Posterior Short-segmental Fixation Combined With Intermediate Screws vs Conventional Intersegmental Fixation for Monosegmental Thoracolumbar Fractures

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Posterior short-segmental fixation is reliable for the management of thoracolumbar fractures; however, it is associated with recurrence of kyphosis and failure of fixation. This study compared the short-term results of short-segmental fixation combined with intermediate screws with those of conventional intersegmental fixation in the treatment of monosegmental thoracolumbar fractures. The records of 62 consecutive patients with thoracolumbar monosegmental fractures who underwent conventional 4-screw intersegmental fixation (35 patients) or short-segmental fixation combined with intermediate screws (27 patients) were reviewed. The study population included 43 men and 19 women (mean age, 44.1 ± 13.6 years). The majority of fractures were L1 (28 [45.1%]) and T12 (21 [33.9%]) fractures. There were no significant differences between the 2 groups with respect to the preoperative relative height of the fractured vertebra or the segmental kyphotic angle. There was a significant difference in the restoration rate between the conventional and short-segmental fixation groups (62.6 ± 38.7% vs 100.4 ± 25.4%, respectively; \( P < .001 \)). However, a statistically significant decrease in postoperative segmental kyphotic angle was noted in both groups (\( P < .001 \)). The mean change of segmental kyphotic angle in the short-segmental fixation group was greater than in the conventional fixation group (14.4 ± 6.8° vs 8.3 ± 7.9°, respectively; \( P = .002 \)). Patients in the short-segmental fixation group ambulated an average of 10 days earlier than those in the conventional fixation group. These findings indicate that compared to conventional intersegmental fixation, short-segmental fixation combined with intermediate screws more effectively restores fractured vertebral height, is associated with a decrease in the segmental kyphotic angle, and allows earlier ambulation.
Thoracolumbar fractures are one of the most common types of traumatic fractures, accounting for 30% to 60% of all spinal fractures. Posterior short-segmental fixation is a reliable method for the surgical management of thoracolumbar fractures; however, the procedure is associated with common complications such as the recurrence of kyphosis, failure of internal fixation, and relative longer period of bed-rest before early ambulation. During the past 30 years, no evidence-based principles have been developed for the surgical treatment of thoracolumbar fractures.

Since Dick et al performed biomechanical studies of pedicle screw fixation in fractured vertebrae in 1994, the technique has evolved, and it has been shown that pedicle screw fixation can achieve stronger fixation compared to conventional 4-screw intersegmental fixation. However, there have been few randomized controlled clinical trials supporting the use of pedicle screw fixation in the management of thoracolumbar fractures, and the majority of studies on its mechanisms are still somewhat one-sided speculations. Intermediate screw fixation combines conventional intersegmental fixation with the screw fixation of the fractured vertebrae; it is a 6-screw fixation and differs from the 4-screw conventional intersegmental fixation or fixation of the fractured vertebrae and the adjacent segments.

The aim of this study was to provide preliminary clinical evidence for the treatment of thoracolumbar fractures with intermediate screw fixation by comparing the short-term results of posterior short-segmental fixation combined with intermediate screws to those of conventional 4-screw intersegmental fixation in the treatment of monosegmental thoracolumbar fractures.

**Materials and Methods**

**Patients**

The records of 102 patients with fractures between T11 and L2 who underwent treatment at the Department of Orthopedic Surgery, Shanghai First People's Hospital, People's Republic of China, between July 2006 and November 2007 were reviewed. Sagittal index >10° or loss of anterior vertebral body height >30% was an indication for surgery. Surgery was not performed in patients with severe bone fractures and dislocation combined with severe kyphosis, or with severe vertebral fractures or pedicle fractures.

Forty of the 102 patients were excluded from the study: 9 patients with serious neurological problems (Frankel grades A and B) who were treated with anterior or combined surgeries, 7 patients who had Magerl type C fractures, 18 patients who were lost to follow-up, 1 patient who died of unrelated medical illness, and 5 patients who were noncompliant with physician's instructions. Thus, the study population comprised 62 patients who were randomized into 2 groups according to their hospital admission date. The conventional fixation group included 35 patients who underwent conventional 4-screw intersegmental fixation, and the short-segmental fixation group included 27 patients who underwent posterior short-segmental fixation combined with intermediate screws.

This study was approved by the hospital's Institutional Review Board. Because the study was a retrospective chart review, the requirement of informed patient consent was waived.

**Internal Fixation Devices**

The TSRH-3D internal fixation system (Medtronic Sofamor-Danek Inc, Minneapolis, Minnesota) or the SINO spinal internal fixation system (Weigao Orthopaedic Device Co Ltd, Weihai City, China) were used. The TSRH-3D system is a pedicle screw system used for the reduction and fixation of spinal fractures; the system was designed specifically for vertebral fracture in the thoracolumbar region. Systems included polyaxial pedicle screws, connecting rods, caps, transverse bar, and ancillary reduction devices.

**Surgical Technique**

All surgeries were performed by the same team of doctors, and the attending surgeon (J.T.) was an associate professor at the hospital. Patients were placed prone with the abdomen suspended after induction of general anesthesia, and closed reduction was performed by ventral (anterior or to the spinal canal) compression of the most prominent site in the thoracolumbar kyphosis with the palm of the hand.

Restoration of the shape of the fractured vertebra and its anterior and middle columns were observed by C-arm fluoroscopy. A posterior midline incision was made over the fractured vertebra to expose the lamina and facet joints.

For the TSRH-3D fixation device, screw placement was the same as in conventional pedicle screw insertion. The pedicle screw for the upper vertebra was placed slightly caudally, and the pedicle screw for the lower vertebra was placed slightly cephalically. The pedicle screw for the fractured vertebra was placed slightly caudally and inserted toward the upper end plate.

After insertion of the pedicle screws, the location of the internal fixation device was identified with C-arm fluoroscopy. If there was invasion of bone fragments into the spinal canal without symptoms and signs of neural compression, indirect decompression achieved by the distraction of the anterior and posterior columns with instruments was sufficient. If there was invasion of bone fragments into the spinal canal with symptoms and signs of neural compression, the spinal canal was explored during reduction to achieve direct reduction of the bone fragments inside the spinal canal.

For patients with Frankel grade D or patients in whom preoperative computed tomography suggested significant spinal canal stenosis, single total laminectomy or hemilaminectomy was performed for decompression. A special fracture reduction device (L-shaped) was used to push bone fragments inside the spinal canal back into the vertebral body.
Connecting rods designed for the TSRH-3D system were applied bilaterally. A distraction device was used to prop open the upper and lower pedicle screws, and a special handle was applied for the reduction of the anterior and middle columns. The posterior column then was propped open with the distraction device, and locking caps were applied to fix the rods. The screw tails were cut off, and in some cases, a transverse bar was applied. After the surgical site was irrigated with normal saline solution, a negative-pressure catheter drain was applied.

Patient-controlled intravenous analgesia was used for postoperative pain control. Drains were removed 48 to 72 hours postoperatively, and then anteroposterior and lateral radiographs were obtained. Sutures were removed 10 to 12 days postoperatively.

Successful surgery was defined as all pedicle screws firmly implanted with satisfactory reduction. Ambulation was started in patients with simple vertebral fractures without osteoporosis 2 to 3 weeks postoperatively with the protection of a brace. If the fracture was a severe bursting fracture associated with osteoporosis, ambulation was started 4 to 6 weeks after the operation with the protection of a brace.

Outcome Measures

Anteroposterior and lateral radiographs were obtained preoperatively and 1 to 3 months postoperatively, and the following data were obtained.

Relative Height of the Fractured Vertebra. The measured anterior height of the fractured vertebra was defined as the height of the fractured vertebra. The mean value of the sum of the height of the vertebrae above and below the fractured vertebra was defined as the normal height of the fractured vertebra. The relative height of the fractured vertebra was defined as the height of fractured vertebra divided by the normal height of the fractured vertebra and expressed as a percentage. The reduction rate of the fractured vertebra was defined as the ratio of the restored vertebral height after surgery to the compressed vertebral height before surgery. This measure reflects the reduction capacity of the surgery relative to the vertebral height and is calculated using the following equation: Reduction Rate of the Fractured Vertebra = (postoperative restored vertebral height - preoperative relative height of the fractured vertebra) / (100% - preoperative relative height of the fractured vertebra).

Pre- and postoperatively, patients were asked to rate their pain on a scale ranging from 0 (no pain) to 10 (most pain imaginable). Patients were asked to rate their pain laying, rolling over in bed, sitting, and walking.

Statistical Analyses

Categorical variables were compared by chi-square and Fisher exact tests, and continuous variables were compared by independent 2-sample t test and data are presented as mean ± standard deviation. Paired t tests were used to compare measurements before and after surgery in each group. All statistical assessments were 2-sided and evaluated at the 0.05 level of significant difference. Statistical analyses were performed using Statistical Package for Social Sciences 15.0 (SPSS Inc, Chicago, Illinois).

RESULTS

Clinical Results

Of the 62 patients studied, 43 were men and 19 were women. Mean patient age was 44.1 ± 13.6 years (range, 22-76 years), and 87.7% of the patients were classified as Frankel grade E. The majority of thoracolumbar monosegmental fractures were located at L1 (28 [45.1%]) or T12 (21 [33.9%]), and the majority of the fractures were AO types A, B, or partial C.

Patient characteristics are summarized in Table 1. There were no statistically sig-
significant differences between the 2 groups with respect to age, sex, type of injury, Magerl type, and Frankel grade (P > .05). However, there was a significant difference in the distribution of lesion location between the 2 groups (P = .003).

Surgery was completed successfully in all 62 patients, and a total of 312 pedicle screws were inserted. Single-side pedicle screw fixation in the fractured vertebra was performed in 2 cases. Mean operative time was 50 minutes, and mean intraoperative blood loss was <250 mL. There was no significant difference in operative time or blood loss between the 2 groups (P > .05).

No complications such as neural injury, delayed wound healing, incision or deep wound infection, cerebrospinal fluid leakage, or bladder or bowel dysfunction occurred in any patient. None of the patients required reoperation, and there were no instrumentation failures, pedicle screw loosening, implant fractures, nonunion in fusion cases, or significant loss of fracture height and angle in cases with simple fractures without fusion, with follow-up ranging from 3 to 6 months. Neurological function was restored to grade E in patients with Frankel grade D; no neurological dysfunction was found in Frankel grade E patients. Based on patient responses when asked about back pain, pain was significantly improved in all patients postoperatively.

### Radiographic Measurements

Table 2 lists preoperative and postoperative vertebral height. There were no sig-
bulation in either group. Representative preoperative and postoperative radiographs are shown in Figure 3.

**DISCUSSION**

This retrospective study evaluated the outcomes of 62 patients with monosegmental thoracolumbar fractures who were treated with either posterior short-segmental fixation combined with intermediate screws or conventional 4-screw interssegmental fixation. Pedicle screw fixation at the fractured vertebra did not achieve greater correction of the segmental kyphotic angle compared to conventional interssegmental fixation; however, pedicle screw fixation more effectively restored the height of the fractured vertebra. Recovery of height is as important as recovery of the angle, and it is helpful for the recovery of the integrity in the adjacent segments and the whole spine. Interestingly, the additional pedicle screw fixation (6-screw fixation) at the fractured vertebra allowed patients to ambulate approximately 10 days earlier than patients who underwent conventional 4-screw interssegmental fixation.

The different outcomes between the 2 groups probably were not due to the bias of patient selection because the patient characteristics were not significantly different for the 2 groups (Table 1), except for the distribution of lesion locations. However, this difference in the distribution of lesion locations did not affect early ambulation time. The early ambulation times for lesion at T11, T12, L1, and L2 within each group were not significantly different.

Many methods exist for the management of thoracolumbar fractures, and there is no consensus or guidelines regarding treatment. Depending on the severity of injury, treatment methods include percutaneous vertebroplasty, percutaneous internal fixation combined with kyphoplasty, external fixation with percutaneous bone grafting, long-segmental instrumentation, and pedicle screw fixation with screws placed at various levels. Modi et al retrospectively analyzed 31 thoracolumbar fractures treated with pedicle screws placed 2 levels above and 1 level below the fractured vertebra; they found that at an average follow-up of 34 months, all patients had a full recovery and that the technique was useful for the

<table>
<thead>
<tr>
<th>Variable</th>
<th>Conventional Fixation (n=35)</th>
<th>Short-segmental Fixation (n=27)</th>
<th>P Valuea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative height of fractured vertebrae, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>57.9±16.1</td>
<td>57.0±17.1</td>
<td>.835</td>
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<tr>
<td>Postoperative</td>
<td>84.0±17.0</td>
<td>98.6±9.7</td>
<td>&lt;.001b</td>
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<td>Restoration rate</td>
<td>62.6±38.7c</td>
<td>100.4±25.4c</td>
<td>&lt;.001b</td>
</tr>
<tr>
<td>Segmental kyphotic angle, deg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>16.9±8.3</td>
<td>17.5±9.2</td>
<td>.770</td>
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<tr>
<td>Postoperative</td>
<td>8.6±6.1</td>
<td>3.1±6.9</td>
<td>.002b</td>
</tr>
<tr>
<td>Change</td>
<td>8.3±7.99c</td>
<td>14.4±6.8d</td>
<td>.002b</td>
</tr>
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<td>Operative time, min</td>
<td>51±10</td>
<td>52±11</td>
<td>.626</td>
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<td>Blood loss, mL</td>
<td>245±62</td>
<td>250±65</td>
<td>.788</td>
</tr>
<tr>
<td>Postoperative time to ambulation, d</td>
<td>24.6±4.0</td>
<td>14.0±4.4</td>
<td>&lt;.0001b</td>
</tr>
</tbody>
</table>

Abbreviation: deg, degrees. 
A P values (conventional group versus short-segmental fixation group) are based on independent 2-sample t test. 
B Significant difference between conventional and short-segmental fixation groups, P<.05. 
C Significant difference pre- and postoperatively based on paired t test, P<.01. 
D Significant difference pre- and postoperatively based on paired t test, P<.05.
prevention of progressive kyphosis. Wei et al13 prospectively compared transpedicular fixation using monosegmental fixation or short-segmental instrumentation for thoracolumbar burst fractures. They reported that radiographic and clinical outcomes between the 2 techniques were similar; however, monosegmental fixation was associated with significantly shorter operative time and blood loss.

Other authors have explored the placement of pedicle screws into the fractured vertebra in short-segmental fixation. Gelb et al20 retrospectively evaluated the radiographs of 46 thoracolumbar fractures treated with short-segmental fixation and found that pedicle screw placement into the fractured vertebra seemed to protect against correction loss. In a prospective, randomized study of 80 patients, Farrokhi et al21 found that placement of pedicle screws into the pedicles of the fractured vertebra during short-segmental fixation for thoracolumbar fractures led to better kyphosis correction, fewer instrument failures, and comparable or better clinical outcomes. In a cadaveric study of unstable thoracolumbar fracture, Baaj et al22 found that the addition of pedicle screws inserted into the fractured vertebra in short-segmental constructs improved stability.

Reduction rate of the fractured vertebra is an index that we propose to identify the capacity of the fractured vertebra for reduction and to eliminate discrepancies in imaging evaluations caused by varying degrees of vertebral compression. We found a significant difference in the reduction rate of the fractured vertebra between the 2 groups, and it correlated with the postoperative height of the fractured vertebra. These results indicate that short-segmental fixation combined with intermediate screws can sufficiently decompress a compressed vertebral body, as evidenced by the early postoperative outcomes. We can postulate on the reasons for the results seen in our review.

First, the screw inserted into the fractured vertebra can assist in the reduction of the fractured vertebra. Many authors13,22,24 considered that together with the lordotically contoured rods, pedicle screw fixation at the fractured vertebra can produce a forward driving force to enhance the reduction and reshaping. Moreover, the screw inserted into the fractured vertebra can be used to directly raise the end plate to assist in the restoration of the compressed vertebral height. In an anatomic study, Du et al25 showed that when the pedicle screw is located at the upper one-fourth of the vertebral body in the sagittal plane, the end of the screw can reach the anterior border of the vertebra, and it will be close (2-3 mm) to the end plate. In addition, a screw in the fractured vertebra can decrease the stress of screws in the upper and lower normal vertebrae to reduce the incidence of screw fracture. That is probably why patients in the short-segmental fixation group with 2 screws inserted in the fractured vertebrae began ambulating 10 days earlier than patients in the conventional fixation group. Early ambulation is critical for these patients to start earlier rehabilitation training and have a better quality of life. However, the effects of earlier ambulation on the long-term outcomes of patients needs further study in the future.

Second, short-segmental fixation combined with intermediate screws can improve the stress distribution of the internal fixation system and hence protect the uninjured vertebra and intervertebral disk. Some studies suggest kyphosis resulting from thoracolumbar fractures occurs mainly in the disk,26,27 and it is the change in the intervertebral space, rather than the vertebral collapse, that induces the kyphosis. Some finite element analysis data support this view.28-30 It can be seen from an evaluation of imaging data of patients with thoracolumbar fractures that most fractures occur at the superior end plate; compression is also located at the upper half of the vertebral body and can be associated with the upper intervertebral space narrowing.29,30 Also, pedicle screw fixation in the fractured vertebrae can produce a forward compression of the vertex of the arc of the rod to the fractured vertebrae by bending and rotating of the rod, which is helpful for distraction of the anterior column and immediate packing of the vertebral body.

If a pedicle screw is inserted into the fractured vertebra, the surgeon can manage the intervertebral spaces one level below and one level above; thus, pedicle screw fixation at the fractured vertebra can effectively control the disk height when propping open the anterior column to prevent excessive distraction of the normal intervertebral space.31 In a biomechanical analysis, Mahar et al11 found that intradisk pressure increased significantly in the normal disk spaces near the fractured vertebra under flexion stress, which suggests the pedicle screw inside a fractured vertebra can share partial flexion stress to improve the stress distribution of the internal fixation system and hence protect the uninjured disk and vertebral body.

Finally, there may be a vertebral body filling effect. Because vertebral compression results in trabecular bone destruction, a cavity is produced within the vertebral body after reduction, which may induce vertebral re-collapse postoperatively. A pedicle screw inserted into the fractured vertebra can fill this cavity, which can result in better reduction of the fractured vertebra. Currently, there is no research that supports this view, and further studies are required. Corticalization of the cancellous bone around the pedicle screw may also be helpful for maintenance of reduction of the fractured vertebra.

Most patients with thoracolumbar fractures have intact pedicles in the fractured vertebra, and this is a requirement for pedicle screw fixation at the fractured vertebrae. For several patients with an incomplete unilateral pedicle, we inserted the pedicle screw into the contralateral intact pedicle. No neurological complication occurred in any of these patients.

There are some limitations to this study. First, the study was retrospective.
However, despite the limitation of a retrospective review, the groups were not statistically different, and the surgeries were conducted by the same team of physicians. In addition, this study focused on short-term results (1-3 months), and findings may not be indicative of long-term results; further follow-up is required to properly evaluate the usefulness of the technique. However, patients ambulated early, and the short-term results are encouraging. Although pain scores were not tabulated, patient interviews indicated that pain was improved for all patients.

In this study, we combined type A and B fractures for analysis. Although type A and B fractures are different and thus behave differently, it is important to determine the integrity of the injured vertebral pedicle in both types. Even if the injured pedicle is broken, it is possible to achieve fixation using pedicle screws. Therefore, in this study, we did not subgroup type A and B fractures.

Finally, we did not obtain accurate measurements for the volume of the spinal canal. However, we maintained a basic principle that if there were no symptoms and signs of spinal cord injury, then the spinal canal volume was recovered by direct or indirect reduction during surgery.

**Conclusion**

In this study, short-segmental fixation combined with intermediate screws more effectively restored fractured vertebral height and also was associated with a decrease in the segmental kyphotic angle compared to conventional 4-screw intersegmental fixation. Compared to conventional intersegmental fixation, short-segmental fixation combined with intermediate screws enhanced the strength of fixation, which is helpful for maintaining reduction of the height and angle of the fractured vertebrae, and allowed much earlier ambulation, which is important for recovery and avoiding complications. Further study with a greater number of patients and longer follow-up of clinical outcomes is warranted.

**References**

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