Ge *et al. BMC Musculoskeletal Disorders* (2025) 26:507
https://doi.org/10.1186/s12891-025-08759-w

BMC Musculoskeletal Disorders

RESEARCH Open Access

Impact of traumatic intervertebral disc injury on loss of correction following pedicle screw fixation for thoracolumbar fractures

Tongfei Ge[1†], Wenbo Li[1†], Jiayang Wu[1†], Qingyuan Wang[1], Cong Li[1], Siming Wang[1], Wu Xiong[1] and Jin Fan[1*]

Abstract

Background Traumatic intervertebral disc injury, while frequently observed in thoracolumbar fractures, is often overlooked in clinical management. This research aimed to investigate how traumatic intervertebral disc injury influences spinal stability and to analyze the risk factors for correction loss after posterior pedicle screw fixation for thoracolumbar fractures.

Methods A retrospective analysis was performed on 194 thoracolumbar fracture patients who received pedicle screw fixation. The assessment of disc injury was conducted using magnetic resonance imaging (MRI). Patients were categorized into intervertebral disc injury (IDI) and non-IDI (nIDI) groups. The clinical variables included visual analog scale (VAS) score, and American Spinal Injury Association score. The radiological data, comprising the vertebral wedge angle (VWA), Cobb angle (CA), disc angle, disc height, anterior (AVBHr), midline (MVBHr), and posterior vertebral body height ratio (PVBHr), were compared before surgery, one week after the operation, and at final follow-up. The mean follow-up duration was 12.7 ± 7.0 months.

Results The mean VAS score showed significant improvement postoperatively. 22.6% of patients with IDI developed the intervertebral vacuum phenomenon. The IDI group exhibited significantly greater CA and VWA, as well as lower disc height, AVBHr and MVBHr than the non-IDI group at the last follow-up. Age (odds ratio [OR] = 1.038, 95% confidence interval [CI] = 1.011–1.066, P = 0.005), male (OR = 2.201, 95% CI = 1.107–4.377, P = 0.025), and IDI (OR = 2.463, 95% CI = 1.105–5.489, P = 0.028) were statistically significant risk factors for kyphosis correction loss according to multivariate logistic regression analysis.

Conclusion Traumatic IDI contributes to loss of correction following thoracolumbar fractures and is closely associated with accelerated disc degeneration. Age, male, and IDI are independent risk factors for postoperative kyphosis recurrence in patients with thoracolumbar fractures.

Keywords Thoracolumbar fractures, Intervertebral disc injury, Posterior pedicle screw fixation, Kyphosis, Intervertebral vacuum phenomenon

†Tongfei Ge, Wenbo Li and Jiayang Wu contributed equally to this work.

*Correspondence:
Jin Fan
fanjin@njmu.edu.cn
[1]Department of Orthopedics, The First Affiliated Hospital with Nanjing Medical University, 300 Guangzhou Road, Nanjing, Jiangsu, China

Background

Thoracolumbar fractures, a prevalent type of spinal fracture, typically occur at the thoracolumbar junction. This region, where thoracic kyphosis transitions into lumbar lordosis, has complex anatomical structures and experiences significant biomechanical stress [1]. These fractures are often associated with severe trauma, including falls from heights or traffic accidents [2]. Patients usually present with pain at the fracture site and restricted movement. In severe cases, neurological deficits may occur, including the loss of motor and sensory function, along with bowel and bladder dysfunction [3]. These symptoms severely impair the patient's quality of life, causing long-term negative effects on psychological well-being.

Currently, the primary surgical treatment for thoracolumbar fractures is pedicle screw fixation [4]. This procedure effectively restores the physiological curvature and stability of the spine in the short term. For patients with accompanying neurological deficits, laminectomy is commonly performed to relieve spinal cord compression [5]. Although this surgery significantly improves spinal function, intervertebral disc injury (IDI) is often overlooked. Intervertebral discs are essential for absorbing pressure, maintaining spinal stability, and ensuring mobility [6]. IDI can compromise spinal biological stability, increasing the risk of postoperative kyphosis recurrence and vertebral instability [7]. An effective tool for assessing IDI is magnetic resonance imaging (MRI), as it detects signal changes and morphological abnormalities in the discs, providing valuable information for clinical diagnosis and treatment [8]. The severity classification system of IDI proposed by Sander et al. [9] integrates MRI signal changes and morphological alterations, allowing for a more accurate assessment of IDI severity. This system is widely implemented in clinical practice.

The IDI is a critical factor influencing postoperative stability of spine and prognosis in thoracolumbar fracture patients. A previous study confirmed that the intervertebral disc level is the primary site of correction loss after thoracolumbar fracture surgery [10]. Hashimura et al. [11] identified severe damage to the disc and endplate as a risk factor for correction loss following short-segment fixation surgery. For thoracolumbar fractures, posterior short-segment pedicle screw fixation is widely adopted in surgical practice; however, it has a relatively high failure rate and a notable incidence of kyphosis recurrence [12–14]. Additionally, intervertebral space collapse and kyphosis recurrence are common complications following thoracolumbar burst fractures. Despite these concerns, research on the prognosis of thoracolumbar fracture patients with IDI remains limited, and the clinical significance of IDI and its influence on patient prognosis have not been fully explored.

This research was designed to explore the impact of IDI on postoperative spinal stability and identify risk factors associated with correction loss after posterior pedicle screw internal fixation by evaluating the clinical and radiographic differences between thoracolumbar fracture patients with and without IDI.

Methods

Baseline data

This single-center, retrospective cohort study involved 194 patients who received surgical treatment for thoracolumbar fractures via posterior screw fixation between August 2019 and May 2024. The research obtained ethical clearance from the ethics committee of the First Affiliated Hospital with Nanjing Medical University. The inclusion criteria were: (1) Age ranging from 18 to 84 years; (2) vertebral fractures involving the thoracic, thoracic-lumbar and lumbar regions; (3) Arbeitsgemeinschaft für Osteosynthesefragen (AO) classification of A2, A3, A4, B2, and C type; (4) treatment with posterior screw fixation surgery; (5) availability of postoperative computed tomography (CT) imaging follow-up data. The exclusion criteria included the following: (1) Osteoporosis (T-score ≤ -2.5) or pathological fractures; (2) severe cognitive impairment or psychiatric disorders; (3) postoperative follow-up of less than six months.

Clinical data

The clinical data involved age, gender, body mass index (BMI), length of hospitalization, operating time, blood loss, thoracolumbar injury classification and severity score (TLICS), load sharing classification (LSC), AO spine thoracolumbar injury classification system, the visual analog scale (VAS; 0–10 scale) for pain assessment, and the American Spinal Injury Association (ASIA) classification for neurological function.

Intervertebral disc evaluation

The classification system of IDI, established by Sander et al., categorizes intervertebral disc injuries into four grades: Grade 0: No difference compared to adjacent normal discs. Grade 1: The injured disc indicates a signal enhancement in the T2-weighted image. Grade 2: The T1-weighted image demonstrates isointense to hyperintense, and the T2-weighted image reveals a reduction in signal intensity alongside peri-focal hyperintense. Grade 3: Disc herniation into the vertebral body or endplate, indicating severe injury. The initial evaluation of the disc injury was performed using MRI. When disc injuries were present bilaterally adjacent to the fracture site, the higher-grade injury was used for definitive classification. Grade 1 and Grade 2 disc injuries were categorized as mild IDI, while Grade 3 injuries were classified as severe IDI.

Radiological evaluation

The assessment was performed via sagittal CT images, with measurements taken preoperatively, one week postoperation, as well as at the last follow-up for both groups. The radiological measures involved the vertebral wedge angle (VWA), Cobb angle (CA), disc angle, disc height, anterior (AVBHr), midline (MVBHr), and posterior vertebral body height ratio (PVBHr), and intervertebral vacuum phenomenon (IVP).

CA was defined as the angle formed by the upper endplate of the superior vertebra and the lower endplate of the inferior vertebra relative to the fractured vertebra. The angle between the upper and lower endplates of the fractured vertebra was referred to as VWA. The disc angle was described as the angle formed between the lower endplate of the upper vertebra and the upper endplate of the lower vertebra of the affected intervertebral disc. If no disc injury was present, or if both the discs above and below the fractured vertebra were damaged, the average of their angles was calculated. Disc height was measured as the mean of anterior, midline, and posterior segment heights. AVBHr was calculated as the percentage ratio of the fractured vertebra's anterior height compared to the average anterior heights of the adjacent upper and lower vertebrae. Similarly, MVBHr and PVBHr were determined using the same calculation method for the midline and posterior vertebral body heights (Fig. 1). In this study, kyphotic deformity recurrence was defined as a CA at the final follow-up that exceeded the CA preoperatively.

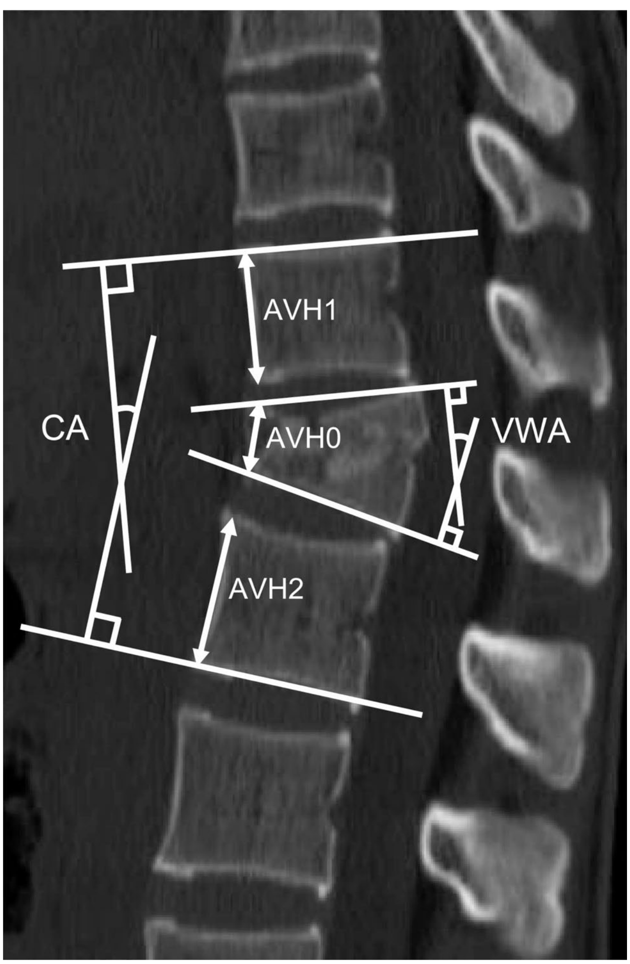

Fig. 1 Radiological measurement was conducted using median sagittal CT. CA, Cobb angle; VWA, vertebral wedge angle; AVBHr = 2AVH0/(AVH1 + AVH2) ×100%

Surgical procedure and postoperative management

Under general anesthesia, all patients underwent posterior pedicle screw fixation combined with posterolateral fusion using allograft bone. Long-segment fixation was generally performed for patients with either three-column injuries or neurological deficits requiring laminectomy, while short-segment stabilization was employed for other cases. They were positioned prone with their chest and pelvis elevated. A C-arm fluoroscope was used to localize the fracture location intraoperatively. An incision was made along the midline of the back, centered on the fractured vertebra, allowing full exposure of the fractured and adjacent vertebrae. The fractured vertebra and its adjacent vertebrae, both above and below, were fixed with bilateral pedicle screws. Rods were then placed, followed by fracture reduction and correction of the kyphotic deformity. The screws were then secured with caps. In patients with concurrent neurological deficits, the laminectomy was performed to relieve spinal cord compression. Upon completion of the surgery, the surgical site was closed in layers after positioning a drainage tube. Postoperatively, the drain was removed once the output was less than 50 mL, and wearing a brace for three months was advised to the patient.

Statistical analysis

For statistical analysis, independent t-tests were used for normally distributed continuous variables. Categorical data were analyzed via the chi-square test or Fisher's exact test. Independent risk factors contributing to postoperative correction loss were identified through logistic regression analysis. Statistical significance was set at $P < 0.05$. Statistical Package for the Social Sciences Statistics (version 27.0) and R (version 4.4.1) software were used for all the statistical analyses.

Results

Baseline information

The study involved 194 thoracolumbar fracture patients: 137 in the IDI group and 57 in the non-IDI (nIDI) group, with 108 males and 86 females. The mean age was 50.0 ± 13.1 years (18–84 years). Follow-up duration averaged was 12.7 ± 7.0 months. The TLICS and LSC scores

Table 1 Clinical features and surgical outcomes between the IDI and nIDI groups

Characteristic	IDI group ($n = 137$)	NIDI group ($n = 57$)	P-value
Age (year)	50.2 ± 13.5	49.4 ± 12.1	0.699
Gender (male/female)	73/64	35/22	0.380
BMI (kg/m^2)	23.9 ± 3.4	23.2 ± 3.1	0.164
Hospitalization days (days)	13.6 ± 8.1	10.8 ± 10.1	0.046
TLICS	5.2 ± 2.8	3.7 ± 2.2	< 0.001
LSC	6.0 ± 1.5	4.8 ± 1.3	< 0.001
Operating time (min)	176.3 ± 63.4	136.2 ± 48.8	< 0.001
Blood loss (mL)	235.2 ± 294.0	114.0 ± 139.2	0.003
Level of fracture			0.503
T3-T10	10 (7.3)	2 (3.5)	
T11-L1	70 (51.1)	33 (57.9)	
L2-L4	57 (41.6)	22 (38.6)	
Fracture type			0.005
A2	3 (2.2)	4 (7.0)	
A3	43 (31.4)	29 (50.9)	
A4	32 (23.4)	14 (24.6)	
B2	53 (38.7)	10 (17.5)	
C	6 (4.4)	0 (0.0)	
Fixation method (long/short)	69/68	11/46	< 0.001
Vacuum phenomenon (yes/no)	31/106	6/51	0.079
Decompression (yes/no)	48/89	7/50	0.002

IDI Intervertebral disc injury, *NIDI* Non-intervertebral disc injury, *BMI* Body mass index, *TLICS* Thoracolumbar injury classification and severity score, *LSC* Load sharing classification.

averaged 4.7 ± 2.7 and 5.7 ± 1.5. Falling from a height (70 cases, 36.1%) was the most common injury mechanism, followed by falls (53 cases, 27.3%) and traffic accidents (34 cases, 17.5%). The most frequently fractured vertebral region was the thoracolumbar junction T11-L1 (103 cases, 53.1%), with 65 cases of L1 fractures (33.5%). According to the AO spine classification system, the most frequent type was A3 (72 cases, 37.1%), followed by type B2 (63 cases, 32.4%), type A4 (46 cases, 23.7%), type A2 (7 cases, 3.6%), and type C (6 cases, 3.1%). Among the 137 patients in the IDI group, 109 patients exhibited unilateral disc injuries, while 28 had bilateral disc injuries, involving a total of 165 intervertebral discs, with 78.2% (129/165) of injuries occurring on the cranial side and 21.8% (36/165) on the caudal side. According to the Sander classification system, 10.9% (18/165) were grade 1, 32.7% (54/165) were grade 2, and 56.4% (93/165) were grade 3. Regarding endplate involvement, 115 had isolated upper endplate injuries, six had isolated lower endplate injuries, and 73 had injuries affecting both the upper and lower endplates. Decompression surgery was performed in 55 patients. During the follow-up period, only one patient experienced implant failure and underwent revision surgery in the IDI group.

Clinical outcomes

The IDI group showed significantly greater TLICS and LSC scores than those in the nIDI group ($P < 0.05$). The IDI group exhibited longer hospitalization days, greater blood loss and extended operative time relative to the nIDI group (Table 1). The average VAS score preoperatively decreased from 5.7 ± 1.6 to 2.9 ± 1.1 postoperatively, with all patients showing significant improvement in pain after surgery. Among the IDI group, 22.6% (31/137) of patients exhibited IVP.

The ASIA classification of two groups showed a significant difference before surgery ($P = 0.009$). Postoperative neurological recovery outcomes are indicated in Table 2. Preoperatively, there were eight ASIA A patients; five patients indicated no improvement, and one could walk with assistive devices. There were four patients in the ASIA B grade, 1 of whom indicated no improvement, while the others exhibited some recovery. Of eight patients in the ASIA C grade, six recovered to normal walking ability.

Radiological parameters

The average CA improved from 8.4° ± 11.4° preoperatively to 3.0° ± 9.9° postoperatively. However, by the final follow-up, it had increased to 6.4° ± 9.7°. At the final follow-up, the CA in the IDI group was significantly larger than that in the nIDI group (7.4° ± 9.9° vs. 4.2° ± 8.9°, $P = 0.035$). The mean VWA indicated significant improvement postoperatively (11.0° ± 7.2° vs. 5.4° ± 5.6°, $P < 0.001$). However, at the final follow-up, the VWA in the IDI group remained larger (7.1° ± 5.9° vs. 5.0° ± 4.0°, $P = 0.018$). Additionally, the disc height in the IDI group was significantly lower compared to that of the nIDI

Table 2 ASIA classification before the operation and the last follow-up between IDI and nIDI groups

	Preoperative (IDI group)					Preoperative (nIDI group)				
ASIA classification	A	B	C	D	E	A	B	C	D	E
Last follow-up										
A	4					1				
B		1								
C	2	2								
D	1		2							
E		1	6	24	94				3	53

Table 3 Comparison of clinical and radiological outcomes between IDI and nIDI groups

Characteristic	IDI group(*n* = 137)	NIDI group(*n* = 57)	*P*-value
VAS			
Preoperative	5.9 ± 1.6	5.1 ± 1.5	0.003
Postoperative	3.0 ± 1.0	2.5 ± 1.1	0.004
Last follow-up	0.2 ± 0.5	0.1 ± 0.3	0.555
CA (°)			
Preoperative	8.7 ± 11.4	7.8 ± 11.3	0.634
Postoperative	3.2 ± 10.2	2.4 ± 9.3	0.577
Last follow-up	7.4 ± 9.9	4.2 ± 8.9	0.035
VWA (°)			
Preoperative	11.2 ± 7.5	10.6 ± 6.6	0.655
Postoperative	5.7 ± 6.1	4.5 ± 3.9	0.169
Last follow-up	7.1 ± 5.9	5.0 ± 4.0	0.018
Intervertebral disc angle (°)			
Preoperative	-1.9 ± 3.5	-2.7 ± 2.5	0.134
Postoperative	-2.2 ± 3.3	-2.4 ± 2.6	0.765
Last follow-up	-1.0 ± 3.3	-2.1 ± 2.6	0.026
Intervertebral disc height (mm)			
Preoperative	6.0 ± 2.0	6.8 ± 2.2	0.034
Postoperative	6.9 ± 2.4	7.2 ± 2.5	0.461
Last follow-up	5.8 ± 1.9	6.5 ± 2.2	0.039
AVBHr (%)			
Preoperative	72.6 ± 17.5	78.6 ± 12.4	0.019
Postoperative	90.4 ± 17.0	93.7 ± 7.8	0.156
Last follow-up	87.9 ± 15.1	92.6 ± 9.7	0.032
MVBHr (%)			
Preoperative	70.4 ± 14.2	79.4 ± 11.0	< 0.001
Postoperative	80.6 ± 14.9	87.3 ± 7.9	0.002
Last follow-up	77.6 ± 15.1	85.1 ± 9.2	0.001
PVBHr (%)			
Preoperative	92.3 ± 8.8	94.0 ± 6.6	0.184
Postoperative	96.1 ± 7.5	97.1 ± 5.2	0.364
Last follow-up	95.3 ± 7.7	96.3 ± 5.1	0.381

IDI Intervertebral disc injury, *NIDI* Non-intervertebral disc injury, *VAS* Visual analog scale, *CA* Cobb angle, *VWA* Vertebral wedge angle, *AVBHr* Anterior vertebral body height ratio, *MVBHr* Midline vertebral body height ratio, *PVBHr* Posterior vertebral body height ratio

Table 4 The relationship between disc injury severity and postoperative correction loss

Characteristic	NIDI (*n* = 57)	Mild IDI (*n* = 49)	Severe IDI (*n* = 88)	*P*-value
CA(°)				
Preoperative	7.8 ± 11.3	7.4 ± 9.4	9.4 ± 12.4	0.557
Postoperative	2.4 ± 9.3	3.2 ± 10.0	3.3 ± 10.4	0.853
Last follow-up	4.2 ± 8.9	6.5 ± 9.0	7.9 ± 10.4	0.076
Correction loss	1.8 ± 3.0	3.2 ± 3.6	4.6 ± 4.3	< 0.001

IDI Intervertebral disc injury, *NIDI* Non-intervertebral disc injury, *CA* Cobb angle

group (5.8 ± 1.9 mm vs. 6.5 ± 2.2 mm, $P = 0.039$). In comparison to the nIDI group, the IDI group showed significantly lower AVBHr and MVBHr at the final follow-up (Table 3). Table 4 demonstrates that correction loss was significantly greater in the severe IDI group (4.6° ± 4.3°) compared to both the mild IDI (3.2° ± 3.6°) and nIDI groups (1.8° ± 3.0°). Representative cases are shown in Figs. 2 and 3.

A total of 37 cases of IVP were observed. Table 5 presents the clinical and radiological differences between patients with and without IVP. During the final follow-up, the IVP group exhibited a notably larger CA compared to the non-IVP group (10.5° ± 8.1° vs. 5.5° ± 9.8°, $P = 0.005$). Moreover, the IVP group showed significantly lower disc height and MVBHr than the non-IVP group. A characteristic case illustrating the coexistence of intervertebral disc vacuum phenomenon and correction loss is presented in Fig. 4.

Logistic regression analysis

Univariate analysis identified seven variables significantly linked to the recurrence of kyphotic deformity ($P < 0.05$). Age, BMI, TLICS score, gender, IDI, laminectomy decompression, and the fixation segment were analyzed using multivariate logistic regression analysis. The findings indicated that age (OR = 1.038, 95% CI = 1.011–1.066,

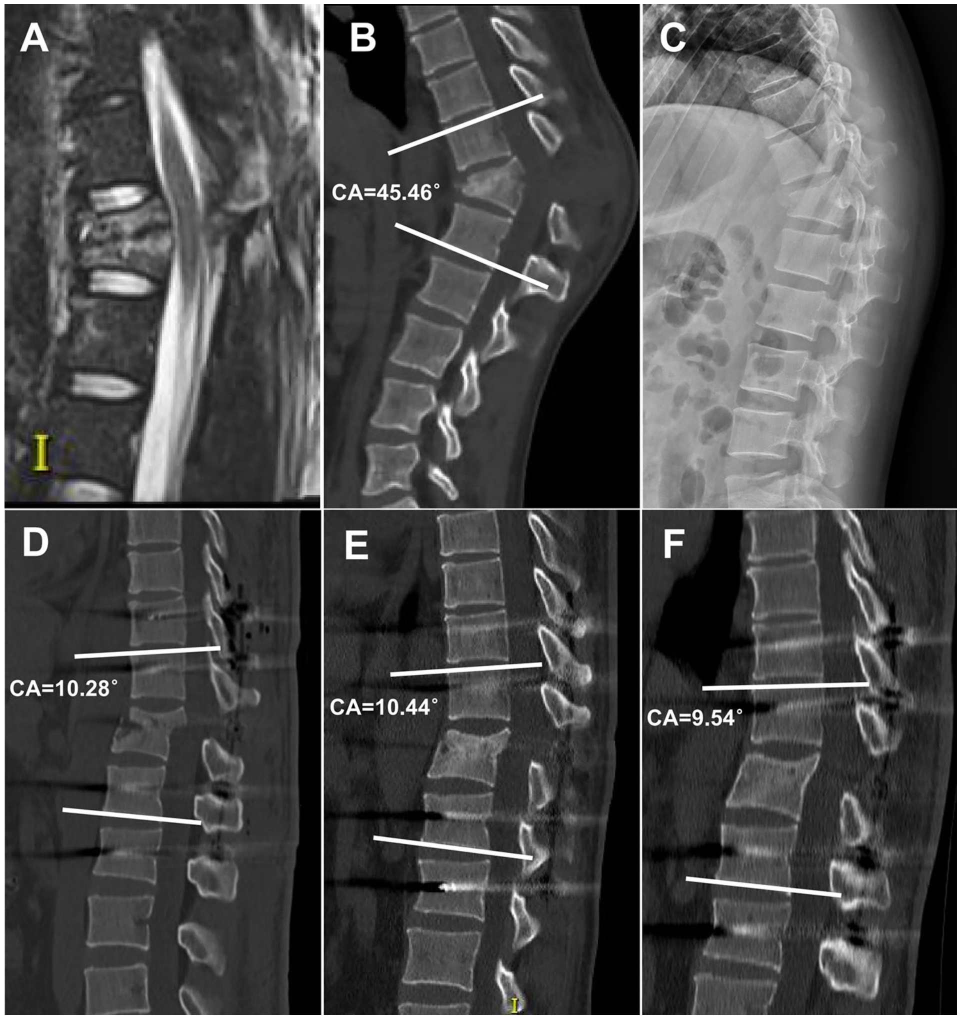

Fig. 2 A 28-year-old male suffered a heavy crush injury resulting in a T12 fracture. **A** MRI revealed rupture of the posterior longitudinal ligament without IDI. **B**, **C** CT and X-ray images demonstrated a T12 vertebral fracture involving the pedicles, with severe vertebral wedging and kyphotic deformity. **D** CT scan showed excellent kyphotic deformity correction and satisfactory vertebral height restoration postoperatively. **E** At the 3-month follow-up, the fracture exhibited good healing. **F** No correction loss was observed at the 18-month follow-up

$P = 0.005$), male gender (odds ratio [OR] = 2.201, 95% confidence interval [CI] = 1.107–4.377, $P = 0.025$), and intervertebral disc injury (OR = 2.463, 95% CI = 1.105–5.489, $P = 0.028$) were identified as independent risk factors for the recurrence of kyphotic deformity (Fig. 5).

Discussion

There is no consensus on the treatment strategies for thoracolumbar burst fractures [15]. Conservative management, anterior surgery, posterior surgery, and combined anterior−posterior surgery are the current treatment options available [16, 17]. While anterior surgery offers the advantage of better kyphotic deformity correction, it is associated with prolonged operative time and a high incidence of complications [18]. In contrast, posterior surgery is the preferred clinical approach due to its short operative time, reduced blood loss, and ability to restore spinal stability in the short term [19, 20]. However, thoracolumbar fractures typically involve injury to the anterior column of the spine, leading to disc injury and spinal instability. As a result, posterior surgery may increase the recurrence of kyphotic deformities in long-term follow-ups. This study found that patients with IDI had poorer postoperative outcomes. The IDI group exhibited greater blood loss, longer operative time, larger CA and VWA, as well as more severe vertebral collapse and disc height reduction at the last follow-up.

At the final follow-up, patients with thoracolumbar fractures complicated by IDI exhibited larger CA and VWA, with more severe vertebral and disc space collapse. These findings suggest that IDI significantly compromises spinal stability. Previous studies have identified vertebral destruction and IDI as significant risk factors for postoperative correction loss [21, 22]. Müller et al.

Fig. 3 Female, 57-year-old, a T12 burst fracture. **A** MRI revealed edema in the posterior longitudinal ligament, with the upper intervertebral disc embedded by the fractured endplates. **B** CT scan showed a fracture in the T12 vertebral body along with its spinous process. **C** After surgery, spinal stability was successfully restored. **D**, **E** During follow-up, the patient developed low back pain after falling; CT scan revealed displacement of the pedicle screws, vertebral collapse, and aggravated kyphotic deformity. **F** After spinal revision surgery, with extension of the fixation segments and vertebral with bone cement reinforcement, the kyphotic deformity showed improvement compared to the preoperative condition

[23] confirmed that disc space collapse is a key contributor to this loss. Xie et al. [24] reported that when injured disc tissue herniates into the fractured vertebral endplate, it triggers bone resorption around the fracture site, increases bone defect volume, and forms a "cavity" within the deformed healing connected to the intervertebral space. This process severely impairs fracture healing and leads to intervertebral height loss, findings that align with our study. These complications may result from high-energy external trauma causing vertebral burst fractures, where fracture fragments directly compress, tear, or even penetrate the adjacent disc [25]. Structural damage to the disc reduces the disc's elasticity and buffering capacity and leads to the collapse of the intervertebral space. This alters the biomechanical relationship between the vertebrae, increases the load on the vertebral bodies, and reduces spinal stability, ultimately resulting in the recurrence of deformity.

Thoracolumbar fractures frequently damage the vertebral endplates, and such fractures are closely linked with disc degeneration [26]. Su et al. [27] demonstrated that restoring the endplate integrity can significantly delay disc degeneration, highlighting the role of endplate injury in this process. The blood supply to the disc comes from the cartilaginous endplate, which provides essential nutrients and oxygen. On the one hand, vertebral burst fractures disrupt the microcirculation within the endplate, impairing nutrient delivery to the disc, reducing the availability of growth factors, accelerating cellular aging, and ultimately leading to poor disc healing and faster degeneration [28]. On the other hand, the post-injury changes in the disc microenvironment trigger

Table 5 Comparison of clinical and radiological results for IVP and non-IVP groups

Characteristic	IVP group ($n=37$)	Non-IVP group ($n=157$)	*P*-value
Age (year)	50.5 ± 15.2	49.9 ± 12.6	0.798
Gender (male/female)	20/17	88/69	0.971
TLICS	5.2 ± 2.8	4.6 ± 2.7	0.302
LSC	5.8 ± 1.4	5.7 ± 1.6	0.735
CA (°)			
Preoperative	11.8 ± 9.4	7.6 ± 11.7	0.046
One week post-operation	6.0 ± 9.2	2.3 ± 10.0	0.042
Last follow-up	10.5 ± 8.1	5.5 ± 9.8	0.005
VWA (°)			
Preoperative	12.1 ± 7.3	10.8 ± 7.2	0.325
One week post-operation	5.7 ± 6.4	5.3 ± 5.4	0.674
Last follow-up	8.1 ± 6.2	6.1 ± 5.3	0.060
Intervertebral disc angle (°)			
Preoperative	-2.3 ± 2.9	-2.1 ± 3.4	0.799
One week post-operation	-1.8 ± 2.7	-2.4 ± 3.2	0.345
Last follow-up	-0.7 ± 2.7	-1.4 ± 3.3	0.205
Intervertebral disc height (mm)			
Preoperative	5.1 ± 1.1	6.5 ± 2.2	< 0.001
One week post-operation	5.9 ± 1.5	7.3 ± 2.6	0.003
Last follow-up	5.2 ± 1.2	6.2 ± 2.1	0.007
AVBHr (%)			
Preoperative	70.5 ± 14.6	75.2 ± 16.6	0.111
One week post-operation	89.8 ± 14.8	91.7 ± 15.0	0.490
Last follow-up	85.9 ± 16.3	90.1 ± 13.1	0.096
MVBHr (%)			
Preoperative	68.4 ± 12.5	74.1 ± 14.0	0.023
One week post-operation	77.9 ± 13.2	83.7 ± 13.5	0.019
Last follow-up	75.2 ± 13.3	80.9 ± 14.0	0.026
PVBHr (%)			
Preoperative	91.8 ± 8.1	93.0 ± 8.3	0.429
One week post-operation	96.0 ± 7.2	96.4 ± 6.9	0.757
Last follow-up	95.2 ± 7.8	95.7 ± 6.9	0.724

IVP Intervertebral vacuum phenomenon, *TLICS* Thoracolumbar injury classification and severity score, *LSC* Load sharing classification, *CA* Cobb angle, *VWA* Vertebral wedge angle, *AVBHr* Anterior vertebral body height ratio, *MVBHr* Midline vertebral body height ratio, *PVBHr* Posterior vertebral body height ratio

inflammatory responses, cellular apoptosis, and necrosis [29]. These factors collectively accelerate disc degeneration, contribute to intervertebral space collapse, and increase the risk of kyphotic deformity recurrence.

IVP is characterized by gas accumulation within the intervertebral disc space and is commonly regarded as a radiographic sign of disc degeneration. The incidence of IVP is high following traumatic thoracolumbar fractures and is considered an indicator of progressive disc degeneration after IDI, potentially leading to loss of correction [30, 31]. In this study, 83.8% (31/37) of patients with IVP had concomitant disc injuries, further supporting the notion that disc injury increases the risk of disc degeneration. Besides, at the final follow-up, patients with IVP exhibited larger CA and lower MVBHr. These findings suggest that more significant correction loss in IVP patients and greater midportion collapse in the injured vertebra during long-term postoperative follow-up.

This study identified age, male, and IDI as independent predictors of postoperative correction loss following thoracolumbar fracture surgery. Hou et al. [32] reported that risk factors for the recurrence of kyphotic deformity after short-segment pedicle screw fixation included male, the upper disc injury, and vertebral wedge angle. These findings align with those of the present study, which also confirmed the impact of IDI on postoperative correction loss. One possible explanation for this study's findings is that spinal stability decreases with age. Additionally, male patients, who typically have greater body weight and are more likely to engage in physically demanding work, experience increased biomechanical stress on the spine, thereby increasing the risk of kyphotic deformity recurrence. The findings of this study indicate that greater attention should be afforded to the age, gender, and IDI in thoracolumbar fracture management. Future studies should further investigate the impact of gender

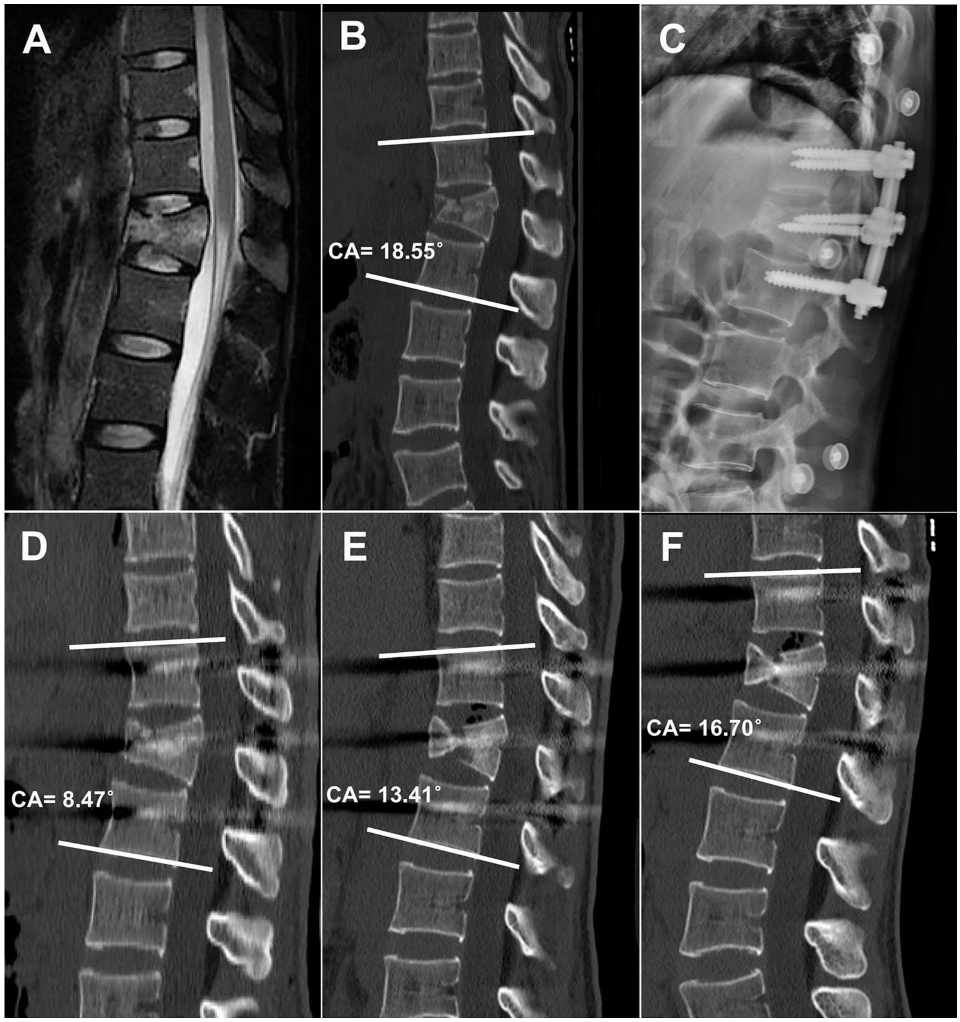

Fig. 4 A 32-year-old woman who sustained an L1 fracture due to a traffic accident. **A** MRI showed IDI adjacent to the fractured vertebral body. **B** CT scan revealed collapse of the anterior and midline fractured vertebral body, along with kyphotic deformity. **C**, **D** Postoperative X-ray and CT scan demonstrated stable fixation, with correction of kyphosis. **E** At the 3-month follow-up, the fracture healing was suboptimal, and the IVP was observed at the superior intervertebral disc. **F** One year postoperatively, the IVP continued to progress, with significant loss of kyphotic deformity correction

differences on surgical decision-making to optimize treatment strategies and improve long-term patient outcomes.

Traditionally, a TLICS score greater than four has been considered an indication for surgery; however, its scoring system has limitations in clinical application [33]. This study revealed that some patients with thoracolumbar fractures accompanied by IDI experienced suboptimal outcomes following posterior pedicle screw fixation, including inadequate fracture healing and unsatisfactory correction of the kyphotic deformity. Some of these patients required additional fusion surgery, further increasing their physical and psychological burdens. Future research should focus on optimizing preoperative scoring systems and treatment strategies, emphasizing the significance of intervertebral disc injuries to improve the prognosis of patients with IDI.

However, several limitations are present in this study. First, as a single-center retrospective study, it could bring about selection bias, thereby influencing the objectivity of the outcomes. Second, the relatively short average follow-up duration and limited functional assessments may not adequately capture the long-term impact of IDI on clinical outcomes. Future studies should incorporate extended follow-up periods and comprehensive functional assessments to provide more definitive evidence. Third, the kyphosis outcomes may be potentially biased due to inclusion of lumbar injuries in this study. Furthermore, the heterogeneity in fracture types and differences in neurological status among patients could influence postoperative stability outcomes. Therefore, future studies should adopt a more comprehensive design, involve multiple centers, and employ a prospective approach to enhance the reliability of findings.

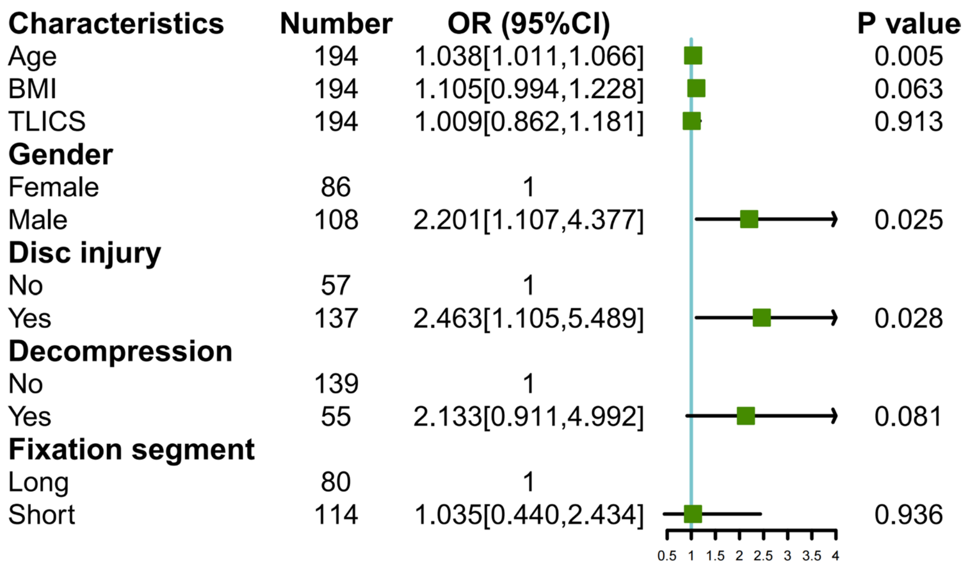

Fig. 5 Forest plot showing independent risk factors of postoperative kyphosis recurrence

Conclusion

This study identifies age, male, and IDI as independent risk factors for correction loss of kyphotic deformity after thoracolumbar fracture surgery. Traumatic IDI not only increases the risk of disc degeneration but also compromises spinal stability and functional recovery. For patients with thoracolumbar fractures and severe IDI, interbody fusion surgery is recommended to enhance spinal stability.

Abbreviations

IDI	Intervertebral disc injury
NIDI	Non-intervertebral disc injury
MRI	Magnetic resonance imaging
AO	Arbeitsgemeinschaft für Osteosynthesefragen
CT	Computed tomography
BMI	Body mass index
TLICS	Thoracolumbar injury classification and severity score
LSC	Load sharing classification
VAS	Visual analog scale
ASIA	American Spinal Injury Association
CA	Cobb angle
VWA	Vertebral wedge angle
AVBHr	Anterior vertebral body height ratio
MVBHr	Midline vertebral body height ratio
PVBHr	Posterior vertebral body height ratio
IVP	Intervertebral vacuum phenomenon

Acknowledgements

Not applicable.

Author contributions

TG, WL, JW, and JF contributed to conception and design of the manuscript. TG, QW, CL, and SW were involved in analysis and interpretation of data. TG and JW were responsible for drafting the manuscript. WL, CL, SW, and WX critically revised the manuscript for important intellectual content. TG, WL, and JW contributed equally to this article. The authors read and approved the final version of the manuscript.

Funding

This study was funded by Jiangsu Province Hospital High-level Talent Cultivation Program (Phase I) (CZ0121002010039) and the National Natural Science Foundation of China (82272499).

Data availability

The datasets used and analysed in this study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The research obtained ethical clearance from institutional ethics committee of the First Affiliated Hospital with Nanjing Medical University (2024-SR-930). Ethical approval for this retrospective study was obtained with a waiver of informed consent from institutional ethics committee. Written informed consent was obtained from all patients whose radiological data are presented in the figures. The research was performed in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Received: 27 March 2025 / Accepted: 14 May 2025
Published online: 23 May 2025

References

1. Denis F. The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. Spine (Phila Pa 1976). 1983;8(8):817–31.
2. Hu R, Mustard CA, Burns C. Epidemiology of incident spinal fracture in a complete population. Spine (Phila Pa 1976). 1996;21(4):492–9.
3. Charles YP, Steib JP. Management of thoracolumbar spine fractures with neurologic disorder. Orthop Traumatol Surg Res. 2015;101(1 Suppl):S31–40.
4. Meyblum J, Portella T, Coudert P, Prost S, Mazas S, Barut N, Khalifé M, Marie-Hardy L. Management of thoracolumbar fracture in France. Analysis of practices and radiologic results of a cohort of 407 thoracolumbar fractures. Orthop Traumatol Surg Res. 2020;106(6):1203–7.
5. Tanasansomboon T, Kittipibul T, Limthongkul W, Yingsakmongkol W, Kotheeranurak V, Singhatanadgige W. Thoracolumbar burst fracture without

neurological deficit: review of controversies and current evidence of treatment. World Neurosurg. 2022;162:29–35.
6. Raj PP. Intervertebral disc: anatomy-physiology-pathophysiology-treatment. Pain Pract. 2008;8(1):18–44.
7. Kanezaki S, Miyazaki M, Ishihara T, Notani N, Tsumura H. Magnetic resonance imaging evaluation of intervertebral disc injuries can predict kyphotic deformity after posterior fixation of unstable thoracolumbar spine injuries. Med (Baltim). 2018;97(28):e11442.
8. Hrabálek L, Houdek M, Vaverka M. [Contribution of MRI to the thoracolumbar spine injuries diagnostics and therapy]. Rozhl Chir. 2009;88(8):461–5.
9. Sander AL, Laurer H, Lehnert T, El Saman A, Eichler K, Vogl TJ, Marzi I. A clinically useful classification of traumatic intervertebral disk lesions. AJR Am J Roentgenol. 2013;200(3):618–23.
10. Aono H, Ishii K, Takenaka S, Tobimatsu H, Nagamoto Y, Horii C, Yamashita T, Furuya M, Iwasaki M. Risk factors for a kyphosis recurrence after short-segment temporary posterior fixation for thoracolumbar burst fractures. J Clin Neurosci. 2019;66:138–43.
11. Hashimura T, Onishi E, Ota S, Tsukamoto Y, Yamashita S, Yasuda T. Correction loss following short-segment posterior fixation for traumatic thoracolumbar burst fractures related to endplate and intervertebral disc destruction. BMC Musculoskelet Disord. 2023;24(1):174.
12. Hu C, Zhong W, Chen Z, Peng J, Li J, Tang K, Quan Z. Comparison of the outcomes between AO type B2 thoracolumbar fracture with and without disc injury after posterior surgery. Orthop Surg. 2022;14(9):2119–31.
13. McLain RF. The biomechanics of long versus short fixation for thoracolumbar spine fractures. Spine (Phila Pa 1976). 2006;31(11 Suppl):S70–79. discussion S104.
14. McLain RF, Burkus JK, Benson DR. Segmental instrumentation for thoracic and thoracolumbar fractures: prospective analysis of construct survival and five-year follow-up. Spine J. 2001;1(5):310–23.
15. Spiegl UJ, Fischer K, Schmidt J, Schnoor J, Delank S, Josten C, Schulte T, Heyde CE. The Conservative treatment of traumatic thoracolumbar vertebral fractures. Dtsch Arztebl Int. 2018;115(42):697–704.
16. Reinhold M, Knop C, Beisse R, Audigé L, Kandziora F, Pizanis A, Pranzl R, Gercek E, Schultheiss M, Weckbach A, et al. [Operative treatment of traumatic fractures of the thorax and lumbar spine. Part II: surgical treatment and radiological findings]. Unfallchirurg. 2009;112(2):149–67.
17. Verheyden AP, Hölzl A, Ekkerlein H, Gercek E, Hauck S, Josten C, Kandziora F, Katscher S, Knop C, Lehmann W, et al. [Recommendations for the treatment of thoracolumbar and lumbar spine injuries]. Unfallchirurg. 2011;114(1):9–16.
18. Danisa OA, Shaffrey CI, Jane JA, Whitehill R, Wang GJ, Szabo TA, Hansen CA, Shaffrey ME, Chan DP. Surgical approaches for the correction of unstable thoracolumbar burst fractures: a retrospective analysis of treatment outcomes. J Neurosurg. 1995;83(6):977–83.
19. Hariri OR, Kashyap S, Takayanagi A, Elia C, Ma Q, Miulli DE. Posterior-only stabilization for traumatic thoracolumbar burst fractures. Cureus. 2018;10(3):e2296.
20. Wang T, Wang Z, Ji P, Zhang J, Zhang C, Zhang L. The efficacy and safety of anterior versus posterior approach for the treatment of thoracolumbar burst fractures: a systematic review and meta-analysis. Ann Transl Med. 2022;10(6):309.
21. Peng Z, Cui Z, Kuang X, Yu C, Ruan Y, Li C, Li S, Lu S. Intervertebral disc injury is the mainspring for the postoperative increase in Cobb angle after thoracolumbar burst fracture. J Orthop Surg (Hong Kong). 2022;30(2):10225536221088753.
22. Hirota R, Teramoto A, Irifune H, Yoshimoto M, Takahashi N, Chiba M, Iesato N, Iba K, Emori M, Yamashita T. Risk factors for postoperative loss of correction in thoracolumbar injuries caused by High-Energy trauma treated via percutaneous posterior stabilization without bone fusion. Med (Kaunas) 2022, 58(5).
23. Müller U, Berlemann U, Sledge J, Schwarzenbach O. Treatment of thoracolumbar burst fractures without neurologic deficit by indirect reduction and posterior instrumentation: bisegmental stabilization with monosegmental fusion. Eur Spine J. 1999;8(4):284–9.
24. Xie H, Wu J, Qin J, Liu J, Cao XJ. [Herniation of intervertebral disc into thoracolumbar fracture vertebral body leads to malunion of fracture and decrease of intervertebral space height]. Zhongguo Gu Shang. 2023;36(6):532–42.
25. Willén J, Lindahl S, Irstam L, Aldman B, Nordwall A. The thoracolumbar crush fracture. An experimental study on instant axial dynamic loading: the resulting fracture type and its stability. Spine (Phila Pa 1976). 1984;9(6):624–31.
26. Subramanian P, Ramachandran K, Arumugam T, Shetty AP, Kanna RM, Shanmuganathan R. Evaluation of disc and endplate degeneration in AO type A fractures using magnetic resonance imaging analysis. World Neurosurg. 2023;178:e758–65.
27. Su Y, Ren D, Chen Y, Geng L, Yao S, Wu H, Wang P. Effect of endplate reduction on endplate healing morphology and intervertebral disc degeneration in patients with thoracolumbar vertebral fracture. Eur Spine J. 2023;32(1):55–67.
28. Feng C, Liu H, Yang M, Zhang Y, Huang B, Zhou Y. Disc cell senescence in intervertebral disc degeneration: causes and molecular pathways. Cell Cycle. 2016;15(13):1674–84.
29. Dudli S, Haschtmann D, Ferguson SJ. Persistent degenerative changes in the intervertebral disc after burst fracture in an in vitro model mimicking physiological post-traumatic conditions. Eur Spine J. 2015;24(9):1901–8.
30. Ekşi M, Özcan-Ekşi EE, Akkaş A, Orhun Ö, Arslan HN, Zarbizada M, Küçüksüleymanoğlu D, Pamir MN, Benzel EC. Intradiscal vacuum phenomenon and spinal degeneration: a cross-sectional analysis of 219 subjects. Curr Med Res Opin. 2022;38(2):255–63.
31. Schömig F, Palmowski Y, Nikiforov I, Hartwig T, Pumberger M, Schwabe P, Jacobs C. Burst fractures lead to a fracture-associated intervertebral vacuum phenomenon: a case series of 305 traumatic fractures of the thoracolumbar spine. Eur Spine J. 2021;30(10):3068–73.
32. Hou GJ, Zhou F, Tian Y, Ji HQ, Zhang ZS, Guo Y, Lv Y, Yang ZW, Zhang YW. [Risk factors of recurrent kyphosis in thoracolumbar burst fracture patients treated by short segmental pedicle screw fixation]. Beijing Da Xue Xue Bao Yi Xue Ban. 2020;53(1):167–74.
33. Pneumaticos SG, Karampinas PK, Triantafilopoulos G, Koufos S, Polyzois V, Vlamis J. Evaluation of TLICS for thoracolumbar fractures. Eur Spine J. 2016;25(4):1123–7.

Publisher's note