Outcomes of 2-level posterior lumbar interbody fusion for 2-level degenerative lumbar spondylolisthesis

Clinical article

HIRONOBU SAKURA, M.D., PH.D., TOMOYA YAMASHITA, M.D., TOSHIKATA MIWA, M.D., KENJI OHZONO, M.D., PH.D., AND TETSUO OHWADA, M.D.

Department of Orthopaedic Surgery, Kansai Rosai Hospital, Amagasaki, Hyogo, Japan

Object. A systematic review concerning surgical management of lumbar degenerative spondylolisthesis (DS) showed that a satisfactory clinical outcome was significantly more likely with adjunctive spinal fusion than with decompression alone. However, the role of adjunctive fusion and the optimal type of fusion remain controversial. Therefore, operative management for multilevel DS raises more complicated issues. The purpose of this retrospective study was to elucidate clinical and radiological outcomes after 2-level PLIF for 2-level DS with the least bias in determination of operative procedure.

Methods. Since 2005, all patients surgically treated for lumbar DS at the authors’ hospital have been treated using posterior lumbar interbody fusion (PLIF) with pedicle screws, irrespective of severity of slippage, patient age, or bone quality. The authors conducted a retrospective review of 20 consecutive cases involving patients who underwent 2-level PLIF for 2-level DS and had been followed up for 2 years or longer (2-level PLIF group). They also analyzed data from 92 consecutive cases involving patients who underwent single-level PLIF for single-level DS during the same time period and had been followed for at least 2 years (1-level PLIF group). This second group served as a control. Clinical status was assessed using the Japanese Orthopaedic Association (JOA) score. Fusion status and sagittal alignment of the lumbar spine were assessed by comparing serial plain radiographs. Surgery-related complications and the need for additional surgery were evaluated.

Results. The mean JOA score improved significantly from 12.8 points before surgery to 20.4 points at the latest follow-up in the 2-level PLIF group (mean recovery rate 51.8%), and from 14.2 points preoperatively to 22.5 points at the latest follow-up in the single-level PLIF group (mean recovery rate 55.3%). At the final follow-up, 95.0% of patients in the 2-level PLIF group and 96.7% of those in the 1-level PLIF group had achieved solid spinal fusion, and the mean sagittal alignment of the lumbar spine was more lordotic than before surgery in both groups. Early surgery-related complications, including transient neurological complications, occurred in 6 patients in the 2-level PLIF group (30.0%) and 11 patients in the 1-level PLIF group (12.0%). Symptomatic adjacent-segment disease was found in 4 patients in the 2-level PLIF group (20.0%) and 10 patients in the 1-level PLIF group (10.9%).

Conclusions. The clinical outcome of 2-level PLIF for 2-level lumbar DS was satisfactory, although surgery-related complications including symptomatic adjacent-segment disease were not negligible.

Key Words • multilevel degenerative lumbar spondylolisthesis • posterior lumbar interbody fusion • clinical outcome • surgery-related complication • adjacent-segment disease

Abbreviations used in this paper: ASD = adjacent-segment disease; DS = degenerative spondylolisthesis; JOA = Japanese Orthopaedic Association; PLIF = posterior lumbar interbody fusion.
of lumbar lordosis. The purpose of this study was to elucidate clinical and radiological outcomes after 2-level PLIF in patients with 2-level DS.

**Methods**

** Patients**

All patients with lumbar DS have been treated using PLIF with pedicle screws in our hospital since 2005 irrespective of severity of slippage, patient age, and bone quality. Based on this surgical strategy, 21 consecutive patients with 2-level DS underwent 2-level PLIF between March 2005 and July 2008. All patients were considered for surgery because of unresponsiveness to conservative treatment, such as medication and/or epidural block. Of the 21 patients, 20 (6 men and 14 women) had been followed up for at least 2 years and were included in this study (2-level PLIF group); 1 patient was lost to follow-up. The mean age (of the 20 patients with long-term follow-up) at time of surgery was 68.3 years (range 44–79 years). The fusion areas were L-3 to L-5 in 17 patients, L-2 to L-4 in one, L-4 to L-6 in one, and L-4 to S-1 in one. The mean duration of the follow-up was 35.4 months (range 24–61 months). Data from these 20 cases were compared to data from 92 consecutive cases involving patients who underwent single-level PLIF for single-level DS during the same time period and had at least 2 years of follow-up (1-level PLIF group, control). The 1-level PLIF group included 40 men and 52 women. Their mean age at the time of surgery was 67.0 years (range 42–86 years). The fusion areas were L-4 to L-5 in 82 patients, L-3 to L-4 in 7, L-5 to S-1 in 2, and L-5 to L-6 in one. The mean duration of follow-up was 40.0 months (range 24–61 months). There were no significant differences between the 2 groups with respect to sex, age at time of surgery, or duration of follow-up. The study protocol was approved by the institutional review board of our hospital, and full informed consent for use of data in research was obtained from all patients.

**Surgical Procedure**

The PLIF procedure was performed using the B Rodriguez I/F cages (DePuy Spine, Inc.) filled with local bone graft from the lamina and spinous process and posterior instrumentation with pedicle screws. The medial walls of the facet joints at the fused segments were resected, preserving the lateral portions. After intervertebral disc material and cartilaginous endplates were removed, 2 cages were inserted into the intervertebral space, and local bone blocks were inserted lateral to the cages.

**Clinical and Radiological Evaluations**

Medical and radiological records were retrospectively examined by a single observer (H.S.), who was not involved in patient care. Operation time and estimated intraoperative blood loss were recorded as factors reflecting the surgical invasiveness of the PLIF. Clinical results were assessed using the JOA scoring system for assessment of the results of treatment for low-back pain. In brief, the score consists of the rating of subjective symptoms, clinical signs, restriction of activities of daily living, and urinary bladder function (Table 1). The total JOA score is 29 points in normal populations.

Standing radiographs of the lumbar spine were obtained before surgery and at various intervals thereafter. Lumbar lordosis was measured preoperatively, immediately after surgery, and at the final follow-up visit. It was measured as the angle between the inferior endplate of T-12 and the superior endplate of S-1 on lateral radiographs of the lumbar spine in the neutral position. The lordosis of fused levels was measured as the angle between the superior endplate of the vertebra at the cranial end of the fusion area and the inferior endplate of the vertebra at the caudal end of the fusion area.

Fusion status was assessed at the final follow-up examination. A solid fusion was defined as the condition in which osseous continuity between the vertebral endplates was evident on both anteroposterior and lateral radiographs, with neither loosening of the pedicle screws nor motion at the fused segments on flexion-extension radiographs.

Patients’ medical records were examined for evidence of intraoperative and postoperative complications, including symptomatic ASD.

**Statistical Analysis**

The unpaired t-test, Mann-Whitney U-test, Fisher exact probability test, Wilcoxon signed-rank test, repeated-measure 1-way ANOVA, and Fisher protected least significant difference were used for statistical analysis with JMP 5.0.1 software (SAS Institute), as appropriate. Values of p < 0.05 were considered significant.

**Results**

**Clinical Results**

The mean operation time and estimated intraoperative blood loss were 218 ± 49 minutes (range 164–393 minutes) and 612 ± 424 ml (range 160–2000 ml) in the 2-level PLIF group and 145 ± 32 minutes (range 82–232 minutes) and 206 ± 143 ml (range 30–649 ml) in the 1-level PLIF group. The operation time and estimated intraoperative blood loss were significantly less in the 1-level PLIF group than in the 2-level PLIF group (p < 0.01).

The mean JOA score improved significantly from 12.8 points before surgery to 20.4 points at the latest follow-up, yielding a mean recovery rate of 51.8% in the 2-level PLIF group. In the 1-level PLIF group, it improved significantly from 14.2 points preoperatively to 22.5 points at the final follow-up (mean recovery rate 55.3%) (Table 2). The JOA score before surgery and at the latest follow-up and the recovery rate were significantly better in the 1-level PLIF group than in the 2-level PLIF group (p < 0.01).

**Radiological Results**

In the 2-level PLIF group, the mean lumbar lordosis angle increased significantly from 30.1° before surgery to 34.3° after surgery, and was maintained at the final fol-
low-up (34.6°) (Table 2). The mean lordotic angle of the fused levels increased significantly from 14.5° before surgery to 18.3° after surgery, but the mean angle declined to 16.4° at the final follow-up because collapsed fusion occurred in 4 patients. In the 1-level PLIF group, the mean lumbar lordosis angle was not significantly changed in the immediate postoperative radiographs, but it increased significantly from 36.1° before surgery to 39.2° at the final follow-up (Table 2). There was no significant difference in the mean lordotic angle measured preoperatively, immediately postoperatively, or at final follow-up.

At the final follow-up, in the 2-level PLIF group, asymptomatic pseudarthrosis was found in 1 patient, union in situ (a solid fusion without loss of graft height) was observed in 15 patients, and collapsed fusion (graft bone collapse or cage subsidence into the adjacent vertebral body) occurred in 4 patients. Thus, solid spinal fusion was achieved in 19 (95.0%) of the 20 patients in the 2-level PLIF group. In the 1-level PLIF group, asymptomatic pseudarthrosis was found in 3 patients, union in situ was observed in 75 patients, and collapsed union was found in 14 patients. Solid spinal fusion was thus achieved in 89 (96.7%) of the 92 patients in the 1-level PLIF group. No significant difference was found between the 2 groups with respect to the rate of non-union.

**Surgery-Related Complications**

Early surgery-related complications, including transient neurological complications, occurred in 6 patients in the 2-level PLIF group (30.0%, Table 3). An intraoperative complication occurred in only 1 patient, who had medial penetration of the left L-3 pedicle screw with irritation of the left L-3 nerve root; this patient underwent revision surgery for decompression and replacement of the pedicle screw. With respect to early postoperative complications, transient radicular pain occurred in 2 patients, and 1 patient experienced transient motor weakness. One of the patients with transient radicular pain complained of mild bilateral lateral leg pain immediately after surgery; her leg pain had been gradually alleviated with medication by 3 months postoperatively. The other patient developed mild right lateral leg pain just after surgery; her leg pain was alleviated with medication and had resolved by the end of the 2nd postoperative week. In the patient with transient motor weakness, mild weakness of the right quadriceps femoris (manual muscle testing: Grade 4) developed immediately after surgery and had fully resolved with rehabilitation by the end of the 3 months after surgery. One patient required revision surgery for evacuation of an epidural hematoma 5 days after initial surgery. A deep wound infection was

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**TABLE 1: Japanese Orthopaedic Association scoring system for assessing the results of treatment for low-back pain**

<table>
<thead>
<tr>
<th>Item</th>
<th>Point Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>subjective symptoms (9 points)</td>
<td></td>
</tr>
<tr>
<td>low-back pain</td>
<td>3, 2, 1, 0</td>
</tr>
<tr>
<td>leg pain &amp;/or tingling</td>
<td>3, 2, 1, 0</td>
</tr>
<tr>
<td>gait (neurogenic intermittent claudication)</td>
<td>3, 2, 1, 0</td>
</tr>
<tr>
<td>clinical signs (6 points)</td>
<td></td>
</tr>
<tr>
<td>straight-leg raising test</td>
<td>2, 1, 0</td>
</tr>
<tr>
<td>sensory disturbance</td>
<td>2, 1, 0</td>
</tr>
<tr>
<td>motor deficit</td>
<td>2, 1, 0</td>
</tr>
<tr>
<td>restriction of activities of daily living (14 points)</td>
<td>1, 0, 0</td>
</tr>
<tr>
<td>turn over while lying</td>
<td>2, 1, 0</td>
</tr>
<tr>
<td>standing</td>
<td>2, 1, 0</td>
</tr>
<tr>
<td>washing</td>
<td>2, 1, 0</td>
</tr>
<tr>
<td>leaning forward</td>
<td>2, 1, 0</td>
</tr>
<tr>
<td>sitting (about 1 hr)</td>
<td>2, 1, 0</td>
</tr>
<tr>
<td>lifting or holding heavy object</td>
<td>2, 1, 0</td>
</tr>
<tr>
<td>walking</td>
<td>2, 1, 0</td>
</tr>
<tr>
<td>urinary bladder function</td>
<td>0, −3, −6</td>
</tr>
<tr>
<td>total*</td>
<td>29 to −6</td>
</tr>
</tbody>
</table>

* A normal total JOA score is 29 points.

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**TABLE 2: Summary of clinical and radiological outcomes**

<table>
<thead>
<tr>
<th>Group &amp; Variable</th>
<th>Preop</th>
<th>Postop</th>
<th>Final Follow-Up</th>
<th>Recovery Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-level PLIF group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JOA score</td>
<td>12.8 ± 4.2</td>
<td>20.4 ± 6.2†</td>
<td>51.8 ± 29.0</td>
<td></td>
</tr>
<tr>
<td>lumbar lordosis (°)</td>
<td>30.1 ± 14.1</td>
<td>34.3 ± 11.0‡</td>
<td>34.6 ± 14.2$</td>
<td></td>
</tr>
<tr>
<td>lordosis of fused levels (°)</td>
<td>14.5 ± 10.0</td>
<td>18.3 ± 7.3‡</td>
<td>16.4 ± 8.1¶</td>
<td></td>
</tr>
<tr>
<td>1-level PLIF group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JOA score</td>
<td>14.2 ± 4.0**</td>
<td>22.5 ± 3.7†**</td>
<td>55.3 ± 26.1**</td>
<td></td>
</tr>
<tr>
<td>lumbar lordosis (°)</td>
<td>36.1 ± 11.2</td>
<td>37.6 ± 10.1</td>
<td>39.2 ± 11.8‡</td>
<td></td>
</tr>
<tr>
<td>lordosis of fused levels (°)</td>
<td>13.8 ± 6.6††</td>
<td>13.3 ± 7.2††</td>
<td>12.7 ± 7.6††</td>
<td></td>
</tr>
</tbody>
</table>

* Values are means ± SDs.
† Significantly higher than before surgery (Wilcoxon signed-rank test, p < 0.01).
‡ Significantly higher than before surgery (Fisher protected least significant difference [PLSD], p < 0.05).
§ No significant difference between postoperative and final follow-up values (Fisher PLSD, p > 0.05).
¶ Significantly lower than after surgery (Fisher PLSD, p < 0.05).
** Significantly higher than before surgery (Wilcoxon signed-rank test, p < 0.01).
†† Significantly higher than 2-level PLIF group (Mann-Whitney U-test, p < 0.01).
††† No significant difference among 3 different time points of assessment (repeated-measure 1-way ANOVA, p > 0.05).
Outcome of 2-level PLIF for 2-level spondylolisthesis

TABLE 3: Summary of surgery-related complications*

<table>
<thead>
<tr>
<th>Complications</th>
<th>2-Level PLIF Group (n = 20)</th>
<th>1-Level PLIF Group (n = 92)</th>
</tr>
</thead>
<tbody>
<tr>
<td>intraoperative</td>
<td></td>
<td></td>
</tr>
<tr>
<td>dural laceration</td>
<td>4 (4.3%)</td>
<td></td>
</tr>
<tr>
<td>misplacement of pedicle screw</td>
<td>1 (5.0%)</td>
<td>3 (3.3%)</td>
</tr>
<tr>
<td>postoperative</td>
<td></td>
<td></td>
</tr>
<tr>
<td>transient radicular pain</td>
<td>2 (10.0%)</td>
<td>2 (2.2%)</td>
</tr>
<tr>
<td>transient motor weakness</td>
<td>1 (5.0%)</td>
<td></td>
</tr>
<tr>
<td>symptomatic hematoma</td>
<td>1 (5.0%)</td>
<td>1 (1.1%)</td>
</tr>
<tr>
<td>deep wound infection</td>
<td>1 (5.0%)</td>
<td>1 (1.1%)</td>
</tr>
<tr>
<td>symptomatic ASD</td>
<td>4 (20.0%)</td>
<td>10 (10.9%)</td>
</tr>
<tr>
<td>additional surgery for ASD</td>
<td>2 (10.0%)</td>
<td>9 (9.8%)</td>
</tr>
</tbody>
</table>

* Data represent numbers of patients (%).

noted in 1 patient who was successfully treated with debridement and irrigation without removal of the implants.

Early surgery-related complications occurred in 11 patients in the 1-level PLIF group (12.0%, Table 3). Intraoperative complications occurred in 7 patients—dural laceration in 4 patients and misplacement of the pedicle screw without irritation of the nerve root in 3 patients. These 3 patients underwent revision surgery for replacement of the pedicle screw immediately after initial surgery. Regarding early postoperative complications, transient radicular pain occurred in 2 patients. One patient complained of mild left lateral thigh pain just after surgery; the pain was alleviated by medication and resolved within 2 weeks of surgery. Another patient developed mild left lateral leg pain immediately after surgery and her leg pain also was alleviated by medication and resolved within 3 weeks of surgery. One patient required revision surgery for evacuation of an epidural hematoma 6 days after initial surgery. A mild deep wound infection was noted in 1 patient who was successfully treated with debridement and irrigation without removal of the implants. The incidence of early surgery-related complications was significantly higher in the 2-level PLIF group than in the 1-level PLIF group (p < 0.05).

Symptomatic ASD was found in 4 patients of the 2-level PLIF group (20.0%, Table 3). All 4 patients developed lumbar spinal canal stenosis at the cranial segment adjacent to the fused level. The mean period between the initial surgery and the onset of symptomatic ASD was 25 months (range 19–36 months). Two of the 4 patients (10% of the 2-level PLIF group) required additional surgery for symptomatic ASD because conservative treatment, such as medication and/or epidural blockade, was not effective (Table 3). The interval between the first and second surgery was 31 months (range 10–46 months). The rate of symptomatic ASD in the 2-level PLIF group was approximately twice that of the 1-level PLIF group (20.0% vs 10.9%), although the difference was not statistically significant.

Discussion

According to the conclusion of a systematic review of the surgical management of DS, a satisfactory clinical outcome is significantly more likely with spinal fusion than with decompression alone. A recent comparative study indicated that patients with DS had better outcomes with decompression and instrumented fusion than with decompression alone. Moreover, some surgeons have reported that patients undergoing PLIF for DS have more favorable surgical outcomes than those treated with posterolateral fusion. However, the role of adjunctive fusion and the optimal type of fusion, with or without instrumentation, remain controversial. Therefore, determination of the operative procedure for multilevel DS includes more complicated issues. To the best of our knowledge, there has been no report of a study evaluating outcomes after a unified surgical procedure for 2-level lumbar DS in the English-language literature. In our institution, 2-level PLIF with pedicle screws has been our standard procedure for all patients with 2-level DS since 2005. Therefore, with the least bias in determination of operative procedure, the present study reports clinical and radiological outcomes after 2-level PLIF for 2-level DS.

In the present study, the mean JOA score–based recovery rate in the patients treated with 2-level PLIF was 51.8%; solid spinal fusion was achieved in 95.0% of these patients, and the mean sagittal alignment of the lumbar spine was more lordotic than before surgery. There has been only one small clinical case series study reporting JOA scores after 2-level PLIF in patients with 2-level DS, and it was published in a Japanese-language journal; in that study, the mean recovery rate of the JOA score after 2-level PLIF in 11 patients with 2-level DS was 45.3%. In the present study, the mean recovery rate in the 1-level PLIF group was 55.3%, which was slightly but significantly better than that in the 2-level PLIF group. Since there has been no other report of a study evaluating outcomes after a unified surgical procedure for 2-level DS using the JOA score, it is impossible to compare the clinical outcome in this study with the outcomes of other surgical procedures, such as 2-level posterolateral fusion with or without instrumentation. Patients who have single-level stenosis tend to improve more than those with multiple-level stenosis after surgery when concomitant DS exists, but because all patients with 2-level DS were treated with 2-level PLIF in our study, determination of the operative procedures did not contribute any bias to the assessment of clinical outcome, and we consider that the clinical outcome in the 2-level PLIF group was satisfactory.

In the 2-level PLIF group, early surgery-related complications occurred in 30.0% of the patients and symptomatic ASD was found in 20.0%. On the other hand, in the 1-level PLIF group, early surgery-related complications occurred in only 12.0% and symptomatic ASD developed
in only 10.9%. The incidence of early surgery-related complications was significantly higher in the 2-level PLIF group than in the 1-level PLIF group. The incidence of early complications following single-level PLIF has been reported to be 18%–37.5%,6,11 and the incidence after 2-level PLIF has been reported as 46%.9 In light of these incidence rates, the risk of early surgery-related complications in patients undergoing 2-level PLIF is not negligible. As to symptomatic ASD, the rate in the 2-level PLIF group was approximately twice that of the 1-level PLIF group, although the difference was not statistically significant. There has been no report of the incidence of symptomatic ASD following 2-level PLIF, but whether the treatment is effective and the relatively short duration of postoperative follow-up. A further long-term follow-up study with a larger number of cases is thus needed to verify the reliability of 2-level PLIF for 2-level DS. Moreover, to clarify the role of adjunctive fusion and the best type of fusion, a prospective randomized study is imperative.

Conclusions

In conclusion, the clinical outcome of 2-level PLIF for 2-level DS was satisfactory, and the mean sagittal alignment of the lumbar spine was more lordotic than before surgery, although the rates of surgery-related complications, including early surgery-related complications and asymptomatic ASD, were not negligible.

Disclosure

The authors declare that they have no conflict of interest. No funds were received in support of this work. No benefits in any form have been or will be received from any commercial party related directly or indirectly to the subject of this manuscript.

Author contributions to the study and manuscript preparation include the following. Conception and design: all authors. Acquisition of data: Sakaura, Yamashita, Miwa. Analysis and interpretation of data: Sakaura, Yamashita, Miwa. Drafting the article: Sakaura, Yamashita, Miwa. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Sakaura. Statistical analysis: Sakaura. Study supervision: Ohzono, Ohwada.

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H. Sakaura et al.

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Address correspondence to: Hironobu Sakaura, M.D., Ph.D., Department of Orthopedic Surgery, Kansai Rosai Hospital, 3-1-69 Inabasou, Amagasaki, Hyogo 660-8511, Japan. email: sakaura04061023@yahoo.co.jp.

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