Posterior lumbar interbody fusion with total facetectomy for low-dysplastic isthmic spondylolisthesis: effects of slip reduction on surgical outcomes

Clinical article

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Object. The management of isthmic spondylolisthesis remains controversial, especially with respect to reduction. There have been no reports regarding appropriate slip reduction. The purpose of this study was to investigate the following issues: 1) surgical outcomes of posterior lumbar interbody fusion (PLIF) with total facetectomy for low-dysplastic isthmic spondylolisthesis, including postoperative complications; 2) effects of slip reduction on surgical outcomes; and 3) appropriate slip reduction.

Methods. A total of 106 patients who underwent PLIF with total facetectomy for low-dysplastic isthmic spondylolisthesis and who were followed for at least 2 years were reviewed. The average follow-up period was 8 years. Surgical outcomes, including the scores assessed using the Japanese Orthopaedic Association scoring system, the recovery rate, and postoperative complications were investigated. As for radiographic evaluations, pre- and postoperative slip and disc height, instrumentation failure, and fusion status were also examined.

Results. The pre- and postoperative average Japanese Orthopaedic Association scores were 14 (range 3–25) and 25 (range 11–29) points, respectively. The average recovery rate was 73% (range 0%–100%). The average pre- and postoperative slip was 24% and 10%, respectively. A significant correlation between postoperative slip and clinical outcomes was found; clinical outcomes were better in proportion to slip reduction. Although no statistical difference was detected in clinical outcomes between postoperative slip of less than 10% and from 10% to 20%, patients with postoperative slip of more than 20% showed significantly worse clinical outcomes. Postoperative complications included neurological deficits in 7 patients (transient motor loss in 6 and permanent motor loss in 1), instrumentation failures in 7, adjacent-segment degeneration in 5, and nonunion in 4. Instrumentation failures occurred significantly more often in patients with more slip reduction, although slip reduction did not affect the other postoperative complications. All patients with instrumentation failure showed postoperative slip reduction within 10%.

Conclusions. The use of PLIF with total facetectomy for low-dysplastic isthmic spondylolisthesis appears to produce satisfactory clinical outcomes, with an average of 73% recovery rate and few postoperative complications. Although clinical outcomes were better in proportion to slip reduction, excessive reduction caused instrumentation failure, and patients with less reduction demonstrated worse clinical outcomes. Appropriate reduction resulted in a postoperative slip ranging from 10% to 20%.

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Key words • posterior lumbar interbody fusion • total facetectomy • isthmic spondylolisthesis • reduction • surgical outcome

RADICULAR pain of the lower extremity is one of the important symptoms of isthmic spondylolisthesis. The causes of this symptom are compression and/or irritation of nerve roots at the foraminal level around the isthmic site. The compressive factors are proliferative fibrocartilagenous tissue at the isthmic site, a bulged or herniated intervertebral disc at the slipped segment, foraminal stenosis associated with large slip, and a combination of these factors. Due to the mechanically unstable nature of isthmic spondylolisthesis, a fusion procedure is standard surgical management for this pathological condition.

Abbreviations used in this paper: ASD = adjacent-segment degeneration; JOA = Japanese Orthopaedic Association; MMT = manual muscle test; PLIF = posterior lumbar interbody fusion.
We perform posterior lumbar interbody fusion (PLIF) with total facetectomy to treat isthmic spondylolisthesis. The PLIF procedure provides sufficient decompression of the nerve root and stabilization of the affected segment. Use of PLIF with pedicle screw fixation has produced satisfactory clinical results, but the necessity for slip reduction and restoration of disc height is still a controversial subject. Slip reduction has an advantage for fusion because the contact area of the interbody arthrodesis site is larger with reduction. On the other hand, the reduction maneuver sometimes causes neurological deficits or instrumentation failure. There have been few reports of the degree of slip reduction, but few reports have been about appropriate slip reduction.

The purpose of this study was to investigate the following issues: 1) surgical outcomes of PLIF with total facetectomy for low-dysplastic isthmic spondylolisthesis, including postoperative complications; 2) effects of slip reduction on surgical outcomes; and 3) appropriate slip reduction. To the best of our knowledge, this is the first report to describe the surgical outcomes of PLIF and appropriate reduction for isthmic spondylolisthesis with uniform instrumentation and a uniform fusion technique, involving more than 100 patients with an average follow-up of 8 years.

Methods

This is a retrospective study. All patients gave informed consent and the study was approved by the institutional review board.

Patient Population

In the present study, low-dysplastic isthmic spondylolisthesis was characterized by a normal vertebral shape, a normal lumbosacral profile, and a balanced pelvis without retroversion. Of 109 consecutive patients who underwent PLIF with total facetectomy for low-dysplastic isthmic spondylolisthesis between 1996 and 2010, 106 patients who were followed for at least 2 years were included in this study. Patients with high-dysplastic spondylolisthesis, which is characterized by a wedge L-5 and a domed and vertical sacrum, were excluded. Patients who had undergone previous lumbosacral fusion surgery were also excluded in this series. The follow-up rate was 97%. There were 36 women and 70 men. The mean age at surgery was 57 years (range 22–79 years), and the average follow-up period was 8 years (range 2–17 years). The levels of operation were L4–5 in 30 patients and L5–S1 in 76 patients.

Surgical Indication and Procedure

All patients considered for surgery had severe, disabling radicular pain with or without low-back pain that was unresponsive to conservative treatment such as medication, physical therapy, and root and/or epidural block. All PLIF procedures were performed using the same technique, which has been described elsewhere. The procedure involves complete resection of the spondylytic floating lamina including bilateral inferior articular processes; bilateral resection of the superior articular processes; decompression of the nerve root by excising proliferative fibrocartilagenous tissue at the isthmic site and performing subtotal discectomy; insertion of the interbody fusion cages and trimmed autologous bone to the intervertebral space; and pedicle screw fixation with the Steffee Variable Spine Plating System (DePuy Spine). We performed bilateral total facetectomies to have wide exposure of the neural elements and the disc space.

Interbody arthrodesis was performed by placing 2 cages that were sandwiched between a minimum of 2 autologous bone blocks, and chips that were trimmed from the excised lamina and facets. The posterior iliac crest was not harvested, and posterolateral arthrodesis was not performed at any level. Cages with a width of 9 mm, a height of 9 mm, and a length of 25 mm were generally used in patients with preoperative slip of less than or equal to 25%, and cages with a width of 9 mm, a height of 7 mm, and a length of 22 mm were used in patients with preoperative slip of greater than 25%. The first size of cage was used in 81 patients, the second size of cage was used in 21 patients, and autologous bone alone was used in 4 patients.

Basically, an interbody arthrodesis procedure was performed bilaterally, but 3 patients underwent unilateral arthrodesis because it was difficult to expose the unilateral interbody space due to the conjoint nerve root. Fluoroscopic guidance or computer navigation was not used during pedicle screw insertion. Pedicle screw fixation was applied at the fused segment, but instrumentation was extended to the cranial adjacent level in 1 patient because of difficulty in screw insertion due to a hypoplastic pedicle. As for technical features of plates and pedicle screw systems, slip reduction depended on plate bending and plate connection with pedicle screws. We did not attempt complete slip reduction, but attempted to achieve it for the length of the grafted cages.

Clinical Assessment

The complete medical records of all patients were available for review. These records were reviewed to determine demographic data, clinical results, and postoperative complications. Clinical outcomes were assessed using the scoring system proposed by the Japanese Orthopaedic Association (JOA). Briefly, the JOA score consists of subjective symptoms (low-back pain, leg pain, and gait; 3 points each); clinical symptoms (straight leg raising test, sensory abnormality, and motor disturbance; 2 points each); restriction of activities of daily living (14 points); and urinary bladder function (6 points). A normal JOA score is 29 points (Table 1). The recovery rate of the clinical outcomes, which indicates the degree of normalization after surgery, was evaluated using the Hirabayashi method, as follows: Recovery rate (%) = (postoperative score − preoperative score) × 100/(full score − preoperative score).

Clinical assessments were performed for all patients before surgery and at 1, 6, 12, 18, and 24 months after surgery, and then annually. Patients were divided into 4 groups according to the recovery rate (excellent, recovery rate greater than or equal to 75%; good, 50%–74%; fair,
Surgical outcomes of PLIF for isthmic spondylolisthesis

TABLE 1: Surgical outcomes in 106 patients who underwent PLIF with total facetectomy

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Value (range)</th>
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<tbody>
<tr>
<td></td>
<td>Preop</td>
</tr>
<tr>
<td>clinical JOA score</td>
<td>14 (3–25)</td>
</tr>
<tr>
<td>% recovery rate</td>
<td>73 (0–100)</td>
</tr>
<tr>
<td>radiological % slip</td>
<td>24 (5–55)</td>
</tr>
<tr>
<td>% slip reduction</td>
<td>14 (0–36)</td>
</tr>
<tr>
<td>disc height in mm</td>
<td>5 (0–9)</td>
</tr>
<tr>
<td>disc height restoration in mm</td>
<td>5 (1–12)</td>
</tr>
</tbody>
</table>

25%–49%; poor, less than 25%), and the number in each group was analyzed.

In the current study, postoperative complications were defined as spine-specific complications such as neurological deficits, instrumentation failure, adjacent-segment degeneration (ASD), and fusion failure. Adjacent-segment degeneration was defined as a condition in which additional surgery was required to treat neurological deterioration caused by the adjacent segment. Complications that were not specific for spine surgery or did not affect recovery (for example, urinary tract infection and anemia) were excluded.

Radiological Assessment

Plain radiographs were obtained in all patients at 1, 6, 12, 18, and 24 months after surgery, and annually thereafter. Slip and disc height were measured on lateral radiographs. As the index of slip, the percentage of slip was used. The maximum value of slip on dynamic lateral radiographs was used as the degree of preoperative slip. Slip reduction was evaluated by comparing the value on the lateral radiograph immediately after operation with the preoperative value. As the index of disc height, the distance between the upper and lower vertebral endplates perpendicularly measured from a point equidistant on the bisector line drawn connecting the middle points of the anterior and posterior disc heights on a neutral lateral radiograph was measured. The change in disc height was evaluated by comparing the immediate postoperative value with the preoperative value. Measurements for slip and disc height were calculated by 3 surgeons (R.Y., T.H., and T.M.) who were blinded to the clinical results.

Fusion status was also examined. Solid fusion was defined as a condition in which bony continuity between graft bone and the vertebra was detected, without loosening of the pedicle screws or motion at the fused segment in flexion and extension lateral radiographs. If solid fusion was not detected 1 year after surgery, plain and reconstruction CT scanning was performed to confirm bony continuity between graft bone and the vertebra. Nonunion was defined as a condition in which bony continuity between graft bone and vertebra was not detected on plain radiographs or reconstructed CT scans, along with loosening of pedicle screws or apparent motion at the fused segment.

Effects of Slip and Disc Height Reduction on Clinical Outcomes

The effects of pre- and postoperative slip and pre- and postoperative disc height on surgical outcomes were investigated.

Statistical Analysis

Findings from these measurements were analyzed statistically by using simple regression analysis, the Student t-test, chi-square analysis, the Fisher exact probability test, and Spearman rank correlation coefficients. A p value less than 0.05 was the minimum level of statistical significance.

Results

Clinical Outcomes

The clinical outcomes are shown in Table 1. Overall, pre- and postoperative average JOA scores were 14 (range 3–25) and 25 (11–29) points, respectively. The average recovery rate was 73% (range 0%–100%). Surgical outcome was excellent in 64 patients (60%), good in 24 (23%), fair in 11 (10%), and poor in 7 (7%).

Radiological Outcomes

The average pre- and postoperative slip values were 24% (5%–55%) and 10% (~8% to 33%), respectively. The average slip reduction was 14% (0%–36%). The average pre- and postoperative disc heights were 5 mm (0–9 mm) and 10 mm (6–15 mm), respectively. The average disc height restoration was 5 mm (1–12 mm) (Table 1).

Postoperative Complications

Postoperative neurological deficits were observed in 7 patients (7%) (Table 2). Motor loss was seen immediately after surgery in 4 patients and a few days after surgery in 3 patients. Of the 4 patients who showed motor loss immediately after surgery, slight motor loss with a manual muscle test (MMT) grade of 4 was observed in 3 patients and they recovered fully, whereas severe motor loss (MMT Grade 1) was seen in 1 patient and was permanent. This patient with permanent motor loss showed a postoperative

TABLE 2: Postoperative complications in 106 patients who underwent PLIF with total facetectomy

<table>
<thead>
<tr>
<th>Complication</th>
<th>No. (%)</th>
</tr>
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<tbody>
<tr>
<td>neurological deficits</td>
<td>7 (7)</td>
</tr>
<tr>
<td>transient motor loss</td>
<td>6 (6)</td>
</tr>
<tr>
<td>permanent motor loss</td>
<td>1 (1)</td>
</tr>
<tr>
<td>instrumentation failure</td>
<td>7 (7)</td>
</tr>
<tr>
<td>ASD</td>
<td>5 (5)</td>
</tr>
<tr>
<td>nonunion</td>
<td>4 (4)</td>
</tr>
</tbody>
</table>
slip value of 33%. Of 3 patients who showed motor loss a few days after surgery, slight motor loss (MMT Grade 4) was observed in 2 patients and they recovered fully, whereas severe motor loss (MMT Grade 2) was seen in 1 patient, who underwent additional surgery for postoperative hematoma and recovered fully thereafter.

Instrumentation failures were observed in 7 patients (7%) (Table 2); pedicle screw loosening was observed in 4 patients, and pedicle screw breakage was seen in 3. All pedicle screw loosening was observed at the cranial side. These patients did not report back pain or radicular pain, but nonunion was detected in 1 asymptomatic patient. In the other 3 patients, bony union was observed at the final follow-up. All pedicle screw breakages were observed at the caudal side. Of the 3 patients with pedicle screw breakage, 2 had no complaints, and bony union was observed at the final follow-up. The remaining patient, who had suffered a traffic accident, complained of severe low-back pain and showed bilateral pedicle screw breakage and nonunion at 3 years after surgery. This patient underwent revision surgery including implant removal, curettage of the bone graft area with addition of iliac bone graft, and extension of the fusion area.

Adjacent-segment degeneration was observed in 5 patients (5%: 3 men and 2 women) (Table 2). The mean age at primary surgery was 49 years (range 34–71 years). Progression of ASD was observed at the cranial segment in all cases. The conditions encountered at the secondary operations were degenerative spondylolisthesis in 1 patient and disc herniation in 4 patients. The average period between the primary and secondary operations was 5.4 years (range 2–9 years).

Nonunion was observed in 4 patients (4%) (Table 2). Of the 4 patients with nonunion, 2 had no complaints, but 2 complained of severe low-back pain that was unresponsive to conservative treatment and was treated with revision surgery. These patients underwent replacement of pedicle screws and addition of iliac bone graft at the revision surgery. Interbody cages and bone graft that had been inserted at the primary surgery were not replaced. One of these patients was mentioned in the “instrumentation failure” section and another showed a postoperative slip value of 33%.

Effects of Slip and Disc Height Reduction on Clinical Outcomes

Significant correlations were detected between final JOA scores and postoperative slip (p = 0.001) and slip reduction (p = 0.010), whereas preoperative slip did not affect clinical outcomes (p = 0.734) (Fig. 1). Significant correlations were also detected between recovery rate and postoperative slip (p = 0.013) and slip reduction (p = 0.016) (data not shown). Clinical outcomes were better in proportion to slip reduction. Although no statistical difference was detected in clinical outcomes between postoperative slip of less than 10% and from 10% to less than 20%, patients with postoperative slip of more than 20% showed significantly worse clinical outcomes (Table 3). Significant differences in postoperative slip (p = 0.030) and slip reduction (p = 0.026) were detected between the excellent and poor groups. Postoperative slip values in the excellent and poor groups were 8% and 18%, respectively, and slip reductions in the excellent and poor groups were 14% and 4%, respectively (Fig. 2). On the other hand, no correlation was detected between pre- and postoperative disc height and clinical outcomes.

As far as postoperative complications, pre- and postoperative slip values and disc height did not affect the occurrence of neurological deficits and ASD. Nonunion appeared to occur more often in patients with less slip reduction, although no significant difference was detected (Fig. 3). The average postoperative slip values with and without nonunion were 20% (7%–33%) and 10% (−8% to 33%), respectively. Instrumentation failure was significantly more common in patients with more reduction than those without instrumentation failure (p = 0.009). The average postoperative slip values with and without instrumentation failure were 4% (0%–10%) and 10% (−8% to 33%).
Surgical outcomes of PLIF for isthmic spondylolisthesis

TABLE 3: Postoperative slip and clinical outcomes in 106 patients who underwent PLIF with total facetectomy

<table>
<thead>
<tr>
<th>Postop Slip</th>
<th>No. of Patients</th>
<th>JOA Score Preop</th>
<th>JOA Score Postop</th>
<th>Recovery Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10%</td>
<td>61</td>
<td>14.4</td>
<td>25.4</td>
<td>75.3</td>
</tr>
<tr>
<td>10%–20%</td>
<td>33</td>
<td>14.6</td>
<td>25.1</td>
<td>72.9</td>
</tr>
<tr>
<td>&gt;20%</td>
<td>12</td>
<td>14.8</td>
<td>20.1*</td>
<td>37.3*</td>
</tr>
</tbody>
</table>

* p < 0.05.

A postoperative neurological deficit is generally considered to be a serious complication. Current instrumentation systems have provided tools to correct slippage. However, these operations involve an increased risk of neurological complications from the screws, and the possibility of distracting neurological elements during the corrective procedure. Ogilvie reviewed the incidence of neurological complications with isthmic spondylolisthesis and found that it has increased with progress in instrumentation surgery, although the incidence of complications with degenerative spondylolisthesis has not increased. Therefore, our concept for reduction, with an average 14% slip reduction appears reasonable. Additionally, total facetectomy can provide more space for PLIF maneuvering and can facilitate retraction of nerve roots.

In previous reports, the incidence of neurological deficits associated with PLIF ranged from 2% to 8%, and the incidence of permanent neurological deficits ranged from 1.7% to 6.5%. The current incidence of neurological complications is substantially lower than that of previous reports. Despite such advances, however, 7 patients (7%) in the present series showed neurological deficits after the primary surgery, and permanent motor loss was observed in 1 patient (1%). No correlation was detected between reduction and the occurrence of postoperative neurological deficits. Thus, it appears that the low rate of permanent motor loss in the current series, compared with previous reports, was due to surgical innovations such as appropriate reduction and total facetectomy.

Fig. 2. Bar graph showing that clinical outcomes were better in proportion to slip reduction. Significant differences in postoperative slip (p = 0.030) and slip reduction (p = 0.026) were detected between the excellent and poor groups. Postoperative slip values in excellent and poor groups were 8% and 18%, respectively, and slip reduction values in the excellent and poor groups were 14% and 4%, respectively. *p < 0.05.
In the present series, nonunion was observed in 4 cases and the union rate was 96%. The causes of these nonunions were not indicated by the patient history or laboratory data. In previous reports, the fusion rate ranged from 65% to 100%. Several reports have noted that the union rate for isthmic spondylolisthesis was worse in nonreduction surgery than in reduction surgery. In the current series, nonunion was found more often in patients with less reduction, although no significant difference was detected. From the point of view of interbody arthrodesis, a larger contact area of the bone graft site by reduction appeared to be desirable. Furthermore, total facetectomy enabled a low postoperative neurological deficit rate combined with a high union rate.

Instrumentation failures were observed in 7 patients, including 4 with pedicle screw loosening and 3 with pedicle screw breakage. In previous reports, the instrumentation failure rate ranged from 2% to 12%. Instrumentation failures were significantly more common in patients with more reduction, although the clinical outcomes were not affected. All patients with instrumentation failure showed postoperative slip values within 10%. Excessive reduction might cause mechanical stress in the instrument or vertebral bone. Interestingly, all pedicle screw loosening was observed at the cranial side, and all breakage occurred at the caudal side. The reasons for this were unclear, but these phenomena might be plate-system–specific instrumentation failures for PLIF.

Adjacent-segment degeneration after PLIF is one of the most important sequelae affecting long-term outcome. Although the development of ASD can occur as a part of the normal aging and degenerative process, this phenomenon appears to be at least partly influenced by the alteration of stresses that occurs as a consequence of lumbar fusion. Poussa and colleagues reported that slip reduction accelerated ASD compared with in situ fusion. Furthermore, Kaito et al. reported that excessive disc height lifting was a risk factor for ASD after PLIF. In previous reports, the revision rate for ASD ranged from 1.4% to 16.8%. In the present series, 5 patients (5%) had ASD, and the rate was almost equal to that in previous reports. No correlation was seen between the reduction in slip and disc height and the occurrence of ASD in this study. These results suggested that our reduction procedure did not affect the occurrence of ASD.

One of the limitations of this study was that spinopelvic parameters such as sacral slope, pelvic tilt, and sagittal vertical axis could not be investigated. However, global sagittal imbalance is rarely observed in low-dysplastic spondylolisthesis. In the present series, no patient presented with either low-back pain alone or global sagittal imbalance as a chief complaint, unlike patients with adult spinal deformity.

In the present study, slip reduction appeared to affect the clinical outcomes, which were better in proportion to slip reduction. Although no statistical difference was detected in clinical outcomes between postoperative slip less than 10% and from 10% to 20%, patients with postoperative slip of more than 20% showed significantly worse clinical outcomes. Twelve patients (11%) retained a postoperative slip more than 20% in spite of our PLIF techniques with total facetectomy and plate systems. These patients showed significantly worse clinical outcomes due to severe postoperative complications such as permanent motor loss and nonunion that required revision surgery. In the present study, it remained unclear whether further forcible reduction should be performed for these rigid cases. On the other hand, excessive reduction caused...
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instrumentation failure. All patients with instrumentation failure showed postoperative slip values within 10%. Although our initial goal for reduction was neither a degree of slip nor an attempt at complete reduction, the present results suggest that appropriate reduction resulted in a postoperative slip ranging from 10% to 20%.

Conclusions

The use of PLIF with total facetectomy for low-dysplastic isthmic spondylolisthesis appears to produce satisfactory clinical outcomes, with an average of 73% recovery rate and few postoperative complications. Although clinical outcomes were better in proportion to slip reduction, excessive reduction caused instrumentation failure and less reduction demonstrated worse clinical outcomes. Appropriate reduction resulted in a postoperative slip ranging from 10% to 20%.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Okuda. Acquisition of data: Okuda. Analysis and interpretation of data: Okuda. Drafting the article: Okuda. 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: Okuda. Statistical analysis: Okuda. Administrative/technical/material support: Okuda. Study supervision: all authors.

References


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