Minimally Invasive Unilateral Pedicle Screw Fixation and Lumbar Interbody Fusion for the Treatment of Lumbar Degenerative Disease

Bin Lin, MD; Yang Xu, MD; Yong He, MD; Bi Zhang, MD; Qiuyan Lin, MD; Mingchang He, MD

abstract

Minimally invasive unilateral pedicle screw fixation for the treatment of degenerative lumbar diseases has won the support of many surgeons. However, few data are available regarding clinical research on unilateral pedicle screw fixation associated with minimally invasive techniques for the treatment of lumbar spinal diseases. The purpose of this study was to evaluate clinical outcomes in a selected series of patients with lumbar degenerative diseases treated with minimally invasive unilateral vs classic bilateral pedicle screw fixation and lumbar interbody fusion. Patients in the unilateral group (n = 43) underwent minimally invasive unilateral pedicle screw fixation with the Quadrant system (Medtronic, Memphis, Tennessee). The bilateral group (n = 42) underwent bilateral instrumentation via the classic approach. Visual analog scale pain scores, Oswestry Disability Index scores, fusion rate, operative time, blood loss, and complications were analyzed. Mean operative time was 75 minutes in the unilateral group and 95 minutes in the bilateral group. Mean blood loss was 220 mL in the unilateral group and 450 mL in the bilateral group. Mean postoperative visual analog scale pain score was 3.10 ± 0.16 in the unilateral group and 3.30 ± 1.10 in the bilateral group. Mean postoperative Oswestry Disability Index score was 15.67 ± 2.3 in the unilateral group and 14.93 ± 2.6 in the bilateral group. Successful fusion was achieved in 92.34% of patients in the unilateral group and 93.56% of patients in the bilateral group. Minimally invasive unilateral pedicle screw fixation is an effective and reliable option for the surgical treatment of lumbar degenerative disease. It causes less blood loss, requires less operative time, and has a fusion rate comparable with that of conventional bilateral fixation.

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Lumbar fusion is recognized as an effective treatment for degenerative lumbar diseases such as lumbar spinal canal stenosis, spondylolisthesis, and segmental spinal instability. The goal of lumbar fusion surgery is to achieve a solid arthrodesis of spinal segments that can sustain loading while maintaining proper disk space height, preserving foraminal dimensions, and restoring sagittal plane alignment. With the development of surgical technology, the advances in lumbar fusion techniques have concentrated on reducing soft tissue injury and maintaining the ability to achieve neural decompression and interbody fusion. Although the modern era of minimally invasive surgery of the spine can only be realistically discussed within the confines of the past decade, interest in these techniques is growing because of a perceived benefit in perioperative morbidity and patient recovery.

Traditionally, bilateral pedicle screw fixation is regarded as a widely accepted method for the management of a variety of spinal diseases. This standard procedure provides rigid fixation and confers both biomechanical and clinical advantages. However, due to the excessive rigidity of bilateral pedicle screw fixation, this instrumentation is suspected to cause degeneration of adjacent segments. In addition, degenerative disk disease and foraminal stenosis may induce nerve root compression, which can cause unilateral symptoms in clinical practice. In that case, the bilateral pedicle screw fixation seems unnecessary. The unilateral construct is attractive because, other things being equal, it avoids soft tissue disruption of the contralateral side, may take less time, and can be associated with lower implant costs.

Encouraged by the development of surgical techniques, minimally invasive unilateral pedicle screw fixation for the treatment of degenerative lumbar diseases has won the support of many surgeons. However, few data are available regarding clinical research on unilateral pedicle screw fixation associated with minimally invasive techniques for the treatment of lumbar spinal disease. The objective of this study was to evaluate the clinical outcomes of lumbar degenerative diseases treated with minimally invasive unilateral pedicle screw fixation vs classic bilateral pedicle screw fixation and lumbar interbody fusion.

**MATERIALS AND METHODS**

All patients treated by decompression with 1-level fusion were followed up for an average of 26 months (range, 18-32 months). The 85 patients studied were randomly assigned to the unilateral pedicle screw fixation group (n=43) or the bilateral pedicle screw fixation group (n=42). Preoperative symptoms included low back pain, unilateral lower-limb radiculopathy, and intermittent claudication. All surgeries were performed by the same surgeon (B.L.).

The unilateral fixation group comprised 19 men and 24 women with a mean age of 67 years (range, 57-74 years). Preoperative diagnoses were spinal canal stenosis (n=9), spondylolisthesis (grade I or II) (n=14), and lumbar disk herniation (giant or far lateral type) (n=20). In the 9 cases of spinal canal stenosis, 4 patients were operated at L3-L4 and 5 at L4-L5. In the 14 cases of spondylolisthesis, 6 patients were operated at L4-L5 and 8 at L5-S1. In the 20 cases of lumbar disk herniation, 5 patients were operated at L3-L4, seven at L4-L5, and 8 at L5-S1 (Figure 1).

The bilateral fixation group comprised 20 men and 22 women with a mean age of 65.5 years (range, 58-76 years). Preoperative diagnoses were spinal canal stenosis (n=8), spondylolisthesis (grade I or II) (n=15), and lumbar disk herniation (giant or far lateral type) (n=19). In the 8 cases of spinal canal stenosis, 3 patients were operated at L3-L4 and 5 at L4-L5. In the 15 cases of spondylolisthesis, 6 patients were operated at L4-L5 and 9 at L5-S1. In the 19 cases of lumbar disk herniation, 6 patients were operated at L3-L4, eight at L4-L5, and 5 at L5-S1 (Figure 2).

Clinical outcomes were assessed using visual analog scale (VAS) pain scoring and the Oswestry Disability Index (ODI) score. Mean preoperative VAS was 7.18±1.14 in the unilateral group and 7.23±1.10 in the bilateral group. Mean preoperative ODI score was 42.2±11.8 in the unilateral group.

**Figure 1:** Sagittal T1- (A) and T2-weighted (B) magnetic resonance images of a 47-year-old woman with lumbar degenerated L5-S1 disk herniation and spinal instability.

**Figure 2:** Anteroposterior (A) and lateral (B) radiographs 6 months after decompression, posterior lateral fusion, and unilateral pedicle screw fixation. The clinical result was excellent.
and 43.0±12.0 in the bilateral group. No statistically significant differences existed between the 2 groups in terms of age, sex, preoperative diagnosis, VAS pain score, or ODI score (Table 1).

**Surgical Technique**

**Unilateral Group**

Patients were placed in the prone position on a radiolucent table after anesthesia. The pedicles of the vertebral arch of the operated level were marked on the skin with a C-arm machine. A paramedial skin incision approximately 2 cm long was made approximately 3 to 4 cm from the medial line of the side of the approach. The lumbar fascia was then incised, and the finger fracture technique was used to dissociate the muscle fibers until contact was made with the facet joint. A retractor was placed after progressively larger dilating bousies were placed (Quadrant; Medtronic, Memphis, Tennessee). The inferior and superior articular processes and part of the vertebral lamina, as well as part of the base of the spinous process, were removed with a high-speed drill or osteotome. These bones were kept for use as an autograft during interbody fusion. The nerve root was decompressed by removal of the ligamentum flavum and bone spur. A sharp knife was used to create a window on the annulus fibrosus. Exeresis of the disk was performed until contact was made with the anterior longitudinal ligament, and progressive intervertebral distraction was performed using progressively larger dilating bousies. The local autograft was implanted after 1 cage implant (VERTE-STACK; Medtronic, Memphis, Tennessee) and 2 pedicle screws (Adena; Sanyou, Shanghai, China) were inserted and fixed on the ipsilateral side.

**Bilateral Group**

Subtotal laminectomy, facetectomy, diskectomy, pedicle screw placement, autologous bone grafting, and rod and cage insertion were performed via the classic approach.

**Postoperative Management**

Drainage was maintained for 48 hours postoperatively. All patients received 24 hours of intravenous antibiotics postoperatively. All patients practiced waist musculi dorsi function exercises and lifting the legs straight. Patients in the unilateral group were allowed early ambulation 24 hours postoperatively if no contraindications existed. Patients in the bilateral group generally needed 2 to 3 weeks to get out of bed.

**Clinical Assessment**

Perioperative parameters included blood loss, operative time, VAS scores for lumbar and leg pain, and ODI scores. Scores were obtained at 1 week and 3, 6, 12, and 24 months postoperatively. These data were compared to evaluate efficacy.

Radiologic parameters included anteroposterior and lateral radiographs preoperatively and at 1 week and 3, 6, 12, and 24 months postoperatively; additional flexion-extension radiographs preoperatively and at 6, 12, and 24 months postoperatively; and 3-dimensional computed tomography preoperatively and at 1 week and 12 and 24 months postoperatively. Radiographic analyses evaluated the fusion rate.

Fusion rate was measured using the criteria of Schulte et al.\(^\text{17}\) The 4 criteria for fusion are bony bridging, bony continuity between endplates, trabecular structure in the anterior bone bridge, and lack of radiolucent lines around implants. In this study, the fusion rate was classified as “fused (3)” (3 criteria positive), “probably fused (2)” (2 criteria positive), “probably not fused (1)” (1 criterion positive), and “pseudarthrosis (0)” (evidence of radiolucent lines). Statistical analysis was performed with SPSS version 13 statistical software (SPSS, Inc, Chicago, Illinois). Demographic data (sex, preoperative index diagnosis, and degenerated segment) were compared with the chi-square test. Operative time and blood loss were analyzed with an independent-samples t test. Fusion rate was tested with the Fisher exact test. Analysis of pain and function (VAS and ODI scores) was performed with a paired t test between groups. In all analyses, a P value less than .05 was considered significant.

**Results**

Mean follow-up was 26 months (range, 18-32 months). No significant differences existed between the 2 groups in terms of patient demographics (Table 1). Mean operative time was 75 minutes in the unilateral group and 95 minutes in the bilateral group. Mean blood loss was 220 mL in the unilateral group and 450 mL in the bilateral group. Patients in the unilateral group required a significantly shorter operative time and experienced less blood loss than patients in the bilateral group.

Mean postoperative VAS score was 3.10±0.16 in the unilateral group and 3.30±1.10 in the bilateral group. Mean

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<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Unilateral Group</th>
<th>Bilateral Group</th>
</tr>
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<tbody>
<tr>
<td>Mean age, y</td>
<td>67</td>
<td>65.5</td>
</tr>
<tr>
<td>Sex, No. F/M</td>
<td>24/19</td>
<td>22/20</td>
</tr>
<tr>
<td>Diagnosis, No.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spinal stenosis</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Spondylolisthesis</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>Lumbar disk herniation</td>
<td>20</td>
<td>19</td>
</tr>
<tr>
<td>Mean VAS pain score</td>
<td>7.18±1.14</td>
<td>7.23±1.10</td>
</tr>
<tr>
<td>Mean ODI score</td>
<td>42.2±11.8</td>
<td>43.01±12.0</td>
</tr>
</tbody>
</table>

Abbreviations: ODI, Oswestry Disability Index; VAS, visual analog scale.

\(^a\)No significant difference in all cases (P>0.05).
postoperative ODI score was 15.67 ± 2.3 in the unilateral group and 14.93 ± 2.6 in the bilateral group. Mean postoperative VAS and ODI scores improved significantly in each group; however, no significant differences existed between the 2 groups (Table 2).

According to the fusion evaluation criteria of Schulte et al.,17 92.34% of patients in the unilateral group (Figure 3) and 93.56% of patients in the bilateral group (Figure 4) achieved successful fusion, which was not a significant difference (P < .05). Neither group showed signs of screw breakage or screw loosening. One patient in the unilateral group had symptoms of low back pain but without nerve compression symptoms postoperatively. With regard to general complications, no significant difference was found between the 2 groups (P < .05). One patient in the unilateral group and 2 patients in the bilateral group developed a superficial wound infection. After intravenous antibiotics and daily dressing, all infections were completely controlled.

**Table 2**  
Operative and Postoperative Data

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unilateral Group</th>
<th>Bilateral Group</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean operative time, min</td>
<td>75</td>
<td>95</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Mean blood loss, mL</td>
<td>220</td>
<td>450</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Mean VAS pain score</td>
<td>3.1 ± 0.16</td>
<td>3.3 ± 1.10</td>
<td>&gt; .157</td>
</tr>
<tr>
<td>Mean ODI score</td>
<td>15.67 ± 2.3</td>
<td>14.98 ± 2.6</td>
<td>&gt; .082</td>
</tr>
<tr>
<td>Fusion rate, %</td>
<td>92.34</td>
<td>93.56</td>
<td>&gt; .116</td>
</tr>
<tr>
<td>Complication rate, %</td>
<td>2.3</td>
<td>4.7</td>
<td>&gt; .103</td>
</tr>
</tbody>
</table>

Abbreviations: ODI, Oswestry Disability Index; VAS, visual analog scale.

*No significant difference in all cases (P > .05).*

**Discussion**

In spinal fusion surgery, whether unilateral pedicle screw fixation can provide sufficient stability to maintain spinal fusion is a controversial issue. The potential downside is an insufficiently stable construct that may result in a higher incidence of instrumentation failure. A higher incidence of nonunion may also be a risk. Harris et al.11 conducted a bending and rotation test of flexion-extension and right-and left-sided bending and reported that fixation with the unilateral pedicle screw system was slightly weaker than that with the bilateral pedicle screw system in all directions (flexion-extension, right-and left-sided bending, and clockwise-counter clockwise rotation), with fixation being weaker in the rotary direction.

Slicky et al.18 reported that unilateral fixation after a transforaminal lumbar interbody fusion procedure provides less rotational stability and stiffness than bilateral pedicle screw fixation. Unilateral pedicle screw fixation may not be as rigid as that provided by bilateral pedicle screw instrumentation in biomechanics. However, whether the more rigid construct is needed was not addressed. Deutsch and Musacchio19 reported that over-rigid instrumentation changes the motion pattern, which accelerates the degeneration of adjacent segments.

Unilateral instrumentation is unadvised due to the effect of inherent asymmetry. In the current study, no significant differences were shown between the right and left side in lateral bending and axial rotation in the fusion procedures.20 Chen et al.21 demonstrated that symmetrical positioning of the cages and bilateral pedicle screw fixation contributed similar annulus stress at the operated or adjacent segment, whereas asymmetrical positioning of a diagonal cage plus unilateral pedicle screw fixation increased range of motion and the stresses concentrated on the neighboring pedicle screw, annulus, and cage-endplate interface, mostly in contralateral axial rotation and lateral bending. Asymmetrical positioning of a diagonal cage is not advocated to avoid the unpleasant effect resulting from inherent asymmetry. Unilateral instrumentation may achieve sufficient stability. The inserted cage can be held by

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**Figure 3:** Sagittal T1- (A) and T2-weighted (B) magnetic resonance images of a 52-year-old man in the bilateral group with lumbar degenerated L5-S1 disk herniation and degenerative spinal stenosis.

**Figure 4:** Anteroposterior (A) and lateral (B) radiographs 6 months after decompression, posterolateral fusion, and bilateral pedicle screw fixation. No metal failure or pseudarthrosis occurred.

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the screw-rod system, and the cage can maintain adequate disk space, which is particularly effective for correcting instability associated with degenerative lumbar diseases. Furthermore, 2 randomized controlled clinical trials showed no clinical benefit of bilateral over unilateral instrumentation.15,16

The bilateral instrumental fusion technique requires wide dissection, which weakens the function of the paraspinal muscle. The unilateral approach can substantially reduce exposure requirements. This technique is easier than a routine bilateral cage-instrumented technique. In the current study, the results obtained in terms of minimally invasive and unilateral pedicle screw fixation were similar to the results obtained with conventional techniques. Unilateral pedicle screw fixation has several advantages compared with bilateral fixation, particularly related to its decreased invasiveness.22,23 Minimally invasive unilateral pedicle screw fixation is likely to increase this advantage. The benefits of this technique lie in the reduction of infection risk, the reservation of muscle-ligament complex structure, and more mild postoperative back pain related to the minimally invasive procedure.24,25

The unilateral approach with minimally invasive lumbar fusion is a reliable technique in the management of lumbar diseases. Nevertheless, this procedure has strict indications, including spinal canal stenosis with unilateral symptoms, spondylolisthesis (grade I or II), and lumbar disk herniation (giant or far lateral type) that have failed approximately 3 to 6 months of conservative treatment.

Minimally invasive procedures carry several potential limitations, including limited space for decompression, surgeon lack of familiarity with minimally invasive-specific instrumentation, and limited ability to visually appreciate anatomical landmarks as with open interventions.26 Changing the angle of the channel formed by the retractor could expand the operating space, and the study of instrumentation and anatomy is essential for a successful operation.

**CONCLUSION**

Based on the results of this study, minimally invasive unilateral pedicle screw fixation causes less blood loss, requires less operative time, and has a fusion rate comparable with that of conventional bilateral fixation. It is an effective and reliable option for the surgical treatment of lumbar degenerative diseases. During follow-up, loose or broken nails resulting from inherent asymmetry were not observed in the unilateral group. However, longer follow-up will be necessary to assess the long-term results of this surgical technique. 

**REFERENCES**

22. Beringer WF, Mobasser JP. Unilateral pedicle screw instrumentation for minimally


