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Comparison Between Posterior Short-segment Instrumentation Combined With Lateral-approach Interbody Fusion and Traditional Wide-open Anterior-Posterior Surgery for the Treatment of Thoracolumbar Fractures

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Abstract: The aim of the study was to compare the radiographic and clinical outcomes between posterior short-segment pedicle instrumentation combined with lateral-approach interbody fusion and traditional anterior-posterior (AP) surgery for the treatment of thoracolumbar fractures.

Lateral-approach interbody fusion has achieved satisfactory results for thoracic and lumbar degenerative disease. However, few studies have focused on the use of this technique for the treatment of thoracolumbar fractures.

Inclusion and exclusion criteria were established. All patients who meet the above criteria were prospectively treated by posterior short-segment instrumentation and secondary-staged minimally invasive lateral-approach interbody fusion, and classified as group A. A historical group of patients who were treated by traditional wide-open AP approach was used as a control group and classified as group B. The radiological and clinical outcomes were compared between the 2 groups.

There were 12 patients in group A and 18 patients in group B. The mean operative time and intraoperative blood loss of anterior reconstruction were significantly higher in group B than those in group A (127.1 ± 21.7 vs 197.5 ± 47.7 min, $P < 0.01$; 185.8 ± 62.3 vs 495 ± 347.4 mL, $P < 0.01$). Two of the 12 (16.7%) patients in group A experienced 2 surgical complications: 1 (8.3%) major and 1 (8.3%) minor. Six of the 18 (33%) patients in group B experienced 9 surgical complications: 3 (16.7%) major and 6 (33.3%) minor. There was no significant difference between the 2 groups regarding loss of correction (4.3 ± 2.1 vs 4.2 ± 2.4, $P = 0.89$) and neurological function at final follow-up ($P = 0.77$). In both groups, no case of instrumentation failure, pseudarthrosis, or nonunion was noted.

Compared with the wide-open AP surgery, posterior short-segment pedicle instrumentation, combined with minimally invasive lateral-approach interbody fusion, can achieve similar clinical results with significant less operative time, blood loss, and surgical complication. This procedure seems to be a reasonable treatment option for selective patients with thoracolumbar fractures.

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Abbreviations: AIS = ASIA impairment scale, AP = anterior-posterior, ASA = American Society of Anesthesiologists, ASIA = American Spinal Injury Association, CT = computed tomography, DLIF = direct lateral interbody fusion, MRI = magnetic resonance imaging, PLC = posterior ligamentous complex, PLIF = posterior lumbar interbody fusion, TLIF = transforaminal lumbar interbody fusion, TLSO = thoracolumbosacral orthosis, XLIF = extreme lateral interbody fusion.

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INTRODUCTION

The treatment of thoracolumbar fractures is still controversial. Posterior short-segment instrumentation has advantages such as being more familiar to the operating surgeon, preserving motion segments, and allowing direct reduction and rapid recovery, which made it the most commonly used method for thoracolumbar fractures.[1–5] However, without sufficient anterior column support, many patients presented with loss of correction and implant failure at long-term follow-up.[6–8] Additional anterior reconstruction is indicated in the setting of incomplete neurological injury and severe burst fractures or distraction injury with posterior ligamentous complex (PLC) injury, which corresponds to arbeitsgemeinschaft für steosynthesefragen (AO) classification type A3.3/type B with PLC injury and type C.[2,4,9]

Compared with the posterior approach, anterior reconstruction can provide direct decompression of the spinal canal, better correction maintenance, and more biomechanical stability.[10,11] However, disadvantages such as massive trauma, massive blood loss, complicated approach, and high risk of perioperative complication limit the extensive application of this wide-open procedure.[12]

Lateral-approach interbody fusion,[13] also known as extreme lateral interbody fusion (XLIF) or direct lateral interbody fusion (DLIF), is a novel minimally invasive surgical technique, which can achieve solid interbody fusion through retroperitoneal fat and psoas muscle with a 4-cm incision.[14,15] This technique can avoid drawbacks associated with traditional anterior reconstruction and has achieved satisfactory results for thoracic and lumbar degenerative disease.[15–19] However, few studies have focused on the use of this technique for thoracolumbar fractures.[20] None has compared the clinical outcomes between lateral-approach interbody fusion and traditional anterior approach in thoracolumbar fractures.

The aim of the present prospective study was to compare the clinical and radiological outcomes between posterior short-segment instrumentation combined with lateral-approach interbody fusion and traditional wide-open anterior-posterior (AP) surgery for the treatment of thoracolumbar fractures.

MATERIALS AND METHODS

The study was approved by the institutional review board. Inclusion criteria were as follows: age between 18 and 60 years; thoracolumbar junction (T10-L2) fractures involving 3 columns; without disruption of posterior longitudinal ligament; and with neurological deficit.

Exclusion criteria were as follows: age <18 or >60 years; pathological or osteoporotic fractures; severe comminution of vertebral body which indicated an anterior corpectomy procedure; and significant spinal ventral compression which indicated anterior decompression.

Patients who met aforementioned inclusion/exclusion criteria were prospectively treated by using posterior short-segment instrumentation combined with second-stage lateral-approach interbody fusion, and classified as group A. A historical group of patients who were treated earlier with posterior short-segment instrumentation combined with traditional wide-open anterior interbody fusion by the same senior surgeon was used as a control group and classified as group B.

At admission, X-rays and computed tomography (CT) scans were performed for all the patients. Kyphotic angles were measured by Cobb method, which are from the superior endplate of the vertebra above the injured level to the inferior endplate of the vertebra below the injured level. The fracture patterns were classified according to the AO classification system.[21] Before the operation, all the patients received evaluation of their surgical risk based on the American Society of Anesthesiologists (ASA) physical status. The neurological function was evaluated by using American Spinal Injury Association (ASIA) impairment scale (AIS).[22]

Surgical Technique

First, all the patients underwent posterior short-segment pedicle instrumentation to achieve reduction, decompression, and fixation. During the operation, the patient was placed in a prone position and the midline incision was made to expose the injury site and adjacent segments. Pedicle screws were inserted into one level above and one level below the fracture segment. The fracture-level screws were inserted as much as possible unless there was a fracture at the index pedicle. Laminectomy was performed to decompress the spinal canal. Reduction of the alignment and correction of the kyphosis were performed by maneuvering the pedicle screws system. Posterior lateral fusion was applied by using autogenous bone grafts harvested from the decompression procedure. The posterior fusion level included one level above and one level below the injury segment.

Anterior reconstruction was performed within 3 weeks after the posterior procedure, depending on the patients' medical condition. In group B, traditional wide-open anterior interbody fusion was performed as the anterior reconstruction. In group A, lateral-approach interbody fusion procedure was performed as the anterior reconstruction. With general endotracheal anesthesia, the patient was placed in a right lateral decubitus position and a left-sided approach was used to access the thoracolumbar region. The corresponding disk space to be operated was identified by lateral fluoroscopic image and marked on the patients' lateral chest wall.

For patients who underwent anterior fusion at L1/L2 segment, retroperitoneal approach was performed according to Karikari et al.[23] In these cases, a small incision was made between T10/11 ribs and the retroperitoneal space was controlled. The surgeon put the index finger into the retroperitoneal space and displaced the diaphragm rostrally to get access to the spine. The above mentioned procedure should be performed against the chest wall and primarily below the diaphragm. Once the operated disk space was identified, the index finger could be used to escort the guide wire and dilators from the same incision to access the disc space to be operated. For patient who underwent anterior fusion at T11/T12 or T12/L1 segment, a thoracotomy approach was applied without accessing the retroperitoneal space.[23] In these cases, little or no lung was visualized and it was not necessary to perform single-lung ventilation during the procedure.

After the working cannula was inserted and fixed on the fusion level, the dilators were removed. This self-designed working cannula was 24 mm in inner diameter, which could accommodate the endoscope with illumination system (Joimax Instrumentation, Germany) and posterior lumbar interbody fusion (PLIF) instrumentation simultaneously. Two tips at the end of the cannula could be helpful in fixing this system on the lateral aspect of the adjacent vertebrae. During the operation, the assistant held the working cannula and fixed it on the lateral aspect of the adjacent vertebrae. The operating surgeon could perform disectomy under direct view or endoscopic view as a standard PLIF procedure. The integrity of the posterior annulus should be preserved. After the intervertebral disk was removed, a single suitable cage (CONCORDE Bullet System, DePuy) packing with allogenic bone grafts was inserted into the intervertebral space. A cage little larger than the final template was preferred to avoid cage migration, since no screw and plate instrumentation was used in the anterior procedure. The thoracic drainage was inserted for patients with thoracotomy approach and then the wound was closed in layers (Figs. 1–8). All the operations were performed by the senior surgeon.

After the combined procedures, the patients were allowed out of bed with a custom-molded thoracolumbosacral orthosis (TLSO) after the drainage tube was removed. The patients were required to wear the TLSO for 3 to 4 months.

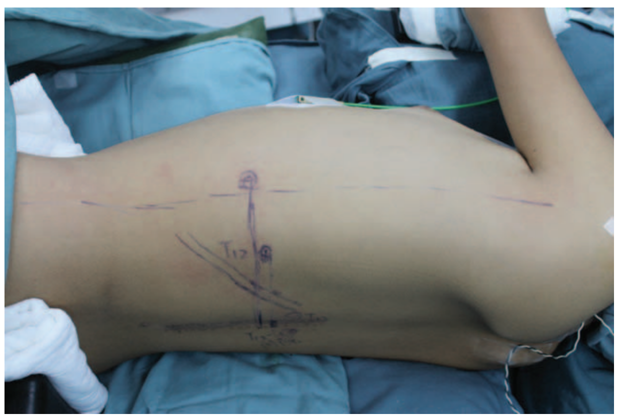

FIGURE 1. Intraoperative photographs of minimally invasive lateral interbody fusion procedure. Patients' position and incision marking.

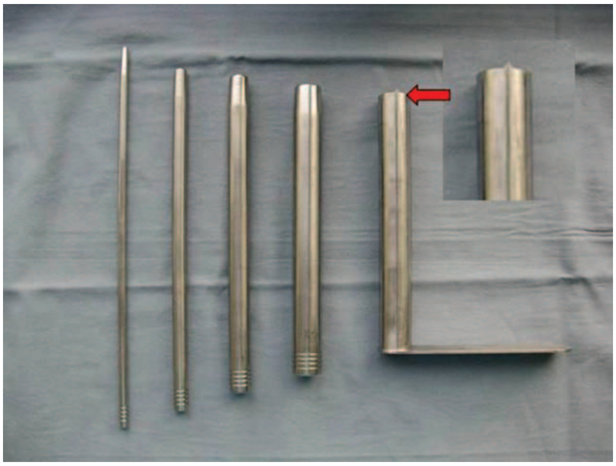

FIGURE 2. Image demonstrating the self-designed sequential dilators and working cannula.

FIGURE 3. Inserting the working cannula through left-sided thoracotomy approach.

Clinical and Radiological Assessment

X-rays were obtained preoperatively, immediately after combined procedure and at final follow-up. Kyphotic angles were measured by Cobb method. CT scans at final follow-up were used to evaluate the status of fusion according to Suk criteria.[24] The implant failure was defined as an increase of

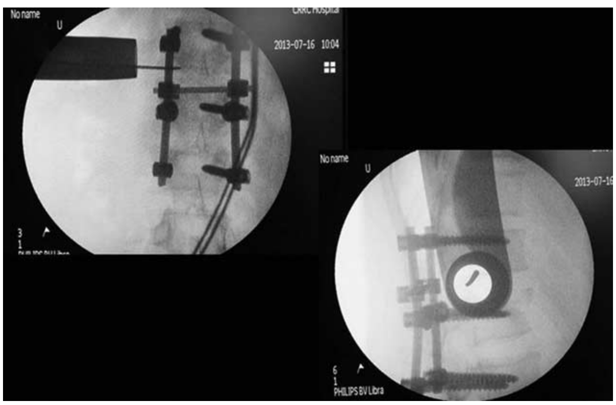

FIGURE 4. Identifying the fusion level by fluoroscopic image.

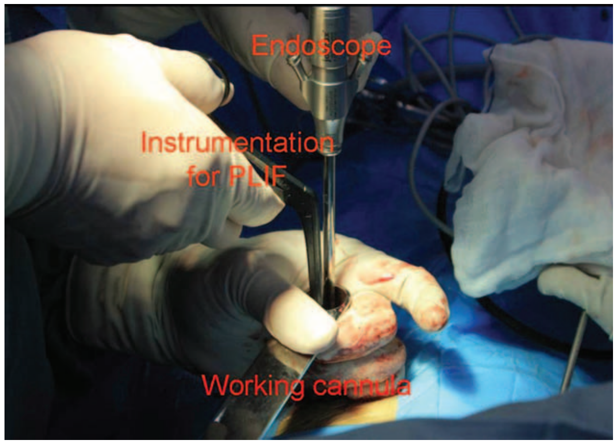

FIGURE 5. Intraoperative photograph of disectomy using PLIF instrumentation under direct view. PLIF = posterior lumbar interbody fusion.

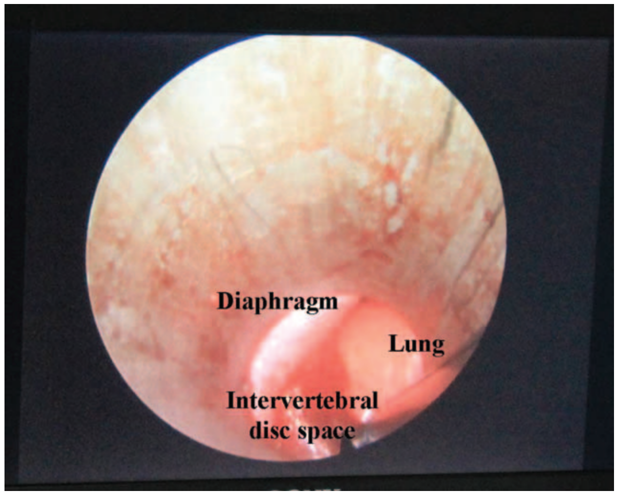

FIGURE 6. Intraoperative photograph of endoscopic view.

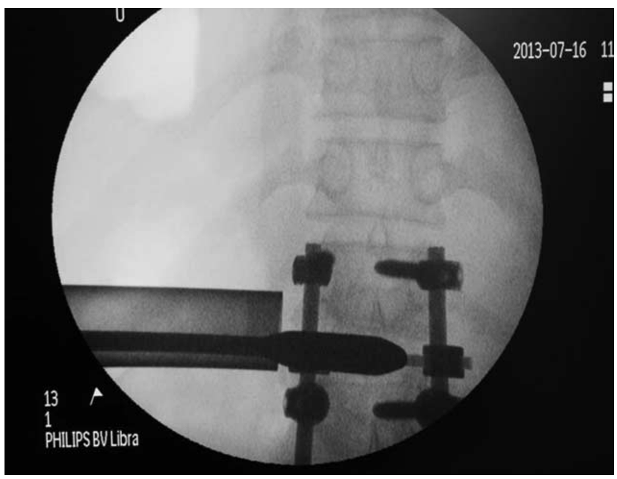

FIGURE 7. Inserting the template.

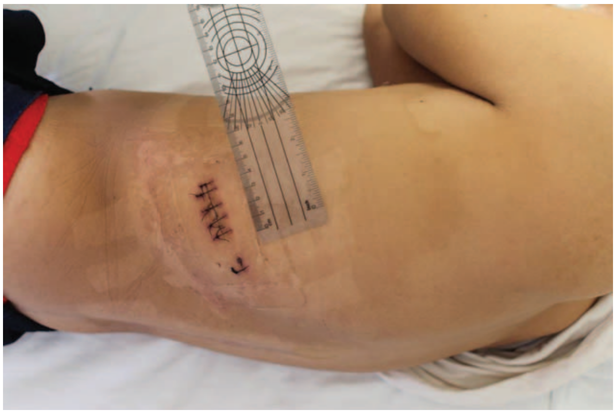

FIGURE 8. Operative photograph of thoracic drainage and incision with about 4.5 cm in length.

more than 10° in correction loss or screw loosening/broken at follow-up.[6]

The medical records of every patient, including age, sex, injury level, fracture type, cause of injury, ASA physical status, underlying disease, operative time, blood loss, extent of fixation, and perioperative complications, were collected. The present study focused on perioperative complications associated with operation which were defined as events that needed treatment or intervention. The perioperative surgical complications were classified as major or minor according to Isaacs et al[17] with minor modification. AIS was used to evaluate the neurological function preoperatively and at final follow-up.

Statistical Analysis

Data were statistically analyzed using SPSS 11.5 software (SPSS Inc., IL). Paired-samples *t* test was used to compare data within the group (Cobb angle: preoperative vs postoperative). A 2-sample *t* test or Pearson chi-square test was used to compare data between the 2 groups. $P < 0.05$ was considered statistically significant.

RESULTS

Patient Characteristics

Between January 2012 and December 2013, 12 patients who met the aforementioned criteria were enrolled in the study and were classified as group A. The study comprised of 10 men and 2 women with an average age of 33 ± 9.4 years (range 21–47 years). No significant difference was observed between the 2 groups regarding age, sex, ASA physical status, underlying disease, injury mechanism, fracture level, and AO classification (Table 1).

TABLE 1. Demographics Data of Patients

	Group A (n = 12)	Group B (n = 18)	*P* Value
Age	33 ± 9.4 (21–47)	29.3 ± 6.8 (22–41)	0.216
Sex			
Male	10	13	0.481
Female	2	5	
ASA physical status			0.944
1	6	8	
2	5	8	
3	1	2	
Underlying disease			0.700
Cardiovascular	1	2	
Diabetes	1	1	
Injury level			
T12	4	5	0.903
L1	5	9	
L2	3	4	
Fracture type			
A3	4	4	0.774
B1	3	6	
B2	5	8	
Anterior fusion level			
T11/12	4	7	0.725
T12/L1	5	5	
L1/2	3	6	
Injury mechanism			
Motor vehicle accident	7	11	0.69
Fall from height	4	4	
Hit by heavy object	1	3	

ASA = American Society of Anesthesiologists.

Primary Outcomes

Outcomes Associated With Surgery

All the patients tolerated the combined procedure well and no intensive care unit (ICU) stay was required. For posterior procedure, no significant difference was noted between the 2 groups regarding mean operative time (group A: 125.8 ± 29 min, group B: 129.2 ± 26 min; $P = 0.74$) and intraoperative blood loss (group A: 460 ± 88.1 mL, group B: 480 ± 69 mL; $P = 0.49$). For anterior procedure, the mean operative time and intraoperative blood loss in group A (127.1 ± 21.7 min and 185.8 ± 62.3 mL, respectively) were significantly less than those in group B (197.5 ± 47.7 min and 495 ± 347.4 mL, respectively) ($P < 0.01$) (Table 2).

Surgical Complications

Two (16.7%; $P = 0.312$) patients in group A had 2 surgical complications, 1 (8.3%; $P = 0.511$) of which was major and 1 (8.3%; $P = 0.113$) was minor. Six of the 18 (33%) patients in group B experienced 9 surgical complications; 3 (16.7%) of these complications were major surgical complications and 6 (33.3%) were minor. Although the rate of surgical complications was less in group A, the results did not achieve statistical significance. The details of the surgical complications are shown in Table 3.

Neurological Function

No patients in both the groups presented with neurological function exacerbation after the combined procedure. For patients with complete spinal cord injury, no improvement in neurological function was noted at final follow-up. For patients with incomplete spinal cord injury, 5 of the 12 patients in group A and 10 of the 18 patients in group B presented with at least 1 grade of improvement in neurological function (Table 4). No significant difference was noted between the 2 groups regarding

TABLE 2. Operation Values

Mean	Group A (n = 12)	Group B (n = 18)	*P* Value
Operative time (min)			
Posterior	125.8 ± 29 (95–180)	129.2 ± 26 (90–170)	0.74
Anterior	127.1 ± 21.7 (100–170)	197.5 ± 47.7 (160–295)	0.00
Blood loss (mL)			
Posterior	460 ± 88.1 (350–620)	480 ± 69 (380–600)	0.49
Anterior	185.8 ± 62.3 (100–300)	495 ± 347.4 (220–1500)	0.005

the neurological function preoperative ($P = 0.97$) and at final follow-up ($P = 0.77$).

Secondary Outcomes

Outcomes Associated With Radiology

No significant difference was observed between the 2 groups regarding preoperative Cobb angle (group A: 31 ± 8.7, group B: 30.2 ± 7.5; $P = 0.76$) and postoperative Cobb angle (group A: 5.1 ± 3.5, group B: 7.7 ± 7.9; $P = 0.30$) (Table 5).

The mean follow-up period was 12.75 ± 4.6 months in group A and 14.8 ± 5.2 months in group B ($P = 0.27$). At final follow-up, no significant difference was found between the 2 groups regarding loss of correction (group A: 4.3 ± 2.1, group B: 4.2 ± 2.4; $P = 0.89$) (Table 5).

No implant failure, pseudarthrosis, or nonunion was noted in both the groups at final follow-up (Figs. 9–15).

DISCUSSION

Insufficient anterior column support is the major cause of implant failure and/or correction loss after posterior short-segment pedicle instrumentation for the treatment of thoracolumbar fractures.[6,7] Various transpedicular procedures aiming to improve the support capacity of vertebral body, such as transpedicular intravertebral bone grafting[25] and vertebroplasty,[26] have been introduced to prevent the aforementioned problems. However, the results are inconsistent.[27]

Recently, a number of studies found that primary correction loss after posterior instrumentation for thoracolumbar fractures occurred at the intervertebral disk space, rather than the vertebral body. In a series of 63 patients, Oner et al[28] analyzed the intervertebral disks adjacent to the fractured level by using magnetic resonance imaging (MRI) at least 18 months after injury, and found that recurrent kyphosis after posterior reduction primarily occurred in the disk space resulting from the creeping of the nucleus pulposus into the central area of the fractured endplate. Wang et al[8] demonstrated the radiological results with 2-year follow-up in 27 patients who underwent posterior fixation for thoracolumbar fractures, and showed that primary correction loss occurred through disk space rather than vertebral body. The height of the reduced vertebral body was preserved even after removal of the implant, which indicated that the gap in the reduced vertebral body was not a key factor for postoperative kyphosis. Haschtmann et al[29] found that the injury of the endplate could induce apoptosis of intervertebral disk cells which may accelerate the degeneration of intervertebral disk.

On the basis of the aforementioned studies, it was speculated that intervertebral fusion aiming to improve the support capacity of the disk space may provide an alternative solution to prevent the correction loss and/or implant failure after posterior short-segment instrumentation for the treatment of thoracolumbar fractures.

Intervertebral fusion can be achieved by an anterior approach or posterior/transforaminal lumbar interbody fusion (PLIF/TLIF) technique. PLIF/TLIF procedure can achieve 360° fusion by a single posterior approach. Recently, Schmid et al[30] reported clinical results on 82 patients who underwent PLIF to treat thoracolumbar burst fractures with disruption of ligaments and intervertebral disks. Bony fusion was achieved in 83% of patients with 3.3° of mean correction loss at an average 15-month of follow-up period. Uncontrolled massive blood loss is one of disadvantages of this procedure. Meanwhile, extensive posterior element resection to get access to anterior disk space

TABLE 3. Surgical Complication

Surgical Complication	Group A (n = 12)	Group B (n = 18)
Major		
Deep vein thrombosis	0	1
Atelectasis	0	2
Hemothorax	1	0
Minor		
Ileus	0	1
Wound delayed healing	1	1
Mild penumothorax	0	2
Postoperative anemia requiring transfusion	0	2

TABLE 4. Summary of Neurological Function

ASIA Impairment Grade (AIS)	Postoperative Group A (n = 12)					Postoperative Group B (n = 18)				
Preoperative	A	B	C	D	E	A	B	C	D	E
A	4					5				
B			1				1	1		
C			1	2	1				5	2
D				2	1				2	2

AIS = ASIA impairment scale, ASIA = American Spinal Injury Association.

TABLE 5. Radiographic Measurements

Cobb Angle (Degree)	Group A (n = 12)	Group B (n = 18)	*P* Value
Preoperative	31° ± 8.7° (15° to 40°)	30.2 ± 7.5° (20° to 40°)	0.76
Postoperative	5.1° ± 3.5° (−2° to 8°)	7.7° ± 7.9° (−8° to 16°)	0.30
Loss of correction	4.3° ± 2.1° (0° to 8°)	4.2° ± 2.4° (2° to 8°)	0.89

may increase the risk of postoperative kyphosis if the bony fusion fails.

Traditional wide-open anterior approach is technically demanding and results in considerable surgical trauma with high risk of complications such as massive blood loss, intercostal neuralgia, pulmonary infection, and visceral injury. This may prevent early mobilization for rehabilitation, which is particularly important for patients with neurological deficit.[12]

Minimally invasive lateral-approach interbody fusion (XLIF/DLIF) is a novel minimally invasive technique which was firstly described by Ozgur et al[14] in 2006. With the help of specially designed retractor, this procedure can achieve solid intervertebral fusion through retroperitoneal fat and transpsoas approach, with a 4-cm incision in the lateral aspect of the abdominal wall. This technique can effectively avoid the drawbacks associated with traditional wide-open anterior approach. Combining with posterior pedicle instrumentation, lateral-approach interbody fusion procedure results in satisfactory coronal correction and solid interbody fusion for the treatment of thoracic and lumbar spinal disease such as degenerative scoliosis, lumbar disk degenerative disease, lumbar spondylolisthesis, and adjacent segment disease after posterior fusion.[15–19]

Given the solid intervertebral fusion and anterior column support provided by lateral-approach interbody fusion technique, it was speculated that this technique could also play a role

FIGURE 9. Illustrative case presentation: A 26-year-old man suffered back injury being struck by an heavy object and presented with T11 spinal cord injury (AIS = A). AIS = ASIA impairment scale. Preoperative lateral X-ray film showed flexion-distraction injury and locked facet joint at T11/T12 segments.

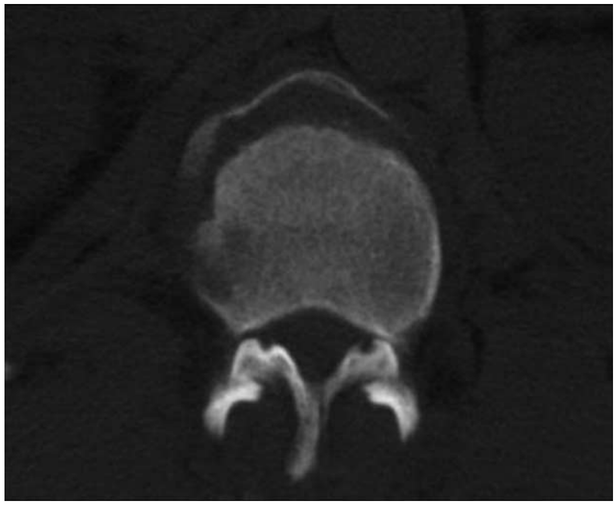

FIGURE 10. CT axial scan showed flexion-distraction injury and locked facet joint at T11/T12 segments. CT = computed tomography.

FIGURE 11. Preoperative T2-weighted fat-suppressed sagittal MRI film showed the disruption of the PLC. MRI = magnetic resonance imaging, PLC = posterior ligamentous complex.

FIGURE 12. Postoperative lateral X-ray film of initial posterior approach.

FIGURE 13. Combined procedure showed that the reduction and kyphosis correction was good.

for preventing anterior collapse and implant failure after posterior short-segment instrumentation for thoracolumbar fractures. The present study verified this hypothesis.

In the present study, the mean loss of correction after lateral-approach interbody fusion with posterior short-segment pedicle instrumentation was 4.3°. Neither implant failure nor pseudarthosis was noted at final follow-up. The results of this study were in accordance with the study by Tofuku et al.[20] Compared with a recent systematic review by Verlaan et al,[27] the present results were superior to the outcomes of posterior short-segment fixation alone, which was reported with 7.6° of correction loss, 11% of implant failure, and 4% of reoperation rate.

Compared with traditional wide-open AP surgery (group A), the present minimally invasive procedure demonstrated similar clinical outcomes in terms of correction loss and implant failure; meanwhile, the safety of the operation improved significantly with less operative time, intraoperative blood loss, and low risk of perioperative complication rate (though the results did not have statistical significance). The results of the present study implied that lateral-approach interbody fusion could avoid drawbacks associated with traditional wide-open anterior approach, which might be an alternative to this traditional procedure.

Self-designed working cannula and spinal endoscope with illumination system (Joimax Instrumentation) were applied in the present study to perform lateral-approach interbody fusion procedure. During the operation, the surgeon operated under both direct view and endoscopic view, which could improve the safety of the operation and avoid the steep learning curve of simple endoscopic technique. Two cases of complications associated with lateral-approach interbody fusion occurred at an early stage of the study, and the mean operative time and intraoperative blood loss (average 127 min and 186 mL, respectively, for single-segment lateral approach interbody fusion procedure) were higher than the results of Isaacs et al[17] (average 58 min and 150 mL for single-segment lateral-approach interbody fusion procedure, respectively). It is believed that the safety of the lateral-approach interbody fusion procedure can improve significantly with accumulation of surgical experience.

The main goal of the present lateral-approach interbody fusion procedure was to prevent the collapse of disk space and implant failure by providing anterior column support and intervertebral fusion, rather than anterior decompression. In the present protocol, the best indication for the present combined procedure was severe flexion-distraction injury involving the anterior disk, which corresponded to B1.1 and B2.2 according to AO classification. For patients with burst fractures, severe comminution of vertebral body, which indicated an anterior corpectomy, should be excluded. When posterior short-segment pedicle instrumentation was performed, the injured vertebra should be instrumented as much as possible to prevent collapse and displacement of the cage.

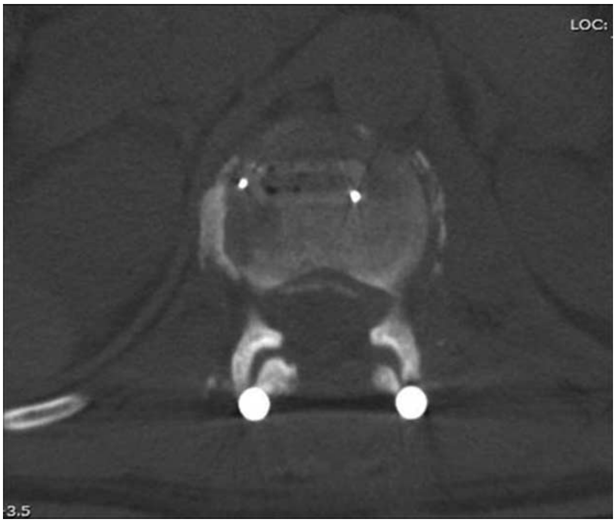

FIGURE 14. Postoperative axial CT scan of combined procedure showed that the placement of the cage was good. CT = computed tomography.

The present study had certain limitations. First, it was not a randomized controlled study and the control group was not prospectively analyzed. Second, all the patients underwent 2-staged procedure, which might increase the morbidity associated with the operation. With accumulation of surgical experience, this combined procedure can be completed in a single stage, which can improve the safety of the operation. Third, as a novel technique, the present study was just a preliminary study. We wanted to evaluate the safety and effectiveness of this novel technique before extensive application. So the sample of included patients was relatively small. Although the rate of surgical complication in group B was less than that in group A, the results did not have statistical significance. Fourth, many patients in the present study came from region far away from our city, which made it difficult to perform long-term follow-up. Finally, all the results were obtained in a single center. Hence, further studies should involve more centers to evaluate the effectiveness of the novel combined procedure.

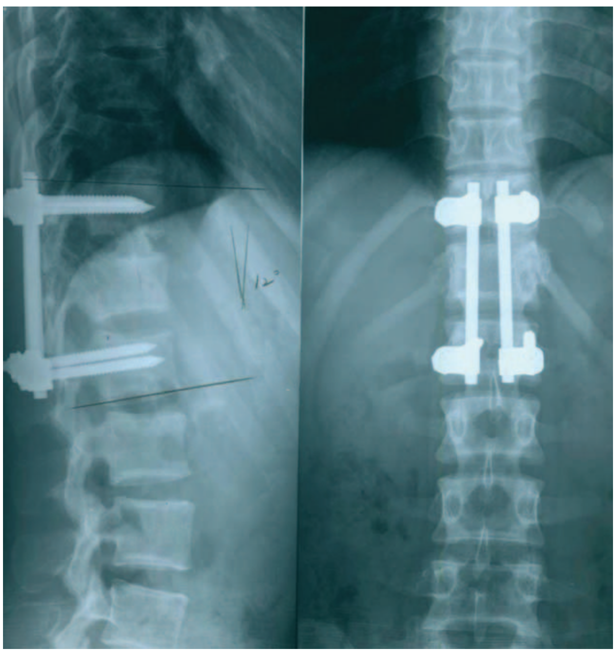

FIGURE 15. One-year follow-up X-ray film in group B.

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