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ORIGINAL ARTICLE

Good 5-year postoperative outcomes after facet fusion using a percutaneous pedicle screw system for degenerative lumbar spondylolisthesis

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Abstract

Many authors have reported no significant differences in clinical outcomes between posterolateral fusion (PLF) and interbody fusion, as well as satisfactory long-term outcomes after PLF. Facet fusion (FF), a minimally invasive evolution of PLF, has also resulted in good clinical outcomes. This study aimed to assess the clinical outcomes 5 years after FF for degenerative lumbar spondylolisthesis (DLS) and determine whether good clinical outcomes were maintained after FF. Records of 115 patients who underwent FF for single-level DLS with at least 5 years of follow-up were retrospectively studied. The therapeutic effectiveness of FF was assessed as a clinical outcome using the Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ), the Roland-Morris Disability Questionnaire (RMDQ), and the visual analogue scale (VAS) preoperatively and at 1 and 5 years postoperatively. Computed tomography was performed for fusion confirmation. The revision surgery rate was also evaluated. The JOABPEQ category scores demonstrated therapeutic effectiveness in 81.7% of patients at 1 year postoperatively and 81.4% of patients at 5 years postoperatively for low back pain; the corresponding proportions for walking ability were 93.8% and 86.6%, respectively. There were no significant differences in therapeutic effectiveness at 1 and 5 years postoperatively for any category, including the RMDQ and VAS scores. The fusion rate was 90.4% at the final follow-up. Four patients required revision surgery for adjacent segment disease 1–5 years after the first surgery (revision surgery rate, 3.5%). Good clinical outcomes were maintained 5 years after FF, and FF had an extremely low revision surgery rate.

Keywords Facet joint fusion · In situ fusion · Fusion rate · Adjacent segment disease · Nonunion · Posterolateral fusion

Introduction

Spinal fusion is generally performed for degenerative lumbar spondylolisthesis (DLS). There are several fusion techniques, such as posterolateral fusion (PLF) and interbody fusion. Many authors have reported no significant differences in clinical outcomes and fusion rates between PLF and interbody fusion [1–4], as well as satisfactory long-term outcomes after PLF [5–8]. We found that facet fusion (FF) using a percutaneous pedicle screw (PS) system, as a minimally invasive evolution of PLF, resulted in good clinical outcomes [9]. After our report was published, some authors also reported that FF achieved good clinical outcomes and fusion rates [10, 11]. This study assessed the clinical outcomes 5 years after FF and determined whether good clinical outcomes, comparable to those of PLF, were maintained after FF.

Methods

Patient population

This was a retrospective study using prospectively collected patient data from the same population as that in our previous reports [9, 12]. We reviewed data from 115 out of 143 consecutive patients (67 women, 48 men; average age, 68.5 years; age range, 49–83 years; follow-up rate,

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80.4%) who underwent FF for single-level DLS with central stenosis between June 2009 and September 2015 with at least 5 years of follow-up. We excluded 28 patients; 26 were lost to follow-up, and two died due to internal diseases. The average duration of postoperative follow-up was 92.2 months (60–138 months). FF was performed at L4–L5 in 107 patients and L3–L4 in 8. All included patients had radiculopathy and intermittent claudication resistant to several months of conservative treatment. We excluded patients who had low back pain (LBP) alone, symptomatic foraminal stenosis, spondylolytic spondylolisthesis, previous lumbar surgeries, or non-degenerative conditions (i.e., tumor, infection, or trauma). The indications for lumbar fusion included (1) sagittal translation of ≥ 8% on a flexion–extension lateral radiograph or (2) anterior wedging of ≥ 5° on a flexion radiograph and a disc range of motion (ROM) of ≥ 10°. All DLS patients who were indicated for lumbar fusion underwent FF, regardless of the spondylolisthesis grade, and other approaches such as interbody fusion or slippage reduction were not used.

Operative technique

The FF procedure was performed according to Miyashita's method [9]. Laminar fenestration and bilateral undercutting of the medial part of the facet joints were used to ensure adequate decompression of the central canal and lateral recess. Milled autologous bone from the spinous process and laminae was grafted into the thoroughly decorticated facet joint spaces (Fig. 1a). Percutaneous PSs were then inserted through the fascia.

Postoperative protocol

Patients were allowed to sit on the bed with a soft brace on the first postoperative day. The suction drain and urine catheter were removed, and ambulation was started 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 the first 3 months, and a soft brace was used for another 3 months.

Radiological assessment

Computed tomography (CT) was performed repeatedly until adequate fusion was confirmed at 3, 6, and 12 months postoperatively and once a few years thereafter. Fusion was assessed according to Miyashita's grading system for FF [9]. Complete (grade I) (Fig. 1b) or partial (grade II) bony continuity on a facet joint was considered adequate fusion. Nonunion was determined when bony continuity could not be confirmed at any portion of the facet joint (grade III) (Fig. 1c) or when there was obvious FF nonunion (grade IV). Three to five axial CT planes through the center of the facet were blindly evaluated on two separate occasions by three experienced spine surgeons. Bony continuity on at least one of the planes was judged as fusion. When judgement differed between observers, discussions were conducted to reach a consensus. ROM at the fixed level was measured on a flexion–extension lateral radiograph preoperatively and 5 years postoperatively for nonunion cases. Three experienced spine surgeons measured the ROM on two separate occasions.

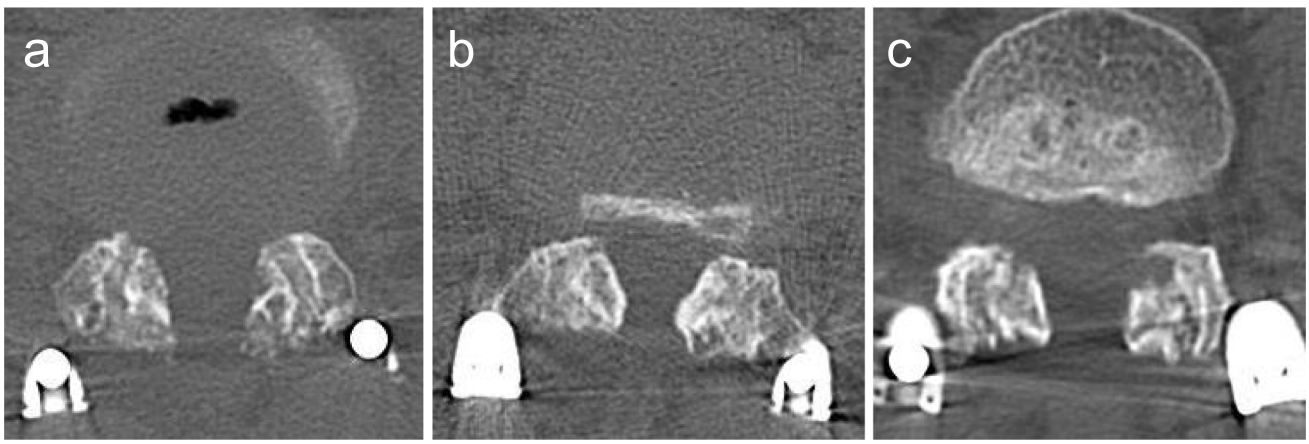

Figure 1 Axial computed tomography of facet fusion. **a** Bone chips pushed into the facet joint spaces are observed immediately after surgery. **b** Complete bony continuity (grade I). **c** Bony continuity cannot be confirmed at any facet joint portion (grade III)

Clinical outcome measures

Clinical outcomes were assessed using the Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ) [13], the Roland-Morris Disability Questionnaire (RMDQ), the visual analogue scale (VAS) of LBP (LBP-VAS), and the VAS of buttock and lower limb pain (BLP-VAS). All tests were performed preoperatively and at 1 and 5 years postoperatively. Previously published minimal clinically important difference values were used to assess therapeutic effectiveness, such as a 20-point increase in the score of each category on the JOABPEQ [13], a 5-point decrease in the RMDQ score [14], a 21-point decrease in the LBP-VAS score, or a 28-point decrease in the BLP-VAS score [15]. Therapeutic effectiveness was compared between 1 and 5 years postoperatively. The following comparisons were performed with respect to RMDQ and VAS values: preoperative vs. at 1 year postoperatively; preoperative vs. at 5 years postoperatively; and at 1 year postoperatively vs. at 5 years postoperatively. Additionally, surgical complications and revision surgeries for the index and adjacent levels were reviewed. Adjacent levels were defined as 2 cephalad and 2 caudad segments adjacent to the fusion level [16].

Statistical analysis

The intraclass correlation coefficient (ICC) was calculated to determine both intra- and inter-observer reliability for judgements of fusion using R (The R Foundation for Statistical Computing, Vienna, Austria). McNemar's chi-square test was employed for assessing differences in the therapeutic effectiveness of each category on the JOABPEQ, the RMDQ, and the VAS at 1 and 5 years postoperatively. The Wilcoxon signed-rank test was used to determine differences in the RMDQ and VAS values between each pair of pre- and 1 and 5 years postoperatively and in the ROM at the fixed level between preoperatively and 5 years postoperatively. The level of significance was set at $P < 0.05$.

Institutional ethics committee approval

This study was approved by the Medical Ethics Committee of our hospital.

Results

Radiological results

The reproducibility of judgements of fusion for each observer was high, and the ICC for intra-observer reliability was 0.852 for observer 1, 0.902 for observer 2, and 0.921 for observer 3. The ICC for inter-observer reliability was 0.775, which is above the statistically acceptable threshold of > 0.7. The fusion rate was 75.7% (87/115 cases) at the 1-year follow-up and 90.4% (104/115 cases) at the final follow-up. The reproducibility of ROM measurements for each observer was also high, and the ICC for intra-observer reliabilities was 0.971, 0.997, and 0.932 for observers 1, 2, and 3, respectively. The ICC for inter-observer reliability was 0.867. In the 11 nonunion patients, the average ROM significantly decreased from 11.8° preoperatively to 3.6° postoperatively ($P = 0.01$).

Clinical outcomes

JOABPEQ category scores demonstrated therapeutic effectiveness in 81.7% of the patients at 1 year postoperatively and 81.4% at 5 years postoperatively for low back pain; 40.0% and 45.1% for lumbar function; 93.8% and 86.6% for walking ability; 63.8% and 58.2% for social life function; and 40.7% and 44.4% for mental health, respectively (Fig. 2). There were no significant differences in therapeutic effectiveness between 1 and 5 years postoperatively for any category.

The average RMDQ value significantly decreased from 11.0 preoperatively to 3.8 at 1 year postoperatively ($P < 0.001$) and maintained a value of 3.5 at 5 years postoperatively ($P < 0.001$) (Fig. 3a). Therapeutic effectiveness was demonstrated in 72.5% of patients at 1 year postoperatively and 75.0% at 5 years postoperatively (Fig. 4a). There were no significant differences between 1 and 5 years postoperatively in the RMDQ value or the therapeutic effectiveness.

The average LBP-VAS value significantly decreased from 52.5 preoperatively to 18.0 at 1 year postoperatively ($P < 0.001$) and maintained a value of 20.7 at 5 years

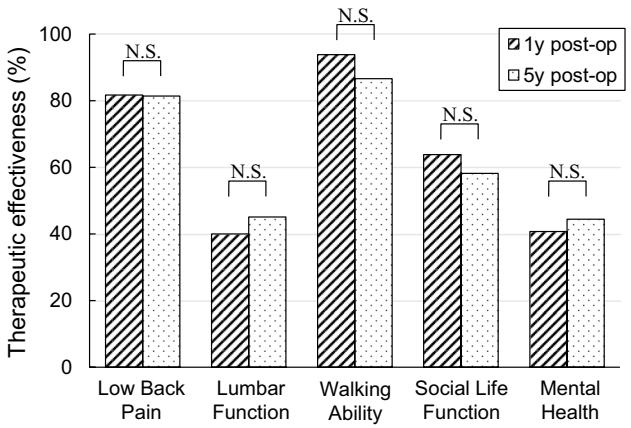

Figure 2 Therapeutic effectiveness of facet fusion with the Japanese Orthopaedic Association Back Pain Evaluation Questionnaire category scores. There is no significant difference in therapeutic effectiveness between 1 and 5 years postoperatively for any category. NS, not significant

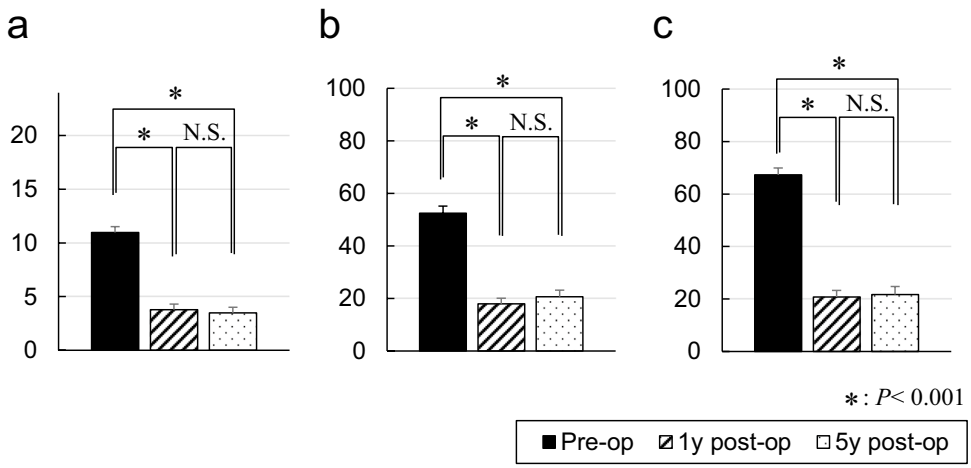

Figure 3 **a** The average Roland-Morris Disability Questionnaire and **b** the average visual analogue scale of low back pain and **c** of buttock and limb pain value change preoperatively and at 1 and 5 years postoperatively. The preoperative value significantly decreases 1 year postoperatively, and the decreased value is maintained 5 years postoperatively in all of categories. There is no significant difference between 1 and 5 years postoperatively. Error bars indicate standard error. NS, not significant.

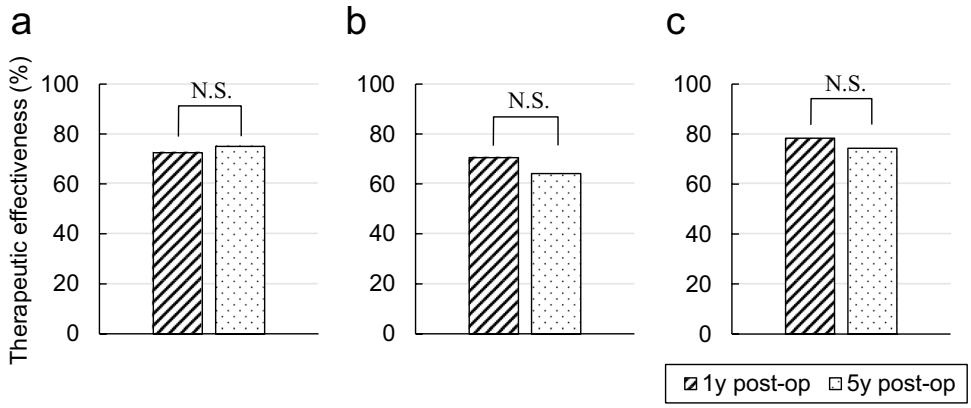

Figure 4 Therapeutic effectiveness of facet fusion as assessed by **a** the Roland-Morris Disability Questionnaire and **b** the visual analogue scale of low back pain and **c** of buttock and limb pain. There are no significant differences in therapeutic effectiveness between 1 and 5 years postoperatively, as assessed by any of the questionnaires. NS, not significant.

postoperatively ($P < 0.001$) (Fig. 3b). Therapeutic effectiveness was demonstrated in 70.5% of patients at 1 year postoperatively and 64.1% at 5 years postoperatively (Fig. 4b). There were no significant differences between 1 and 5 years postoperatively in the LBP-VAS value or the therapeutic effectiveness.

The average BLP-VAS value significantly decreased from 67.3 preoperatively to 20.8 at 1 year postoperatively ($P < 0.001$) and maintained a value of 21.7 at 5 years postoperatively ($P < 0.001$) (Fig. 3c). Therapeutic effectiveness was demonstrated in 78.3% of patients at 1 year postoperatively and 74.3% at 5 years postoperatively (Fig. 4c). There were no significant differences between 1 and 5 years postoperatively in the BLP-VAS value or the therapeutic effectiveness.

Complications and revision surgeries

There were no major complications, including pulmonary embolism, cardiac events, implant failure, neural or vascular injury, and deep wound infection. Revision surgery for complications or poor clinical outcomes immediately after surgery was not required. The 6 patients that underwent revision surgery required it not for the index level but for adjacent segment disease (ASD) between 1 and 9 years after the first surgery. The revision surgery rate was 3.5% (4/115 cases) at 5 years after the surgery and 5.2% (6/115 cases) at the final follow-up (average, 7.7 years) (Table 1). In the

Table 1 Details for the six patients requiring revision surgery

Age	Sex	Fusion level	ASD	Months after the first surgery
83	F	L4–L5	L2–L3 LDH	13
			L3–L4 LDH	19 (6 months after the revision)
63	M	L4–L5	L5–S1 FS	21
74	M	L4–L5	L3–L4 LSS	35
70	M	L4–L5	L2–L3 LDH	53
73	F	L4–L5	L3–L4 LSS	65
71	F	L3–L4	L2–L3 LDH	110

F indicates female; *M*, male; *ASD*, adjacent segment disease; *LDH*, lumbar disc herniation; *FS*, foraminal stenosis; *LSS*, lumbar spinal stenosis

excluded 28 patients who were followed up for less than 5 years postoperatively, none required revision surgery during the follow-up period (average, 2.8 years).

Discussion

This study demonstrated that good clinical outcomes were maintained 5 years after FF, and FF had an extremely low revision surgery rate of 3.5%. The fusion rate was 75.7% at the 1-year follow-up and 90.4% at the final follow-up. In nonunion cases, the average ROM significantly decreased from 11.8° preoperatively to 3.6° postoperatively.

Clinical outcomes 5 years after surgery

Several studies have assessed clinical outcomes 5 years after surgery for DLS. Kornblum et al. reported that satisfactory clinical outcomes assessed according to relief from pain and increased activity and measured using the LBP-VAS and BLP-VAS were achieved 5 years after PLF [6]. Park et al. found that the improvement in Oswestry Disability Index (ODI) at 2 years after transforaminal lumbar interbody fusion (TLIF) was maintained 5 years postoperatively [17]. Gaffney et al. reported no significant differences in scores on the ODI, LBP-VAS, BLP-VAS, or the therapeutic effectiveness of each between PLF and PLF + TLIF, even at 5 years postoperatively [18]. In this study, good clinical outcomes were maintained 5 years after FF, comparable to those of other techniques reported. When the outcomes determined via the JOABPEQ were analyzed in detail, therapeutic effectiveness decreased in categories such as walking ability and social life function at 5 years postoperatively, although these differences were not statistically significant (Fig. 2). When patients cannot walk, ascend stairs, or perform daily activities, even if they are without pain, functional scores in these categories decrease [13]. Considering that good RMDQ and VAS values were maintained, the decreased 5-year postoperative therapeutic effectiveness in the categories might have been a function of aging.

Revision surgery rate

The revision surgery rate of 3.5% at 5 years after FF was extremely low compared to previously reported rates of 12.1% (15/124 cases) [17] and 12.9% (176/1368 cases) [19] at 5 years after interbody fusion. Moreover, the previously reported rates could be higher than reported because their data included cases that were followed up for less than 5 years postoperatively. These studies described that some cases required revision due to cage migration or cage-related pain after nonunion. Sato et al. reported a lower revision rate of 7.8% at 5 years after posterior lumbar interbody fusion (PLIF) [20]. However, their rate increased to 14.4% at the final follow-up (average, 5.9 years). Our rate was 5.2% at the final follow-up (average, 7.7 years). Gaffney et al. indicated that the revision surgery rate of 6.5% (2/31 cases) at 5 years after PLF for L4-L5 DLS was significantly lower than the rate of 27.6% (16/58 cases) after PLF + TLIF [18]. They also suggested that there were no revision cases for the index level after PLF, although there were 5 cases for the level after the PLF + TLIF. These findings support that the insertion of cages can result in complications such as cage migration or cage-related pain, which could increase revision surgery rate after interbody fusion.

Postoperative spinal alignment and ASD

The theoretical benefits of interbody fusion include better lumbar lordosis and disc height restoration. However, recent studies have shown no differences in these measurements between interbody fusion and PLF [1, 3, 18, 21, 22]. Colman et al. concluded that the benefits of interbody fusion are probably overstated for most cases of DLS [1]. Kaito et al. reported that excessive distraction of the disc space during PLIF was a significant risk factor for ASD and suggested that distraction of the disc space by cage insertion exerted significant mechanical stress on the adjacent segment [23]. Miyashita et al. suggested that total lumbar alignment will eventually return to the preoperative neutral position, i.e., "settle to the comfortable position," with ASD and/or cage subsidence, even if the local alignment is corrected by cage insertion [24]. For the above reasons, distraction of the disc space and correction of the local alignment by cage insertion could cause ASD. Lee et al. analyzed the incidence of ASD requiring revision surgery after PLF and PLIF and indicated that patients treated by PLIF experienced a 3.4 times higher incidence of ASD requiring surgery than patients treated by PLF [25]. Revision surgeries could be needed more commonly after interbody fusion than after PLF and FF (for both the index and adjacent levels).

Fusion rate and nonunion cases

Another theoretical benefit of interbody fusion is a better fusion rate. Reported fusion rates of interbody fusion range from 77 to 100% [26]. However, the definition of successful fusion is controversial. Santos et al. found that plain radiographs appeared unreliable in fusion assessment, and CT offered the most reliable method [27]. In previous reports with high fusion rates, assessments were performed using flexion–extension radiographs with a 5° angular motion cutoff [2, 21, 28], which could result in including many nonunion cases [27]. In our study, CT was used for the assessment of FF, and the fusion rate of 90.4% was thought to be comparable to or higher than the rate observed with other

fusion techniques, as assessed by CT. In nonunion cases of FF, the average ROM significantly decreased from 11.8° preoperatively to 3.6° postoperatively. Good clinical outcomes after FF were also achieved in nonunion cases, and revision surgery for nonunion itself was not required, likely due to unstable DLS stabilization [12].

Optimal fusion technique for DLS

Although the optimal fusion technique for DLS has been controversial, many authors have reported no significant differences in clinical outcomes among different fusion techniques [1–4]. Norton et al. analyzed the Nationwide Inpatient Sample database in the USA from 2001 to 2010 and identified a study population of 48,911 patients who underwent surgery for DLS, of which 4989 (10.2%) had undergone PLF and 41,051 (83.9%) had undergone PLIF/TLIF [29]. Although PLIF/TLIF represented the most frequently used procedure, they found that PLF significantly reduced the length of hospital stay, hospital charges, and postoperative complications, as compared to any other procedures. They concluded that PLIF/TLIF might be overutilized and that PLF is being underutilized. Moreover, we previously reported that FF, as a minimally invasive evolution of PLF, achieved better clinical outcomes than PLF [9]. In the present study, good clinical outcomes were maintained 5 years after FF. Thus, FF is useful for the management of DLS.

Limitations

This study has several limitations. First, our study has no control group for comparison. The most ideal control group would be a matched cohort of patients undergoing interbody fusion, and a prospective randomized study is needed to show the efficacy of FF more clearly. Second, the observers of the radiological assessment were the same as the surgeons, and the bias of the observers might have impacted the results. Although the intraclass correlation coefficient for both intra- and inter-observer reliability was much higher than the statistically acceptable threshold, radiologists would be appropriate for observers to eliminate the bias. Third, it is not clear whether our indications for lumbar fusion were appropriate for the management of DLS. Although we indicate lumbar fusion only for the obvious instability present at the time of surgery, other radiological parameters may indicate future intervertebral instability and spondylolisthesis. Fourth, sagittal alignment was not included in the radiological assessments, which could have implications for clinical outcomes. However, spinal alignment was not a primary issue in the patient population studied, and good clinical outcomes were maintained 5 years after FF. Fifth, the study evaluated midterm clinical outcomes; further studies are required to clarify long-term outcomes after FF.

Conclusions

The current study demonstrated that good clinical outcomes were maintained 5 years after FF, and FF had an extremely low revision surgery rate of 3.5%. The fusion rate was 90.4% at the final follow-up. In nonunion cases, the average ROM significantly decreased from 11.8° preoperatively to 3.6° postoperatively, indicating unstable DLS stabilization. FF did not require revision surgery for nonunion itself.

Author contribution TM and TT contributed to the study conception and design. Data collection was performed by all authors. TM conducted the analysis and interpretation of data. The first draft of the manuscript was written by TM, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Availability of data and material The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Code availability Not applicable.

Declarations

Ethics approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Medical Ethics Committee of our hospital (#25–13).

Consent to participate Informed consent was obtained from all individual participants included in the study.

Consent for publication Informed consent for publication was obtained.

Conflict of interest The authors declare no competing interests.

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