($P < 0.001$), and the postoperative value in the FF group was also significantly lower than the corresponding value in the conventional PLF group (7.1; $P < 0.05$) (Figure 6). Among patients with inadequate fusion, the average RMDQ value also significantly decreased from 10.0 preoperatively to 4.5 postoperatively ($P < 0.05$).

The average preoperative LBP-VAS, BLP-VAS, and BLN-VAS values in the FF group were 54.7, 71.0, and 67.4, respectively (Figure 7). At 1 year postoperatively, these values significantly decreased to 21.3, 24.4, and 27.0, respectively ($P < 0.001$). The postoperative VAS values in the conventional PLF group were 36.3, 31.6, and 25.5, respectively. Although the postoperative LBP-VAS and BLP-VAS values in the FF group were lower than those in the PLF group, the differences were not statistically significant. Among patients with inadequate fusion, the average LBP-VAS, BLP-VAS, and BLN-VAS values significantly decreased from 48.6, 66.3, and 62.1 preoperatively to 26.7, 19.9, and 22.3 postoperatively, respectively ($P < 0.05$).

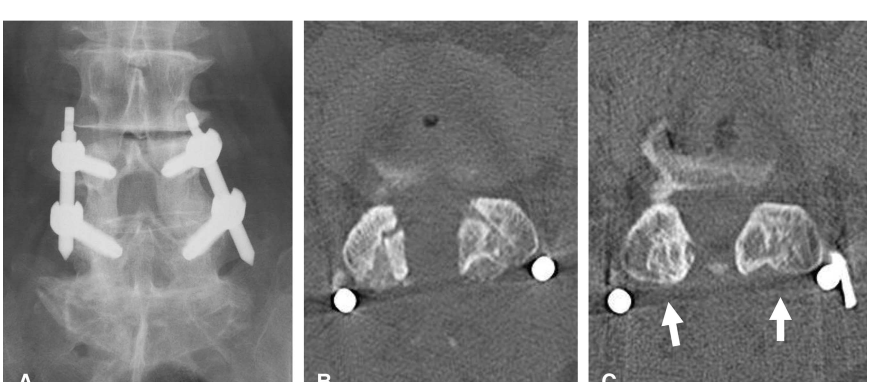

Figure 3. Postoperative images of minimally invasive facet fusion in the same patient as Figure 2. **A,** An anteroposterior radiograph illustrates the appropriate insertion of percutaneous pedicle screws into L4 and L5. **B,** An axial CT scan immediately after the operation shows plenty of bone chips grafted into the L4–L5 facet joints. **C,** An axial CT scan taken 6 months after the operation demonstrates bony continuity at the L4–L5 facet joints, indicating mature facet fusion (arrows). CT indicates computed tomographic.

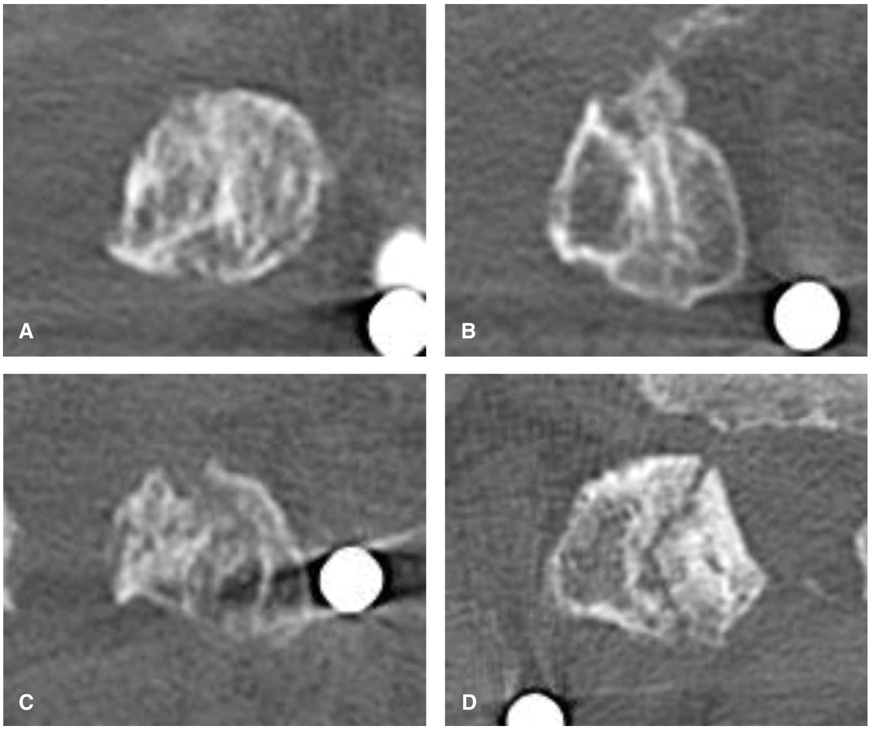

Figure 4. Grading system for the assessment of facet fusion on an axial computed tomography image. **A,** Grade I: Complete bony continuity is achieved, which covers a whole facet joint. **B,** Grade II: Partial bony continuity is observed on a facet joint. **C,** Grade III: Bony continuity is not confirmed with certainty at any portion of a facet joint. **D,** Grade IV: Obvious non-union of a facet fusion.

Complications

There was no implant failure or displacement, and no revision surgery was required. No major complications such as neural and vascular injury or deep wound infection occurred.

DISCUSSION

This study clearly demonstrated that the clinical outcomes and fusion rate of FF with the PPS system were good. It also indicated that the outcomes of FF were superior to those of conventional PLF. Therefore, this procedure represents an alternative minimally invasive technique to PLF for DLS.

In our long-term clinical and radiological follow-up study of PLF for DLS, we reported good clinical outcomes after PLF as *in situ* fusion, a low incidence of adjacent segment disease, and the lack of a need for slippage reduction.[1] Many reports have indicated satisfactory long-term outcomes after PLF.[2,3] In addition, some authors found no significant differences in clinical outcomes and fusion rates between PLF and posterior lumbar interbody fusion, thereby questioning the need for anterior support in short lumbar fusions.[4–6] However, the only drawback of PLF is its invasiveness into the paraspinal

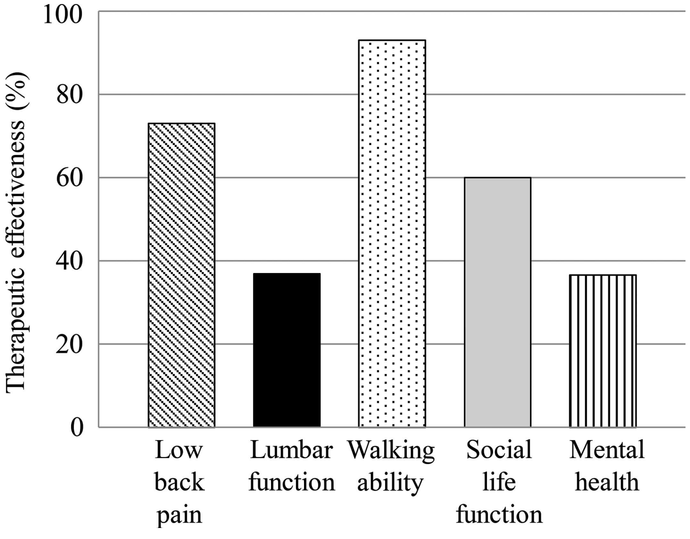

Figure 5. Therapeutic effectiveness of minimally invasive facet fusion with the JOABPEQ. JOABPEQ category scores demonstrated therapeutic effectiveness in 93.0% of the patients for walking ability and in 73.0% of the patients for low back pain. JOABPEQ indicates Japanese Orthopaedic Association Back Pain Evaluation Questionnaire.

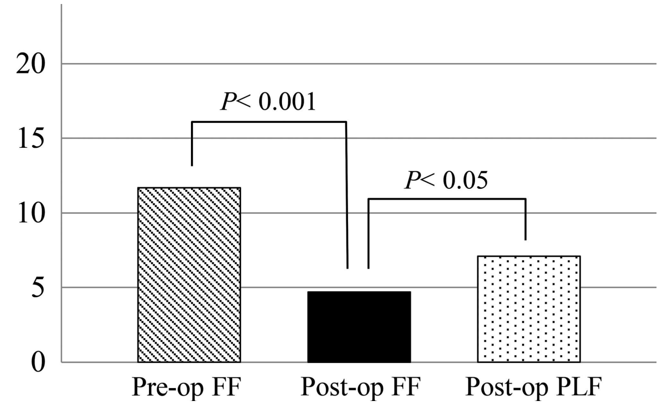

Figure 6. Roland-Morris Disability Questionnaire. The average preoperative Roland-Morris Disability Questionnaire value in the FF group was significantly reduced postoperatively and was significantly lower than the postoperative value in the PLF group. Pre-op indicates preoperative; Post-op, postoperative; FF, facet fusion; PLF, posterolateral fusion.

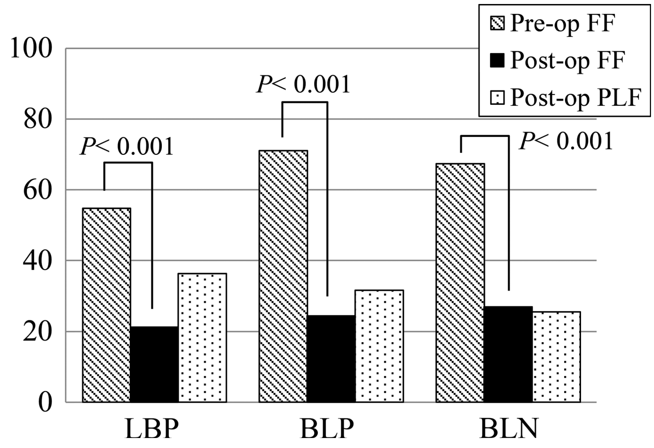

Figure 7. Visual analogue scales of low back pain (LBP-VAS), buttock and lower limb pain (BLP-VAS), and buttock and lower limb numbness (BLN-VAS). The average LBP-VAS, BLP-VAS, and BLN-VAS values in the FF group were significantly reduced 1 year after the operation. Pre-op indicates preoperative; Post-op, postoperative; FF, facet fusion; PLF, posterolateral fusion.

muscles, which is reportedly associated with unfavorable postoperative outcomes such as residual LBP.

We experienced one illustrative PLF case in which the bone graft between the transverse processes was resorbed after the pedicle screws had been removed. However, this case showed complete fusion solely by FF. Kanayama *et al*[8] reported that FF eventually occurred in 32.6% of patients after Graf ligamentoplasty. These findings demonstrate that FF alone can be sufficient for spinal fusion.

Generally, FF has always been performed as a part of spinal fusion.[9–12] Park *et al*[13,14] reported that instrumented FF alone is an effective surgical option for DLS. However, in their method, a bone graft was harvested from the iliac crest and a conventional pedicle screw system was used. Our technique, which uses a local bone graft and a PPS system, is much less invasive.

FF has several advantages for spinal fusion. First, there are potential revision surgery options, such as PLF and lumbar interbody fusion, after a failed FF. We think that preserving the intervertebral disc is very important and that it is the least invasive point. Second, the technique is simple and safe and can be performed easily by any spinal surgeon. Although some technical pitfalls may be encountered in using the PPS system, the FF procedure is nearly identical to that of decompressive laminar fenestration. In addition, Park *et al*[13,14] mentioned some other advantages, such as the ease of access and preparation of the fusion base and the shortest distance between the 2 adjacent segments.

Kotani *et al*[15] described minimally invasive PLF. Although their technique included a 4-cm skin incision and fixation with a PPS, other steps of the technique were the same as those of conventional PLF, such as detachment of the paraspinal muscles from the laminae to the transverse processes and harvesting a bone graft from the ilium. Their technique is not necessarily minimally invasive compared with our technique.

In the current study, the postoperative RMDQ value in the FF group was significantly lower than that in the conventional PLF group. Although statistical significance was not achieved, the LBP-VAS score in the FF group was also lower than that in the PLF group. These results show that the effect of FF on back muscle preservation is superior to that of PLF.

The fusion rate of FF was comparable with the reported rates for conventional PLF[12,15–19] (Table 1). Although the fusion rate achieved by using our technique was not the highest, we think that the actual fusion rates in the aforementioned reports might be lower because the presence of implants limited the accuracy of the radiographical assessment of PLF and because vague criteria for spinal fusion were used. Kant *et al*[20] observed the fusion mass of 75 patients with PLF directly at the time of hardware removal 1 year after fusion and reported that the accuracy of radiographical interpretation for spinal arthrodesis was only 69.1%. Christensen *et al*[21] described the difficulty of radiography-based assessment of PLF and noted that although the mean fusion rate was 81%, it decreased to 68% if agreement among all 4 observers was required. Our fusion rate was accurately determined by using computed tomography to assess the bony continuity of the facets. Furthermore, we performed FF alone in patients with definite radiological indications, whereas in most reports,

TABLE 1. The Reported Fusion Rates of Instrumented Conventional Single-Level Posterolateral Fusion for Degenerative Lumbar Spondylolisthesis

Authors	Fusion Rate (Fused/No. in Group)	Radiological Indication for Posterolateral Fusion
Fischgrund *et al*[16]	82.9% (29/35)	ND
Ohtori *et al*[17]	87.8% (72/82)	>5% slip in the neutral position or >3-mm translation on a bending radiograph
Kimura *et al*[18]	92.9% (26/28)	>3-mm translation on a bending radiograph
Kho and Chen[19]	93.3% (84/90)	ND
Fernandez-Fairen *et al*[12]	96.7% (29/30)	>5-mm translation on a bending radiograph
Kotani *et al*[15]	97.7% (42/43)	ND

ND indicates not described.

the indications for spinal fusion were not described or spinal fusions were indicated for stable spondylolisthesis.[15,16,19] Even if neither facet was fused, the ROM significantly decreased postoperatively, indicating stabilization of unstable spondylolisthesis, and clinical outcomes were good, as previously reported.[16,22] Thus, FF with a PPS system is a useful technique for the management of DLS.

This study has some limitations. First, it had a retrospective design. Second, the number of conventional PLF cases was small, and it is possible that inclusion of a greater number of PLF cases would lead to statistically significant differences between the groups in LBP-VAS outcomes. Third, the study evaluated mid-term clinical outcomes; a further study is required to clarify long-term outcomes after FF.

We have recently begun to perform FF using cortical bone trajectory screws.[23] This makes instrumented FF much less invasive because cortical bone trajectory screws can be inserted directly from the exposed laminae, thus avoiding exposure of subcutaneous tissue and damage to the paraspinal muscles by inserting PPSs through the fascia.

CONCLUSION

This study demonstrated that FF achieved good clinical outcomes, which were superior to those of conventional PLF—that is, intertransverse process fusion with pedicle screw instrumentation—with a comparable fusion rate. Therefore, FF represents a minimally invasive evolution of PLF and is useful for the management of DLS.

➢ Key Points

- We assessed the clinical outcomes and fusion rate of FF with a PPS system for DLS.
- The fusion rate was 88.6% (78/88 cases). Among 10 patients with inadequate fusion, the average ROM significantly decreased from 14.4° preoperatively to 4.3° postoperatively.
- The JOABPEQ category scores demonstrated therapeutic effectiveness in 93.0% of the patients for walking ability and in 73.0% of the patients for LBP.
- The average preoperative RMDQ value and the VAS scores of LBP, buttock and lower limb pain, and buttock and lower limb numbness were significantly reduced postoperatively.
- FF is useful for managing DLS and is a minimally invasive evolution of PLF.

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