Pedicle screw fixation for isthmic spondylolisthesis: does posterior lumbar interbody fusion improve outcome over posterolateral fusion?

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Object. Posterolateral fusion involving instrumentation-assisted segmental fixation represents a valid procedure in the treatment of lumbar instability. In cases of anterior column failure, such as in isthmic spondylolisthesis, supplemental posterior lumbar interbody fusion (PLIF) may improve the fusion rate and endurance of the construct. Posterior lumbar interbody fusion is, however, a more demanding procedure and increases costs and risks of the intervention. The advantages of this technique must, therefore, be weighed against those of a simple posterior lumbar fusion.

Methods. Thirty-five consecutive patients underwent pedicle screw fixation for isthmic spondylolisthesis. In 18 patients posterior lumbar fusion was performed, and in 17 patients PLIF was added. Clinical, economic, functional, and radiographic data were assessed to determine differences in clinical and functional results and biomechanical properties.

At 2-year follow-up examination, the correction of subluxation, disc height, and foraminal area were maintained in the group in which a PLIF procedure was performed, but not in the posterolateral fusion–only group (p < 0.05). Nevertheless, no statistical intergroup differences were demonstrated in terms of neurological improvement (p = 1.0), economic (p = 0.43), or functional (p = 0.95) outcome, nor in terms of fusion rate (p = 0.49).

Conclusions. The authors’ findings support the view that an interbody fusion confers superior mechanical strength to the spinal construct; when posterolateral fusion is the sole intervention, progressive loss of the extreme correction can be expected. Such mechanical insufficiency, however, did not influence clinical outcome.

Key Words • spondylolisthesis • spinal fusion • pedicle screw • posterior lumbar interbody fusion

Spondylolisthesis is the anterior subluxation of one VB onto another. Because there is a failure of the compensatory mechanisms to maintain an adequate posteriorly directed force vector, the shear forces that exist in the intervertebral disc space cause anterior VB slippage. This failure in the isthmic form is caused by a defect in the pars interarticularis, and occurs in up to 8% of the general population in individuals of all ages.12–14,16

Spondylolisthesis is a condition characterized by a failure of the three-column support with severe complex instability requiring reconstruction of the altered supporting structures. The use of posterior lumbar pedicle screw instrumentation is now the standard for reconstruction of the affected segment; its widespread application introduced the era of segmental spinal fixation.3,4,10,26,47

Biomechanically, pedicle screw systems allow three-column stabilization that exerts a stronger grip force than other posterior fixation systems; require no intact posteri-

Abbreviations used in this paper: DSH = disc space height; PLIF = posterior lumbar interbody fusion; SD = standard deviation; VB = vertebral body.
Given this controversy, we retrospectively reviewed data obtained in 35 consecutive patients surgically treated for isthmic spondylolisthesis; the procedure involved segmental fixation and either posterolateral fusion or PLIF. Our goal in comparing the techniques was to investigate whether there are differences in clinical and functional outcome, as well as biomechanical property differences.

Clinical Material and Methods

Demographic Data and Selection Criteria

Between June 1997 and June 2000, 35 adult patients with isthmic spondylolisthesis underwent implantation of an identical pedicle screw system.

In 18 cases, treated between June 1997 and April 1999, a simple posterolateral fusion was performed, whereas a PLIF was added in 17 patients treated between May 1999 and June 2000. The population consisted of 21 men and 14 women, and the mean age was 57.2 years (range 32–74 years).

Symptoms consisted of back, buttoc, and posterior thigh claudication pain or lumbosacral radiculopathy in all patients. Lumbosacral tenderness was present in 24 patients (68.6%), reduced lateral bending in 17 (48.6%), dermatomal sensory disturbances in 20 (57.1%), motor disturbances in 16 (45.7%), positive straight-leg raising responses in 15 (42.9%), reduced reflex in nine (25.7%), and bladder dysfunction in four (11.4%). Twelve patients were cigarette smokers.

In patients receiving conservative medical treatment, including bedrest, antiinflammatory medication, physiotherapy, and external brace therapy, treatment failed to resolve symptoms.

Preoperative and postoperative economic (activity) and functional (pain) statuses were assessed and using the system proposed by Prolo, et al.34 (Table 1).

Preoperative radiographic evaluation consisted of standard anteroposterior, lateral, oblique, and flexion–extension studies performed in standing position. The percentage of VB slippage was measured according to the Meyerding classification system for spondylolisthesis.2 Subluxation was classified as Grade I (10 patients), Grade II (20 patients), and Grade III (five patients) lumbar or lumbosacral spondylolisthesis, and the maximum percentage of subluxation was 65%. The study was completed after we obtained bone window computerized tomography and magnetic resonance imaging studies to evaluate the extent of neural compression.

Preoperative clinical, economic, and neuroimaging data are summarized in Table 2.

Operative Technique

All patients underwent fusion combined with implantation of the SOCON-SRI system (Aesculap AG and Co., Tuttlingen, Germany). Decompressive surgery consisted of removal of the spinous process, bilateral laminectomy, partial bilateral facetectomy, and foraminotomy was performed prior to screw insertion and reduction maneuvers.33 The disc spaces were carefully assessed for herniated disc material or prominent bulges, and the discs were removed if necessary. Positioning of the instrumentation has been described elsewhere.33 After pedicle screw insertion, distraction of the instrumented vertebrae was performed using a longitudinal threaded spindle. Reduction maneuvers were then performed using the removable levers inserted in the pedicle screws.

Fusion Site Preparation

Posterolateral fusion was performed. The osseous surfaces of the transverse and articular processes were decorticated using a high-speed drill. Cancellous bone obtained from the posterior arch was packed over the decorticated surface. Cortical strips were then packed over the cancellous graft material.

In 17 patients a PLIF was performed using the Prospace PLIF system (Aesculap AG and Co.) composed of a solid titanium block with a cuboidal shape (7 mm wide, 7–13 mm high, 22 mm long) and a porous pure titanium coating that has been demonstrated to facilitate bone growth.41,42 After the dural sac was mobilized, disc removal and preparation of endplates were performed in a three-step procedure (reaming, rasping, and broaching) in which dedicated instruments were used. The cortical bone was roughened and only partially removed. Titanium fusion block pairs were then inserted and advanced. Autologous cancellous bone was packed into the grooves in the side of the implant medially and laterally.

Clinical and Neuroimaging Follow Up

All patients underwent serial clinical evaluations at regular 3-month intervals between the 3rd and the 24th postoperative months.

Preoperative records were reviewed, and the patients were interviewed. Economic and functional grades (Table 1) were assigned postoperatively by a third party not involved in the surgical treatment and hospital care of patients.

The changes in economic and functional grades were calculated for each patient, and intergroup differences were then calculated.

### TABLE 1
Summary of Prolo economic and functional scale

<table>
<thead>
<tr>
<th>Grade</th>
<th>Economic (activity)</th>
<th>Functional (pain)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>complete invalid (worse)</td>
<td>total incapacity (worse)</td>
</tr>
<tr>
<td>2</td>
<td>no gainful occupation (including housework or retirement activities)</td>
<td>moderate-to-severe daily pain (no change)</td>
</tr>
<tr>
<td>3</td>
<td>working/active (but not at premorbid level)</td>
<td>low-level daily pain (improved)</td>
</tr>
<tr>
<td>4</td>
<td>working/active (at previous level w/ limitation)</td>
<td>occasional or episodic pain</td>
</tr>
<tr>
<td>5</td>
<td>working/active (at previous level w/o limitation)</td>
<td>no pain</td>
</tr>
</tbody>
</table>
Posterolateral and interbody fusion for isthmic spondylolisthesis

**Table 2**

| Summary of preoperative clinical and radiographic data* |
|---|---|---|---|
| | PLF | PLF + PLIF | p Value |
| economic score | 2.5 | 2.5 | NS |
| functional score | 2.3 | 2.8 | NS |
| slippage (%) | 38.9 | 36.2 | NS |
| slip angle (°) | 68.9 | 70.6 | NS |
| sacral inclination (°) | 42.7 | 47.6 | NS |
| segmental lordosis (°) | 16.9 | 16.7 | NS |
| foraminal area (mm²) | 115.6 | 104 | NS |
| DSH (mm) | 3.2 | 4 | NS |

* NS = not statistically significant; PLF = posterolateral fusion.

Radiographs were obtained postoperatively and at regular 3-month intervals for 24 months to evaluate the reduction of spondylolisthesis and to identify the correct placement and stability of the implant.

Successful fusion was defined as the following: 1) absence of motion on flexion-extension radiographs; 2) absence of halo around the implant demonstrated on imaging studies; and 3) presence of bilateral continuous trabecular bone between the fused segments. Postoperative bone window computerized tomography or magnetic resonance imaging studies were obtained in all patients to evaluate the results of neural decompression.

Other radiographic parameters were then calculated to compare the two fusion techniques. The neural foraminal area was calculated on lateral radiographs before, immediately after, and 2 years after intervention. Similarly we calculated the disc height, sacral inclination, sagittal rotation, and segmental lumbar lordosis. The segmental lumbar lordosis was measured at L4–5 or L5–S1. Segmental L4–5 lordosis was determined by drawing lines parallel to the cephalad L-4 endplate and the caudal L-5 endplate. A L4–5 lordosis was determined by drawing lines parallel to the cephalad L-4 endplate and the superior aspect of the sacrum. Sacral inclination and sagittal rotation were measured according to the method of Wiltse and Winter.

The Fisher exact test was used to compare the nonunion rate; the same test was used to compare the neurological recovery rate. The Mann–Whitney U-test was used to compare categorical data (economic and functional outcome). A probability value of 0.05 was used to define statistical significance. Statistical analysis was performed using the INSTAT 3.0 software (GRAPHPAD, San Diego, CA).

### Results

Thirty-five pedicle screw systems were implanted. No major surgery-related complications occurred, including wound infection, additional neurological dysfunction, or screw placement–related vascular injuries. No patient died or required reoperation or hardware removal after fusion.

### Preoperative Variables

There were no statistically significant intergroup differences for age, sex, prior surgery, cigarette smoking history, involvement in claims for Workers’ Compensation or litigation following accidents, or variables demonstrated to affect outcome in patients with low-back instability.

Preoperative clinical, economic, and neuroimaging variables were not statistically different between the two cohorts (Table 2).

### Neurological Outcome

Intergroup comparison of motor and sensory deficit improvement is summarized in Table 3.

In the group in which posterolateral fusion alone was performed, significant improvement was demonstrated in eight (80%) of 10 patients who presented sensory deficits. Motor disturbances improved in seven (100%) of seven cases. Reflex responses were not shown to change appreciably after surgery, presumably because of the longlasting clinical symptoms. Significant amelioration of function was seen in one patient with preoperative urinary disturbance.

In patients in whom PLIF was performed, in addition to posterolateral fusion, significant improvement was demonstrated in nine (90%) of 10 patients who presented with sensory deficit. Motor disturbances improved in eight patients (80%). In three patients with preoperative urinary incontinence recovery of bladder control was demonstrated.
Economic and Functional Outcome

Table 3 summarizes economic and functional data recorded preoperatively and at the 2-year follow-up examination.

**Posteriorlateral Fusion.** In the subgroup of patients treated with posterolateral fusion alone, the mean preoperative Prolo economic grade was 2.5 (range 1–4), whereas postoperatively it was 3.8 (range 2–5). In 12 patients (66.7%) good outcome was observed (Grade 4–5), whereas in three (16.7%) fair (Grade 3) and in two (11.8%) poor outcomes (Grade 1–2) were demonstrated. The mean change ± SD in grade in this subgroup was 1.3 ± 0.5.

The mean preoperative Prolo functional grade was 2.3 (range 1–4), whereas postoperatively it was 3.8 (range 2–5). In 12 patients (66.6%) good outcome was observed, whereas in six patients (33.3%) fair (Grade 3) and in three (16.7%) poor outcomes (Grade 1–2) were demonstrated. The mean change ± SD in function was 1.5 ± 0.7.

**Posterior Lumbar Interbody Fusion.** In the subgroup of patients in which PLIF was added, the mean preoperative Prolo economic grade was 2.5 (range 1–4), whereas postoperatively it was 3.8 (range 2–5). In 12 patients (70.6%) good outcome (Grade 4–5) was observed, whereas in three patients (17.6%) fair (Grade 3) and in two (11.8%) poor outcomes (Grade 1–2) were demonstrated. The mean change in grade ± SD was 1.3 ± 0.5.

The mean preoperative Prolo functional grade was 2.8 (range 1–4), whereas postoperatively it was 4.2 (range 2–5). In 13 patients (76.5%) good outcome (Grade 4–5) was observed, whereas in four patients (23.5%) fair (Grade 3) and none (0%) poor outcomes (Grade 1–2) were demonstrated. The mean change in function ± SD was 1.4 ± 0.6.

The mean changes were calculated for both economic and functional score and compared. Changes were not statistically different.

**Neuroimaging-Based Outcome**

**Hardware Failure.** In the posterolateral fusion group, we documented a detachment of the rods from the screws in one case. In this group two cases of nonunion were documented. Neither fusion failure nor hardware breakage was demonstrated in the follow-up studies in the PLIF group (p > 0.05).

**Anatomical Correction.** The percentage of slippage, the foraminal area, DSH, angle of VB slippage, sacral inclination, and segmental lordosis were calculated preoperatively. Table 4 provides a summary of pre- and immediate postoperative values. Statistical analysis within groups demonstrated that surgery changed the percentage of subluxation, angle of slippage, foraminal area, and DSH, but did not influence sacral inclination and segmental lordosis.

At the 2-year follow-up examination slippage, foraminal area, and DSH had changed in both groups compared with the values obtained immediately postoperatively with a tendency to return toward the preoperative values, whereas angle of subluxation did not change significantly in either group (Figs. 1 and 2). Data analysis showed that the maintenance of the corrected deformity was significantly greater in the PLIF-treated group (Fig. 3). Table 5 provides a summary of the magnitude and difference of the changes in the groups.

**Discussion**

All patients underwent segmental lumbar fusion involving placement of a pedicle screw system for the correction of spinal alignment;25,44 in an earlier treated group posterolateral fusion alone was performed, whereas in a more recently treated group, this procedure was combined with PLIF. The technique successfully achieved solid fusion with nerve root decompression, and good economic and functional results. Overall, superior mechanical reliability, intended as the maintenance of spinal alignment, was associated with the PLIF procedure (p < 0.05). When clinical outcome was reviewed no significant intergroup difference was documented (p > 0.05).

Two cohorts of patients were retrospectively reviewed. Patients in whom only posterolateral fusion was performed underwent surgery at the beginning of the study period, early in our operative experience with the implant system, whereas later in the study period, when our experience was greater, we added a PLIF procedure. It is likely that the learning curve was similarly influenced in both treatment groups. Furthermore, characteristics in the two groups were homogeneous in terms of most preoperative clinical and radiographic parameters (Table 2) and the same system was implanted by the same surgeons. The two groups were therefore considered comparable and selection bias to be reasonably limited.

Segmental lumbar fixation was combined with a reduction/distraction procedure to restore physiological lumbar
balance. Correction of the lumbar curvature may improve the fusion rate by reducing the shearing forces that cause anterior slippage. Furthermore, reduction narrows the gap between the fusion bases and reduces the bending moment over the graft. Reduction/distraction procedures also can potentially correct VB slippage–induced angular changes in the sagittal plane that create additional lumbar stress and cause posture/gait irregularities and low-back pain.

In this study we found that the instrumentation-augmented procedure is safe and effective in correcting spondylolisthesis-induced anatomical changes in the lumbar spine (Figs. 1 and 2) and that it has the potential to reduce subluxation and angle of VB slippage, restoring at the same time the DSH and neural foraminal area. Those changes, however, tended to be somewhat temporary in patients who underwent simple posterolateral fusion, in whom a significant loss of correction was recorded at the 2-year follow up (Fig. 3). The correction was maintained in those patients in whom anterior support was provided. This difference relates to the different biomechanical properties of the two techniques.

In the lumbar spine the physiological axial load is supported 80% through the anterior column and 20% through the posterior elements. In fused segments, the absence of anterior support makes the entire axial load pass through the system, reducing, as a result, its longevity. Additionally, because the transpedicular systems require posteriorly attached screws and a large lever arm, flexion movements may cause the screw to accommodate extreme stress.11,17 Interbody fusion devices, on the other hand, are placed in the center of segmental motion and require the shortest lever arm allowing the greatest potential for inhibiting motion.

The authors of several biomechanical studies have confirmed the aforementioned concepts. Results of static and the fatigue tests strongly indicated the need for anterior-column support, demonstrating that posterior pedicle

**FIG. 1.** Radiographic studies obtained in a patient with spondylolisthesis. Left: Preoperative lateral x-ray film demonstrating an isthmic L5–S1 subluxation with 45% VB slippage. The foraminal area measured 147 mm² and the angle of subluxation 70.4°. Center: Postoperative lateral x-ray film obtained after pedicle screw fixation and posterolateral fusion. The slippage was reduced to 15%, foraminal area increased to 167.5 mm², and DSH increased to 4.7 mm. The angle of slippage measured 74.5°. Right: Two-year follow-up x-ray film demonstrating the return of the subluxation to 25%, with a change in the shape and area of the foramen measuring 140.8 mm² (DSH 2 mm and angle of slippage 71.8°).

**FIG. 2.** Radiographic studies obtained in a patient with spondylolisthesis. Left: Preoperative lateral x-ray film revealing an isthmic L5–S1 subluxation of 20%, a foraminal area of 68.4 mm², and a DSH height of 4.3 mm. The angle of slippage measured 77.9°. Center: Lateral x-ray film obtained after pedicle screw fixation and interbody fusion. The subluxation was reduced to 0%, the foraminal area increased to 137.8 mm², and the DSH increased to 7.7 mm. The angle of slippage measured 68.3°. Right: Long-term follow-up x-ray film demonstrating that correction of slippage, shape and area of the foramen, DSH, and angle of slippage were maintained.
Screw systems are at a distinct disadvantage in resisting physiological loads because of the cantilever nature of their design. On the other hand, other authors have demonstrated that this superior stability is provided when interbody fusion devices are combined with screw/rod systems, which indicates that the latter should not be used as stand-alone devices to treat lumbar spondylolisthesis.

Our findings underscore the observations that the addition of PLIF confers greater superior mechanical strength to the spinal construct.

Despite these considerations, we did not record any significant intergroup differences with regard to fusion rate. In the posterolateral fusion–treated subgroup fusion was achieved in 88.9% whereas in the posterolateral/PLIF–treated group it was 100% (p = 0.49). This result is not surprising and is supported in the literature. Comparing posterolateral fusion with PLIF in segmental fixation for isthmic spondylolisthesis, Suk, et al., found a 7.5% fusion failure in the subgroup treated with instrumentation-augmented posterolateral fusion, whereas fusion was achieved in all cases in which PLIF was added; however, there was no intergroup statistical significance. Similar results have been recently reported by Madan and Boeree. It has been documented that fusion of the posterior lumbar elements combined with placement of instrumentation represents a valid solution for lumbar instability and may result in a solid fusion in up to 95% of cases.

Thus, two points exist. First, in vitro biomechanical findings have demonstrated that pedicle screw systems provide insufficient mechanical strength and require anterior support to establish the mechanical environment for fusion. Second, clinical findings have shown that a posterolateral arthrodesis represents a valid solution for lumbar instability and is potentially associated with a high fusion rate.

Our findings, supported by those of others, suggest that after posterolateral arthrodesis a high fusion rate can be expected and that the manifestation of the hardware-related mechanical insufficiency demonstrated by the biomechanical studies may be limited to the loss of extreme stress-inducing angle and curvature correction. Furthermore, it is worth noting that disc space collapse and the more direct contact between the two adjacent vertebral endplates may have compensated for the absence of anterior support and positively influenced the fusion of the posterior columns as well as the overall clinical outcome.

One of our aims was also to determine if the radiographic differences were associated with different clinical outcomes.

Neurological improvement as well as changes in functional and economic scores—namely the pain and daily working activity outcome—were not vastly different between the two groups (p > 0.05). In other words, similar results were achieved in the two subgroups independent of the mechanical properties of the two systems.

Of note, comparison of overall good outcome (68.5% economic and 71.4% functional) with fusion rate (94.3%) did not demonstrate a complete overlapping of the two values. Although somewhat surprising, this is actually a common finding in the literature. There is, indeed, disagreement as to whether fusion correlates with clinical outcome in the treatment of lumbar disorders. In series of patients treated for spondylolisthesis, satisfactory fusion and pain outcomes have not been shown to correlate in all series, and even when outcome in pain status is satisfactory, return to premorbid daily activity is not assured. Even in studies focused on the lumbosacral balance rather than fusion, interestingly, lordosis and clinical outcome measures do not clearly correlate when this association is explicitly examined. Furthermore, there are a great number of factors that may significantly influence the functional and economic outcomes of those patients, regardless of fusion technique. Compensation-related issues and previous surgery are highly significant risk fac-

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**Figure 3.** Bar graphs showing preoperative (white bars), postoperative (black bars), and 2-year follow-up values (gray bars) VB slippage (upper), foraminal area (center), and disc height (lower). Intervention corrected preoperative values in both posterolateral fusion (PLF) and posterolateral fusion combined with PLIF (PLF + PLIF) groups. These changes were maintained in the PLIF-treated group but tended to return to the preoperative values in the posterolateral fusion–treated group. Asterisks indicate statistically significant differences.
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Conclusions

Despite the large number of variables involved in a definition of “good results” in spondylolisthesis, as in other conditions of spinal segmental instability, it can be concluded that the aforesaid segmental pedicle screw fixation technique can be used to achieve solid fusion and nerve root decompression.

Our findings support the view that, when a three-column instability is present, interbody fusion confers superior mechanical strength upon the construct. The mechanical insufficiency associated with a posterolateral fusion alone is not, however, represented by the failure of fusion but, rather, by a progressive loss of the stress-shielding effect of the system, in which the overall body’s weight passes through the screw/rod connections. Such structural insufficiency of the spinal fixator when used as a standalone device caused a collapse of the intervertebral space. This possibly offered the necessary anterior support to a posterior-only approach, influencing both the fusion rate and clinical outcome. Furthermore, numerous clinical variables other than the spinal alignment may more significantly affect the outcome. In comparing two subgroups in which fusion techniques differed but in which clinical variables were homogeneous, we found no statistically significant differences.

References

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