


## CLINICAL ARTICLE

# Comparison of the Outcomes between AO Type B2 Thoracolumbar Fracture with and without Disc Injury after Posterior Surgery

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**Objective:** The type AO B2 thoracolumbar fracture is a kind of flexion-distraction injury and the effect of disc injury on treatment results of patients with B2 fracture remains unclear. The objective of the current study was to compare and analyze the outcomes in AO Type B2 thoracolumbar fracture patients with and without disc injuries in terms of the Cobb angle of kyphosis, the incidence of complication, and the rate of implant failure.

**Methods:** This is a retrospective study. Of the 486 patients with thoracolumbar fractures who underwent posterior fixation, 38 patients with AO type B2 injuries were included. All the patients were divided into two groups according to changes in the adjoining discs. Disc injury group A included 17 patients and no disc injury group included 21 patients. Clinical and radiologic parameters were evaluated before surgery, after surgery, and at follow-up. Clinical outcomes included visual analogue scale (VAS) scores, incidence of complications, and incidence of implant failure. Radiologic assessment was accomplished with the Cobb angle (CA), local kyphosis (LK), percentage of anterior vertebral height (AVBH%), intervertebral disc height, and intervertebral disc angle. Fisher's precision probability tests were employed and chi square test were used to compare categorical variables. Paired sample *t* tests and independent-sample *t* tests were used to compare continuous data.

**Results:** Disc injury mainly involved the cranial disc (15/19, 78.9%). The mean follow-up period for the patients was  $30.2 \pm 20.1$  months. No neurologic deterioration was reported in the patients at the last follow-up. Radiological outcomes at the last follow-up showed significant differences in the CA ( $18.59^\circ \pm 13.74^\circ$  vs  $8.16^\circ \pm 9.99^\circ$ ,  $P = 0.008$ ), LK ( $12.74^\circ \pm 8.00^\circ$  vs  $6.55^\circ \pm 4.89^\circ$ ,  $P = 0.006$ ), and %AVBH (77.16% vs 90.83%,  $P = 0.01$ ) between the two groups. Implant failure occurred after posterior fixation in five patients with disc injury who did not undergo interbody fusion during the initial surgery. Additionally, in the subgroup analysis, interbody fusion in the implant failure group were significantly different than in the no implant failure group (0% vs 75%,  $P = 0.009$ ).

**Conclusions:** AO B2 fracture patients with disc injury have higher risk of complications, especially implant failure after posterior surgery. Interbody fusion should be considered in AO type B2 fracture patients with disc injury.

**Key words:** Disc injury; Flexion distraction injury; Posterior surgery; Thoracolumbar fracture

## Introduction

A thoracolumbar fracture is a common type of spine trauma that accounts for approximately 50%–70% of spine fractures and 6.9% of all blunt injuries.<sup>1</sup> The thoracolumbar junction is the most common region of the

spine involved in spine trauma because it is the transition area between the kyphotic thoracic spine and the lordotic lumbar spine.<sup>2</sup> Traffic accidents and falls from heights are two major causes of traumatic thoracolumbar fractures, which results in low back pain, spine instability, and even

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Received 4 August 2020; accepted 23 June 2022

neurological dysfunction.<sup>1,3</sup> The purpose of surgical treatment is to stabilize the fracture, restore the normal alignment of the spine, correct the kyphosis, and decompress the neural elements.<sup>4,5</sup> Anterior, posterior and combined approaches have been widely used to treat thoracolumbar fractures in the past decades.<sup>6</sup> Currently, posterior pedicle screw fixation is one of the most commonly recognized surgical methods because of its effectiveness in stabilizing the spinal column in a shorter operation time. Even though canal compromise can only be retracted by posterior indirect decompression when the posterior longitudinal ligament is not injured.<sup>7,8</sup> The indication for long or short-segment fixation is mainly based on the morphology of the vertebral body and the severity of the kyphosis.<sup>9,10</sup> However, the morphology of the disc is rarely discussed.

To date, treating a thoracolumbar fracture is challenging and controversial despite the introduction of several classifications and scoring systems.<sup>10-12</sup> Among them, a flexion-distraction injury (FDI) is an uncommon type of thoracolumbar spine fracture. In Denis' three column spine concept, a flexion-distraction injury was also named seat-belt type injuries in order to distinguish it from a flexion-distraction type of fracture-dislocation.<sup>13</sup> According to the Magerl classification and AO classification, this type of fracture is mainly composed of three subtypes: Group B1 (posterior disruption predominantly ligamentous), Group B2 (posterior disruption predominantly osseous), and Group C2<sup>14</sup> (type B injuries with rotation). Among these subtypes, a B2 injury is one of the major types of thoracolumbar FDIs. One typical example of the injury is a chance fracture. In several cases, this type of fracture can be conservatively or surgically treated.<sup>15-18</sup> However, this classification does not separately discuss the effect of disc disruption, even though disc lesions can be observed in type B2.2 injuries.

A disc injury is a common occurrence in thoracolumbar fractures. MRI is one of the most efficient and commonly used examination methods for thoracolumbar trauma, and a thorough preoperative evaluation of the disc injury on MRI is essential.<sup>19,20</sup> Oner *et al.*<sup>21</sup> divided the changes of the disc into six types: normal or near normal disc, black disc, Schmorl-type change, anterior collapse, central herniation, and degenerated disc. This classification system is cumbersome and does not classify the severity of the disc injury between different types. Sander *et al.*<sup>22</sup> proposed a more practical classification based on MRI. Since the upper and lower discs facilitate the acute flexibility of the segment,<sup>23</sup> disc lesions are important factors that influence spinal stability and prognosis after surgical treatment. Previous research suggests that an endplate-disc complex injury may influence the clinical outcomes of posterior surgery for a thoracolumbar fracture.<sup>24,25</sup> In a few studies, spontaneous interbody fusion was observed in a disc injury with a thoracolumbar fracture.<sup>26-28</sup> The consequent effect of a disc injury has not been fully emphasized in clinical treatment compared to many other factors.

Implant failure and kyphosis recurrence are two serious complications that occur after posterior fixation. Previous

literature has tried to predict kyphosis recurrence by many radiologic assessments, such as Cobb angle, local kyphosis angle, vertebral body compression ratio and compromised canal ratio, before surgery.<sup>29-31</sup> Unfortunately, the role of a disc injury in postoperative complications has not been clarified. Additionally, although some authors have investigated the effects of a disc injury in the last few years, several studies have focused on disc lesions in a thoracolumbar burst fracture, a B2 injury has a different mechanism and morphology compared to a burst fracture.<sup>24,25</sup> The effect of an adjoining disc lesion on surgical treatment for an AO type B2 fracture remains unclear. Research on the impact of a disc injury on a thoracolumbar AO type B2 fracture is rare. Whether the disc injury in a type B2 fracture should be treated with interbody fusion is still unanswered.

The aims of this study are as follows: (i) investigating the impact of a disc injury on clinical and radiological outcomes in B2 injury patients treated with posterior fixation; and (ii) discussing whether posterior short segment fixation alone is adequate treatment for a B2 fracture with an adjoining disc lesion. We hypothesize that the disc injury can result in poorer clinical and radiological outcomes in patients with AO type B2 fractures.

## Materials and Methods

### Patients

Following approval by the Ethics Committee of the First Affiliated Hospital of Chongqing Medical University (ID:2020-637), we retrospectively reviewed the records of consecutive patients who underwent posterior pedicle fixation between October 2012 and June 2019. All patients were treated in the orthopedic department at the First Affiliated Hospital of Chongqing Medical University. Inclusion criteria were as followed: (i) patients with traumatic AO type B2 thoracolumbar fractures; and (ii) posterior long-segment pedicle screw fixation or posterior fixation with interbody fusion.

Patients were excluded: (i) if they previously underwent combined anterior-posterior surgeries; (ii) could only commit to a follow-up of less than 6 months; and (iii) had osteoporotic fractures and pathological fractures. In total, 38 AO type B2 fracture patients were included in the study.

### Disc Injury Evaluation

Disc change was determined by the classification described by Sander *et al.*<sup>22</sup> (Fig. 1). Grade 0: no difference between the injured disc and a comparable uninjured disc. Grade 1: hyperintense appearances in T2-weighted/T2 TIRM images. Grade 2: decrease of signal intensity with perifocal hyperintense appearances in the T2-weighted/T2 TIRM images and isointense to hyperintense appearances in T1-weighted images. Grade 3: infraction of the disc into the vertebral body, annular tears, or herniation into the endplate. Sander classification grades 1 to 3 were defined as an injured disc. According to the disc evaluation on MRI, all patients were divided into a disc injury group or a no disc injury group

depending on whether the disc lesion was found near the fractured vertebrae. The significant differences in demographic data and surgical outcomes were analyzed between the two groups. The results are represented as the mean  $\pm$  standard deviation.

### Surgical Procedure

All patients underwent open, posterior surgery under general anesthesia. After successful induction of general anesthesia, patients were placed in a prone position on a posture mat that supported the body at the front of both shoulders and the anterosuperior iliac spine, with the abdomen suspended. A posterior median incision was made using a conventional approach, and pedicle screws were inserted into the vertebrae above and below the fracture level with or without pedicle fixation at the level of the fracture. A laminectomy was performed for decompression at the level of the pedicles in patients with neurologic deficits. Instrumentation reduction and fixation were performed. Then, the posterior column was shortened to correct kyphosis. All procedures were conducted at a single medical center. Patients in both groups were told to wear a brace for 3 months after the initial surgery. The implant was removed after bone healing was confirmed on X-ray radiographs.

### Clinical Evaluation

Demographic information was collected for all patients, which included age, sex, smoking status, causes of injury, TLICS score and load sharing score. All B2 injury patients were initially classified according to the AO spine system using plain radiographs, computed tomography (CT), and magnetic resonance imaging (MRI). Total operative time, blood loss, and length of hospital stay were obtained *via* chart review from the surgeon's operative notes, the

operating room records, and the discharge summary. Whether each patient underwent interbody fusion during surgery was also recorded. American Spinal Injury Association (ASIA) was applied for the neurological evaluation. The degree of low back pain was evaluated using the visual analog scale (VAS; 0–10).

### American Spinal Injury Association (ASIA) Score

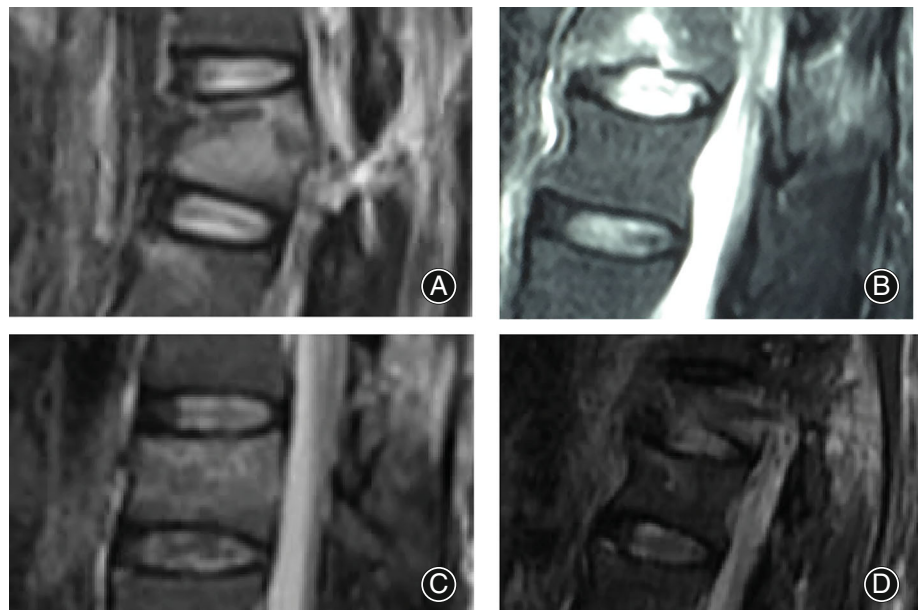
The ASIA score system was used to evaluate the neurological status of patients with thoracolumbar spine fractures.<sup>32</sup> The sensory examination evaluates 28 specific dermatomes bilaterally for light touch and pinprick sensation. The motor examination evaluates five specific muscle groups in the upper extremities and five specific muscle groups in the lower extremities. Motor strength is graded from 0–5. The level of neurologic injury is ranged as A–E grades. Grade A means complete spinal cord injury, grades B–D mean incomplete spinal cord injury, and grade E means normal neurological function.

### Visual Analogue Scale (VAS)

The VAS score system was used to evaluate low back pain. The VAS pain scoring standard (scores from 0 to 10) was as follows: 0 means no pain; 1–3 means mild pain that the patient could endure; 4–6 means the patient experienced a medium level of pain and was able to sleep; and 7–10 means the patient experienced severe pain and was unable to sleep.

### Radiological Evaluation

Radiographies were conducted at 3 months, 6 months, 1 year, and 2 years after the initial surgery. The Cobb angle (CA), local kyphosis (LK), and percentage of anterior vertebral body height (AVBH%) were measured directly on lateral plain radiographs (Fig. 2A). The radiological



**Fig. 1** Classification of traumatic intervertebral disc lesions in B2 injuries: Photographs of discs showing (A) grade 0 (cranial), (B) grade 1 (cranial), (C) grade 2 (caudal), and (D) grade 3 (cranial)

parameters of the adjoining discs were also collected (Fig. 2B). The radiological data were compared between the two groups.

#### Cobb Angle

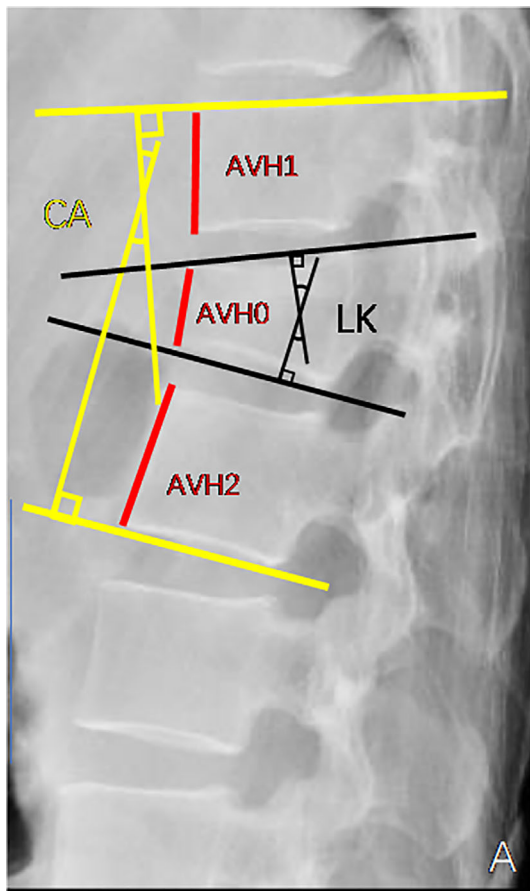
The Cobb angle was measured at one level above and one below the previously fractured vertebra. This angle indicates the degree of kyphosis of the thoracolumbar spine.

#### Local Kyphosis Angle

The local kyphosis angle was defined as the angle between the upper and lower edges of the fractured vertebra on a lateral plain radiograph. This angle indicates the degree of kyphosis of the injured segment.

#### Percentage of Anterior Vertebral Body Height (% AVBH)

The percentage of anterior vertebral body height (% AVBH) was defined as the anterior height of the injured vertebra divided by the mean of the anterior height of the adjacent two



**Fig. 2** Radiological measurement using plain lateral radiography.  $AVBH = [2AVH0/(AVH1 + AVH2) \times 100]$ .  $UIDH = (a1 + a2 + a3)/3$ ,  $LIDH = (b1 + b2 + b3)/3$ . CA, Cobb angle; LK, Local kyphosis; AVBH, anterior vertebral body height; UIDA, upper intervertebral disc angle; LIDA, lower intervertebral disc angle

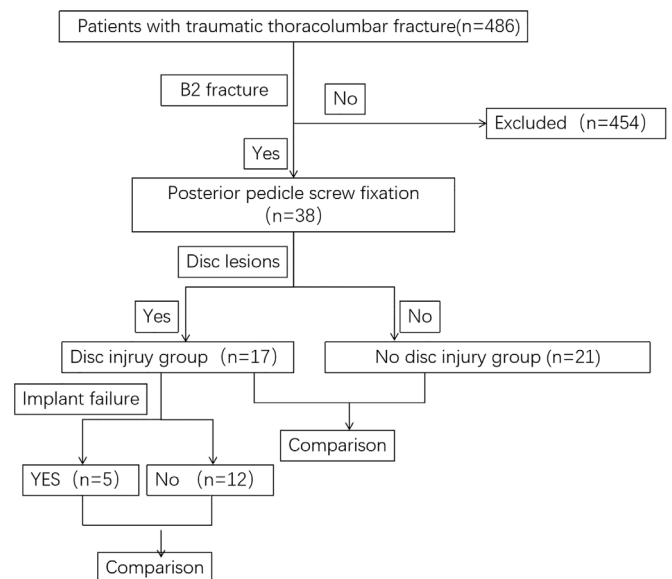
vertebrae using the formula  $\%AVBH = [2AVH0/(AVH1 + AVH2) \times 100\%]$ , where AVH0 means the anterior vertebral body height of fractured vertebra; AVH1 means the anterior vertebral body height of the proximal vertebra; and AVH2 means the anterior vertebral body height of the distal vertebra. Percentage of anterior vertebral body height indicates the degree of collapse in anterior column.

#### Intervertebral Disc Height (IDH)

Intervertebral disc height is used to evaluate the degree of disc degeneration. The IDH was measured by averaging the height obtained from the anterior, middle, and posterior portions of each intervertebral disc in the lateral spine radiograph. In patients with one disc lesion, the IDH was measured in the intervertebral space of the injured segment. In patients with upper and lower disc lesions or with no disc lesion, the IDH was the average of the IDHs of the upper and lower intervertebral disc spaces.

#### Intervertebral Disc Angle

The upper intervertebral disc angle (UIDA) was identified as the angle between the inferior margin of the upper vertebra and the superior margin of the fractured vertebra, and the lower intervertebral disc angle (LIDA) was identified as the angle between the inferior margin of the fractured vertebra and the superior margin of the lower vertebra. In patients with one disc lesion, the intervertebral disc angle was measured in the intervertebral space of the injured disc. In patients with upper and lower disc lesions or with no disc lesions, the intervertebral disc angle was the average of the upper and lower intervertebral disc angles.  $IDA > 0^\circ$  indicated kyphosis in the corresponding disc space. The intervertebral disc angle indicates akyphotic change in the disc space.



**Fig. 3** The flow chart of the study



**TABLE 1 Comparison of the operative data and radiological outcomes between two groups**

Variables	Disc injury group	No disc injury group	t value ( $\chi^2$ )	P value
Age years	51.53 ± 9.02	44.76 ± 13.75	1.746	0.089
Sex (M/F)	13/4	13/8	0.923	0.486
Smoking (yes/no)	11/6	8/13	2.661	0.191
Level of fracture			2.278	0.590
T12	9	7		
L1	2	6		
L2	1	2		
L3	5	6		
Thoracolumbar injury classification and severity score (TLICS) score	6.88 ± 0.99	6.67 ± 1.80	0.469	0.643
Duration from injury to surgery (days)	5.88 ± 2.76	6.05 ± 2.89	-0.179	0.859
Operating time (min)	143.82 ± 43.77	122.57 ± 39.05	1.599	0.119
Blood loss (ml)	304.71 ± 286.10	175.71 ± 172.03	1.635	0.115
Duration of hospitalization (days)	14.65 ± 9.96	11.95 ± 4.70	1.101	0.278
Short segment fixation	5	12	2.033	0.111
Long segment fixation	12	9		
Interbody fusion	9	4	1.279	<b>0.042</b>
No interbody fusion	8	17		
Cobb angle (CA)				
Pre-operative	16.39 ± 7.22	17.10 ± 10.51	-0.234	0.816
Post-operative 1 week	6.71 ± 8.14	5.00 ± 7.80	0.657	0.515
Last follow up	18.59 ± 13.74	8.16 ± 9.99	2.795	<b>0.008</b>
Local kyphosis (LK)				
Pre-operative	17.36 ± 8.56	15.79 ± 7.09	0.618	0.540
Post-operative 1 week	6.59 ± 6.14	4.91 ± 3.97	1.020	0.315
Last follow up	12.74 ± 8.00	6.55 ± 4.89	2.936	<b>0.006</b>
Anterior vertebral body height (AVBH%)				
Pre-operative	67.27 ± 11.53	70.09 ± 18.23	-0.563	0.577
Post-operative 1 week	88.66 ± 14.68	93.99 ± 8.72	-1.389	0.174
Last follow up	77.16 ± 18.07	90.83 ± 9.26	-2.831	<b>0.010</b>
Total complications (yes/no)	9/8	3/18	6.497	<b>0.016</b>
Implant failure (yes/no)	5/12	0/21	7.112	<b>0.012 †</b>
Neurological deterioration (yes/no)	2/15	1/20	0.634	0.577 †
Infection (yes/no)	2/15	1/20	0.634	0.577 †
Others (yes/no)	0/17	1/20	0.831	1.000 †
Intervertebral disc height (mm)				
Preoperative	11.39 ± 2.49	13.09 ± 2.72	-1.988	0.054
Postoperative	10.90 ± 2.12	12.70 ± 1.89	-2.767	<b>0.009</b>
Last follow-up	8.96 ± 2.89	11.66 ± 2.43	-3.603	<b>0.001</b>
Intervertebral disc angle (°)				
Preoperative	-4.43 ± 5.13	-5.24 ± 3.10	0.602	0.551
Postoperative	-3.92 ± 4.46	-6.07 ± 3.18	1.731	0.092
Last follow-up	-2.38 ± 4.16	-4.89 ± 2.88	2.193	<b>0.035</b>

Note: Bold values indicate  $P < 0.05$ .; † Using Fisher's precision probability test.

**TABLE 2 The clinical and radiological outcomes of AO type B2 patients after posterior fixation**

Variables	Pre-operative	Post-operative	Last follow-up	t1 value	P1 value	t2 value	P2 value
Visual analogue scale (VAS) score	5.37 ± 1.22	2.97 ± 0.94	1.74 ± 1.74	12.187	<b>&lt;0.001</b>	4.573	<b>&lt;0.001</b>
Cobb angle (CA)	16.78 ± 9.08	5.76 ± 7.89	12.67 ± 12.79	2.173	<b>0.036</b>	-4.722	<b>&lt;0.001</b>
Local kyphosis (LK)	16.49 ± 7.71	5.67 ± 5.05	9.32 ± 7.09	4.880	<b>&lt;0.001</b>	-3.816	<b>&lt;0.001</b>
Anterior vertebral body height (AVBH%)	68.83 ± 15.80	91.61 ± 11.90	84.71 ± 15.33	-4.823	<b>&lt;0.001</b>	3.416	<b>0.002</b>
Upper intervertebral disc height (UIDH)	11.62 ± 2.62	11.29 ± 1.94	9.63 ± 2.53	4.128	<b>0.036</b>	4.309	<b>&lt;0.001</b>
Lower intervertebral disc height (LIDH)	13.82 ± 2.55	13.28 ± 2.11	12.52 ± 2.19	3.024	<b>0.017</b>	1.954	0.058
Upper intervertebral disc angle (UIDA)	-3.09 ± 4.49	-4.39 ± 4.15	-3.20 ± 4.16	0.155	0.878	-2.273	<b>0.029</b>
Lower intervertebral disc angle (LIDA)	-8.17 ± 4.21	-6.70 ± 3.88	-5.50 ± 3.94	-3.853	<b>&lt;0.001</b>	-2.213	<b>0.033</b>

Note: Bold values indicate  $P < 0.05$ . P1 < 0.05 indicates significant difference between pre-operative group and last follow-up group; P2 < 0.05 indicates significant difference between post-operative group and last follow-up group.

**Statistical Analysis**

Categorical data, such as sex or smoking status, were assessed using the chi-square test. However, when the theoretical frequency was  $<5$ , Fisher's precision probability tests were employed. Paired sample *t* tests were used to analyze continuous data for preoperative data, postoperative data and the last follow-up data in the same group, while independent-sample *t* tests were conducted for intergroup comparisons. A *P* value of less than 0.05 was considered statistically significant. The statistical analysis was performed using IBM SPSS Statistics 23.0 (SPSS Inc., Chicago, IL, USA).

**Results****AO Type B2 Patient Characteristics**

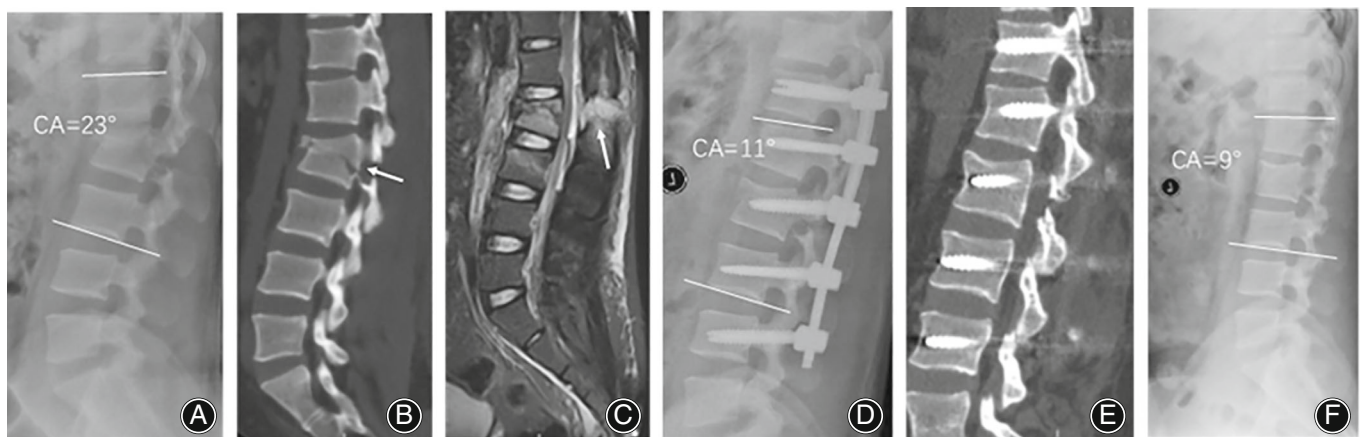
Altogether, 486 patients with traumatic thoracolumbar fractures underwent posterior fixation between October 2012 and June 2019. Among them, 62 (12.8%) patients with FDIs, and 38 (7.8% of the total patients and 61.3% of the

62 patients with a thoracolumbar FDI) of them with AO Type B2 fractures met the inclusion criteria and were included in the study (17 with disc injuries, 21 without disc injuries). The flow chart of the study is shown in Fig. 3.

The average age at the time of trauma was  $47.8 \pm 12.2$  years (range 19–68 years). There were 26 males and 12 females. Nineteen patients had a history of smoking. The main causes of injury were as follows: 19 cases were falling injuries, six cases were car accident injuries, and 13 cases were other kinds of injuries. The most common vertebral body fracture segments were T11 L1 (16 patients, 42.1%) and T12 (11 patients, 28.9%), followed by L2 (eight patients, 21.1%) and L3 (three patients, 7.9%). The mean TLICS score for all patients was  $6.74 \pm 1.43$ , and the mean load sharing score was  $5.95 \pm 1.27$ . Preoperative neurological dysfunction was observed in 22 patients (ASIA grade A–D). Nineteen disc lesions were detected in 17 patients (six grade 1 cases, two grade 2 cases and 11 grade 3 cases according to Sander's classification), 13 patients had cranial disc injuries alone, two

**TABLE 3** American spinal injury association (ASIA) scores before operation, immediately after operation and at last follow-up

Preoperative	Cases	Postoperative					Last follow-up				
		A	B	C	D	E	A	B	C	D	E
A	4	3	1	0	0	0	3	0	1	0	0
B	2	0	1	1	0	0	0	0	0	2	0
C	3	0	0	2	1	0	0	0	0	3	0
D	13	0	0	0	7	6	0	0	0	5	8
E	16	0	0	0	0	16	0	0	0	0	16
Total	38	3	2	3	8	22	3	0	1	10	24



**Fig. 4** A 19-year-old male who presented with an AO Type B2 fracture at L1-L2 and severe back pain. (A, B) CT scan of the lumbar spine showed an L2 fracture involving the vertebral body and extending through the bilateral pedicle posteriorly. (C) Preoperative MRI revealed disruption of the posterior ligamentous complex, including ligamentum flavum and supraspinous ligament, but the adjacent discs were intact. (D) The patient underwent posterior long pedicle screw fixation without arthrodesis. Postoperative lateral radiograph showed satisfactory restoration of the spinal alignment and the L2 anterior vertebral body height. (E) CT scan showing internal fixation with pedicle screws *in situ* at 18 months postoperatively, without loss of correction. (F) After implant removal, the patient denied any lower back pain, and the lateral radiograph showed healing of the fracture in the vertebral body at L2

patients had caudal disc injuries alone, and two patients had cranial and caudal disc injuries. Among the 38 patients, 32 patients had endplate involvement. In the disc injury group, injury to the endplate and the adjacent disc was observed in 15 patients, and there were 17 endplate injuries in patients without disc injury.

### Surgical Strategies

The mean time from injury to surgery in the patients was  $5.97 \pm 2.80$  days. In the disc injury group, 12 patients underwent long segment posterior fixation, while nine patients underwent long segment posterior fixation in the no disc injury group ( $P > 0.05$ ). Nine of the 17 patients in the disc injury group underwent interbody fusion in the fractured segment, and four of the 21 patients underwent interbody fusion in the fractured segment ( $P = 0.042$ ). The mean

duration of hospitalization was  $13.16 \pm 7.53$  days. The surgical options of the patients in the two groups are shown in Table 1.

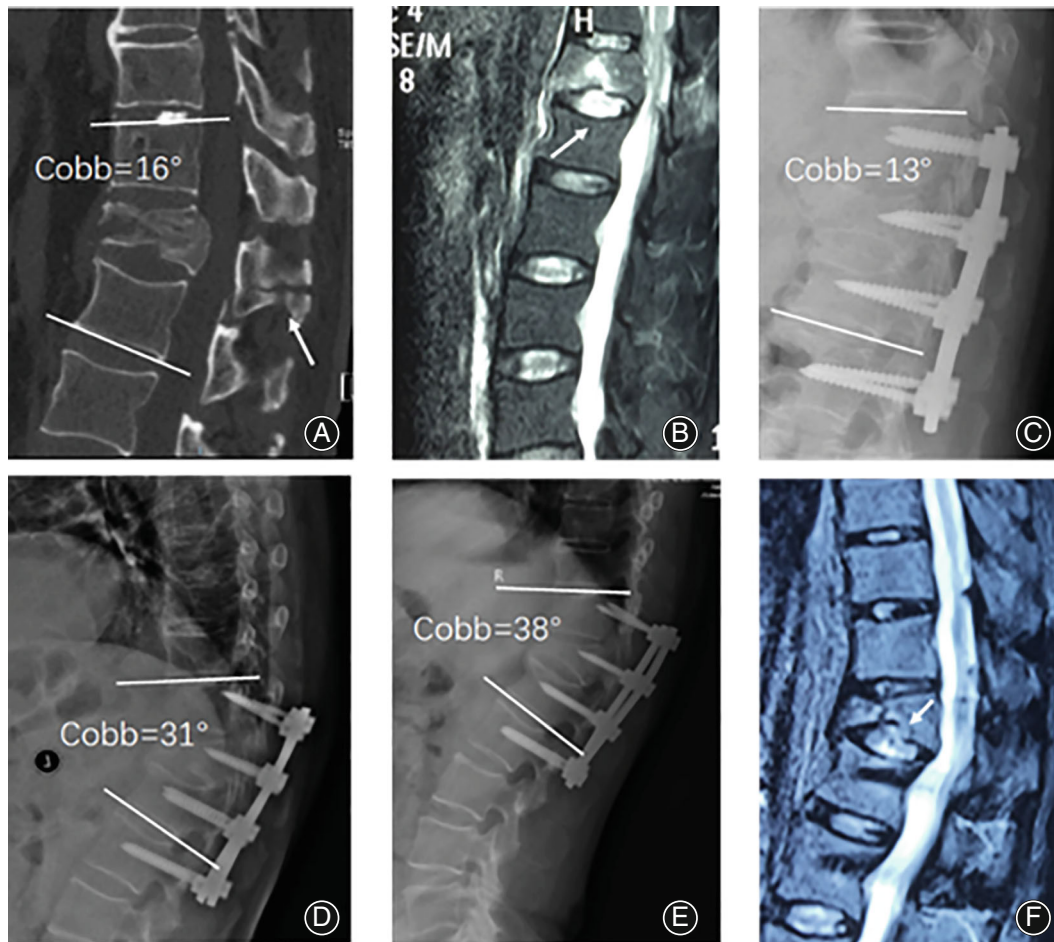
### Surgical Outcomes

#### Visual Analogue Scale

All patients showed significant improvement of their VAS scores from preoperative measurements to the last follow-up (Table 2). In patients with thoracolumbar flexion-distraction injuries, the preoperative VAS pain score was  $5.37 \pm 1.22$  and  $1.74 \pm 1.74$  at last follow-up ( $P < 0.001$ ).

#### American Spinal Injury Association (ASIA) Score

The recovery of neurologic functions postoperatively is shown in Table 3. Varying degrees of improvement was



**Fig. 5** A 64-year-old male with a T12 chance fracture (AO B2) caused by a fall from height. (A) Preoperative sagittal CT images show transosseous failure of the posterior column at T12 with an inferior endplate fracture in the vertebral body. (B) MR image showing a signal increase in the T12/L1 disc, indicating edema of the disc. (C) The patient underwent posterior long percutaneous pedicle screw fixation without fusion. Postoperative lateral radiograph showed correction of kyphosis from  $16^\circ$  to  $13^\circ$ . (D) After 6 months, the X-rays showed pedicle screw failure at T11, and T12 had kyphosis (Cobb angle  $31^\circ$ ). (E) Lateral radiographs taken at 15 months after the surgery show loosening of the implant. The Cobb angle was increased to  $38^\circ$  in the thoracolumbar junction. (F) MRI depicts an intraosseous herniation in the fractured vertebra



present in all patients with preoperative neurological deficits, but neurological deficits remained unchanged at the follow-up in three ASIA A patients.

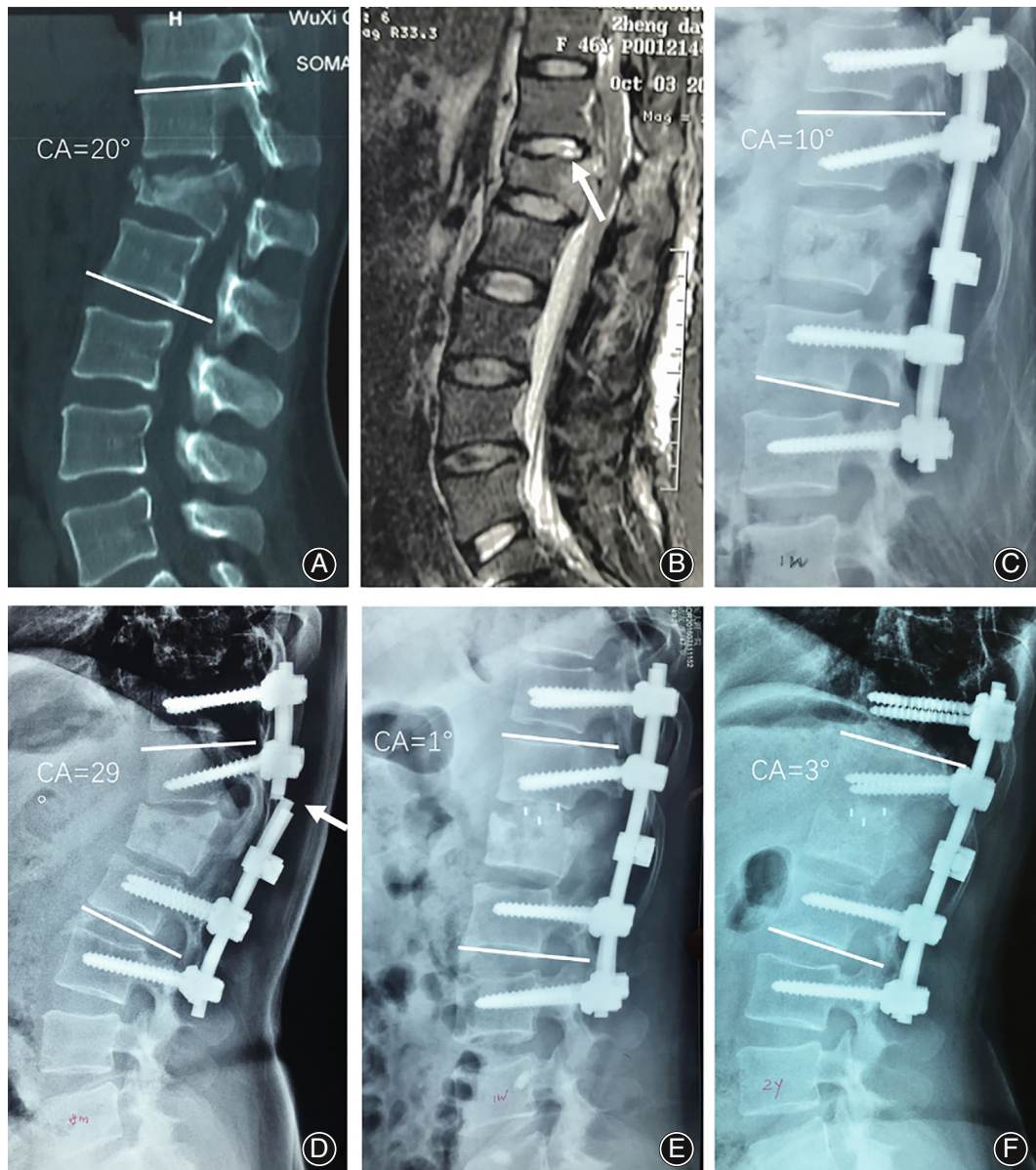
#### Cobb Angle

The mean Cobb angle of the kyphosis was improved from  $16.78^\circ \pm 9.08^\circ$  before surgery to  $5.76^\circ \pm 7.89^\circ$  after surgery but progressed to  $12.67^\circ \pm 12.79^\circ$  at the last follow-up

(Fig. 3). The mean Cobb angle in the disc injury group was significantly higher than in the no disc injury group ( $18.59^\circ \pm 13.74^\circ$  vs  $8.16^\circ \pm 9.99^\circ$ ,  $P = 0.008$ ).

#### Local Kyphosis Angle

The average local kyphosis angle before posterior fixation was  $16.49^\circ \pm 7.71^\circ$ . Immediately after surgery and at the last follow-up visit, the mean local kyphosis was  $5.67^\circ \pm 5.05^\circ$



**Fig. 6** A 46-year-old female patient who had a fall from a height. She suffered a L1 B2 with L1 A3 fracture according to the AO Classification. (A) Sagittal CT scans show the flexion-distraction fracture of L1. (B) Preoperative MRI showing hyperintense appearances in the T12/L1 disc (arrow). (C) Postoperative X-ray lateral plain showed the Cobb angle was corrected from  $20^\circ$  to  $10^\circ$ . (D) 8 months after the initial operation, the patient complained of severe back pain. Lateral plain radiograph showed rod breakage (arrow) and recurrent kyphosis (Cobb angle =  $29^\circ$ ) (E) The patient underwent revision surgery and interbody fusion at T11-L3, the sagittal alignment was restored (Cobb angle =  $1^\circ$ ). (F) At the 2-year follow-up after the revision surgery, lateral X-ray showed solid fusion at T12/L1, and no loss of correction. (Cobb angle =  $3^\circ$ )



and  $9.32^\circ \pm 7.09^\circ$ , respectively. There was significant loss of correction in the local kyphosis angle postoperatively, immediately and at the last follow-up ( $P < 0.001$ ). The mean local kyphosis in the disc injury group was significantly higher than in the no disc injury group ( $12.74^\circ \pm 8.00^\circ$  vs  $6.55^\circ \pm 4.89^\circ$ ,  $P = 0.006$ ).

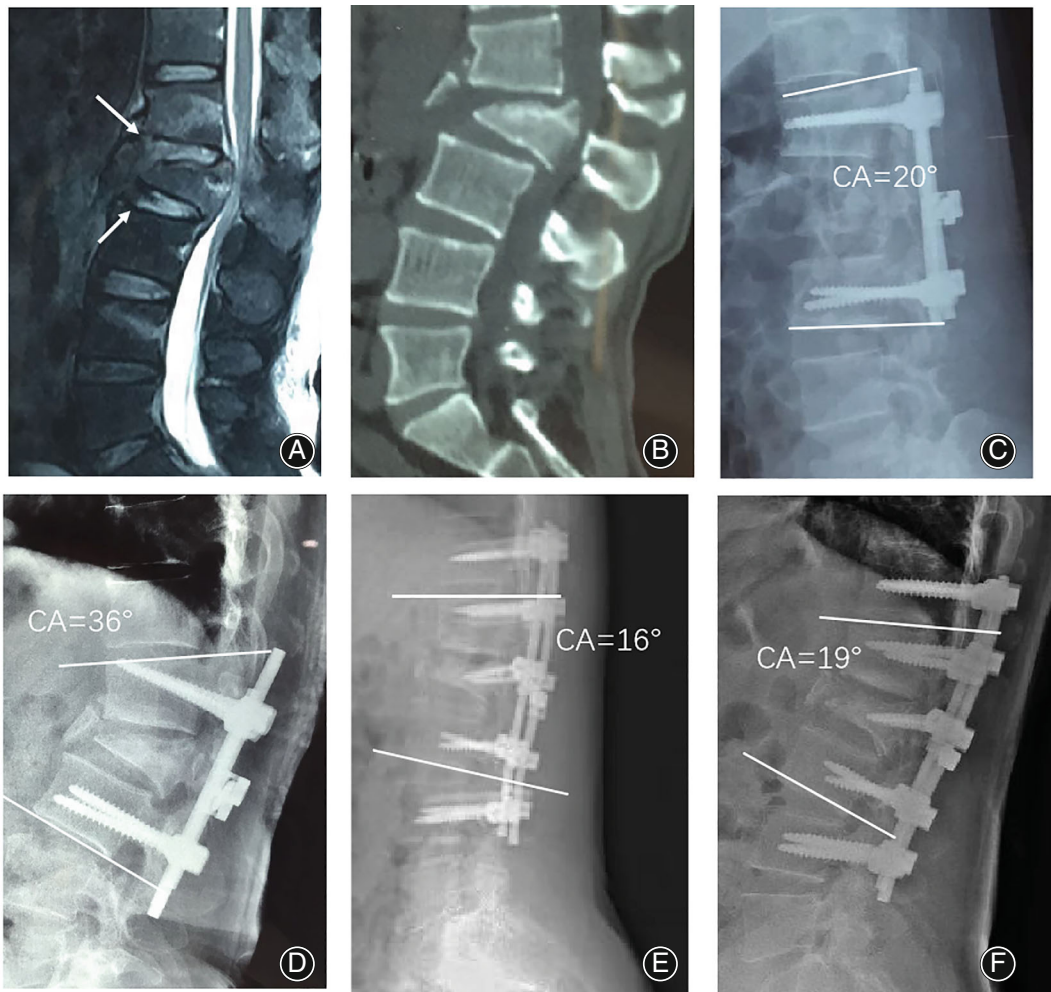
#### Percentage of Anterior Vertebral Body Height (% AVBH)

The percentage of anterior vertebral body height (% AVBH) was  $68.83\% \pm 15.80\%$  before the operation,  $91.61\% \pm 11.90\%$  after the operation and  $84.71\% \pm 15.33\%$  at the last follow-up. The mean percentage of anterior vertebral body height (%AVBH) at the last follow up was significantly different

between the two groups ( $77.16\% \pm 18.07\%$  vs  $90.83\% \pm 9.26\%$ ,  $P = 0.01$ ).

#### Intervertebral Disc Height

As shown in Table 1, narrowing of the upper intervertebral spaces was observed during the follow-up ( $11.29 \pm 1.94$  vs  $9.63 \pm 2.53$  mm,  $P < 0.001$ ), which indicated degeneration of the discs. The intervertebral disc heights in the disc injury group were significantly different between the two groups ( $10.90 \pm 2.12$  vs  $12.70 \pm 1.89$  mm,  $p = 0.009$  after the operation and  $8.96 \pm 2.89$  vs  $11.66 \pm 2.43$  mm,  $P = 0.001$  at the last follow-up).



**Fig. 7** A 48-year-old male patient who had a vehicle accident. He suffered a L1-L2 B2 with L2 A4 fracture according to the AO Classification. (A) Preoperative MRI showing abnormal shapes in the cranial and caudal discs near the L2 vertebral body, with appearances in the T12/L1 disc (arrows). (B) Sagittal CT scans show a flexion-distraction fracture at L1-L2. (C) After posterior short-segment fixation, postoperative lateral plain X-ray showed that kyphosis was corrected from  $28^\circ$  to  $20^\circ$ . (D) 17 months after the operation, kyphosis was increased, but the patient denied any pain in the back. Lateral plain showed the upper pedicle screws were inserted into the intervertebral space (arrow); the Cobb angle was  $36^\circ$ . (E) The patient underwent revision surgery and interbody fusion at T12-L4. Postoperative lateral standing radiographs show satisfactory sagittal alignment (Cobb angle  $16^\circ$ ). (F) 3 months after the revision surgery, the lateral X-ray did not show implant failure or loss of correction (Cobb angle =  $19^\circ$ )

**TABLE 4 Comparisons of variables between patients with or without implant failure in disc injury group**

Variables	Implant failure group	No implant failure group	P value
Sex (M/F)	4/1	9/3	1.000
Age (years)	56.20 ± 8.84	49.58 ± 8.70	0.175
Smoking (yes/no)	3/2	8/4	1.000
Thoracolumbar injury classification and severity score (TLICS) score	7.00 ± 0.71	6.83 ± 1.11	0.764
Duration from injury to surgery (days)	5.40 ± 1.14	6.08 ± 3.23	0.657
Operating time (min)	110.00 ± 25.50	157.92 ± 41.08	<b>0.030</b>
blood loss (ml)	144.00 ± 94.50	371.67 ± 314.93	<b>0.039</b>
Interbody fusion (fusion/non-fusion)	0/5	9/3	<b>0.009 †</b>
Fixation (short-segment/long segment)	3/2	2/10	0.117 †
Duration of hospitalization (days)	11.60 ± 2.07	15.92 ± 11.69	0.433
Fracture-level fixation	3/2	6/6	1.000 †
Visual analogue scale (VAS) score			
Pre-operative	5.80 ± 0.84	5.67 ± 1.07	0.808
Post-operative 1 week	3.40 ± 0.55	3.42 ± 1.00	0.973
Last follow up	3.20 ± 2.78	2.25 ± 1.87	0.419
Cobb angle (CA)			
Pre-operative	19.20 ± 5.40	15.23 ± 7.75	0.316
Post-operative 1 week	11.20 ± 6.46	4.83 ± 8.26	0.147
Last follow up	35.00 ± 10.00	11.75 ± 8.06	<b>0.032</b>
Local kyphosis (LK)			
Pre-operative	19.20 ± 8.56	16.59 ± 8.81	0.587
Post-operative 1 week	11.40 ± 5.08	4.59 ± 5.53	<b>0.032</b>
Last follow up	19.60 ± 7.20	9.88 ± 6.62	<b>0.017</b>
Anterior vertebral body height (AVBH%)			
Pre-operative	68.26 ± 14.43	66.86 ± 12.34	0.841
Post-operative 1 week	94.01 ± 9.96	86.44 ± 16.10	0.349
Last follow up	68.44 ± 22.79	80.80 ± 15.39	0.208

Note: Bold values indicate  $P < 0.05$ .; † Using Fisher's precision probability test.

### Intervertebral Disc Angle

The change in the intervertebral disc angle is shown in Tables 1 and 2. Kyphotic changes were obvious after the pedicle screws were placed. At the last follow-up, the IDA in the disc injury group was  $-2.38^\circ \pm 4.16^\circ$ , while the IDA in no disc injury group was  $-4.89^\circ \pm 2.88^\circ$ . The intervertebral disc angle at the last follow-up was statistically significant ( $P = 0.035$ ). Fig. 4 shows a typical case of posterior fixation in a patient with a B2 injury.

### Postoperative Complications

Twelve (31.6%) patients suffered complications after surgery. In the disc injury group, nine of the 17 (52.9%) patients experienced general complications, including postoperative neurologic deterioration in two (11.8%), pulmonary infection in one (5.9%) and urinary tract infection in one (5.9%). Five patients (29.4%) encountered implant failure and underwent revision surgery (Figs 5–7). Patients with implant failure presented with different severities of lower back pain, and two of the patients felt leg pain after posterior pedicle screw fixation. In patients without disc injuries, three (14.3%) complications were observed, which included one (4.8%) case of neurologic deterioration, one (4.8%) cases of pulmonary infection, and one (4.8%) case of hyphemia after surgery,

but there was no implant failure. Differences in the incidences of total complications ( $P = 0.016$ ) and implant failure ( $P = 0.012$ ) between the two groups were observed. The results of other comparisons between the two groups before surgery and at the final follow-up were summarized in Table 1.

### Comparison of Implant Failure in the Disc Injury Intragroup

There was a high incidence of implant failure (29.4%). To investigate factors that might be associated with implant failure in patients with disc injury, we subsequently conducted the comparison of implant failure in the disc injury intragroup. A disc injury intragroup comparison of the patients with complications and the patients without complications was performed in the disc injury group, and the results are presented in Table 4. There were no significant differences in age, sex, smoking status or level of vertebral body fracture between the two groups ( $P > 0.05$ ). However, the implant failure group had a shorter mean operation time ( $P = 0.030$ ) and less mean intraoperative blood loss ( $P = 0.039$ ) than the no implant failure group, and the incidence of interbody fusion was significantly different ( $P = 0.009$ , Table 4), which indicated that interbody fusion and long segment fixation

are recommended in AO type B2 fracture patients with disc injury.

### Discussion

The anatomy of the thoracolumbar junction makes the location more vulnerable in blunt trauma, especially high-energy trauma.<sup>2</sup> In Katsuura's<sup>1</sup> systematic review, thoracic trauma, an associated injury, occurred in 22.64% of patients with thoracolumbar spine fractures. Reports found that 38.7% of patients with flexion-distraction injuries sustained intraabdominal injuries. The demographic data in this study is comparable to previously published literature. At last follow-up, the higher Cobb angle, local kyphosis, and the less percentage of anterior vertebral body height were found in the disc injury group. With regard to the postoperative complications, disc injury was associated with a greater rate of implant failure. The subgroup analysis showed no interbody fusion may lead to a higher incidence of implant failure for patients with disc injury.

### B2 Injury in Thoracolumbar Fracture

Magerl *et al.* proposed the most systematic classification of a thoracolumbar fracture to date.<sup>14</sup> In this classification, the instability of a B2-type injury was slightly increased when compared with that of a posterior B1 fracture because of disruption of the osseous structures, but the patients with type B2 injuries accounted for 5.54% of all thoracolumbar fracture patients. The incidence of type B2 injuries in thoracolumbar spine injury patients treated with posterior fixation was lower than that found in this study. This difference may be because only patients with thoracolumbar fractures at the T10-L3 level were included in the study, even though type B injuries are more often found. It is interesting that a fracture at T10 or T11 was not involved in the current study, and this finding may be due to immobilization by the ribs.

### Intervertebral Disc Injury

The intervertebral disc of the fractured segment is involved in B2.2 injuries.<sup>14</sup> Lee *et al.* first proposed the concept of a superior disc-endplate complex injury, and they believed a disc injury occurs after an endplate injury.<sup>25,33</sup> In Lee *et al.*'s study, 24 out of 74 (32.4%) intervertebral discs with B2 injuries were injured. In the present study, 41 endplate fractures were observed, and 15 (36.6%) of them had adjacent disc injuries. The incidence of disc injury was slightly higher than that in our study (25%). However, considering the cases of chance fractures that were osseous failures from the posterior column in our study, disc injuries in FDIs were common. In our case series, adjacent endplate fractures were found in all patients with disc injuries. In the disc injury cases, most of the lesions were found at cranial discs. These results are consistent with previous observations.<sup>34</sup> As the upper endplate is thinner and supported by less dense trabecular bone, the upper vertebral endplate and cranial disc are more prone to injury. One patient (Fig. 5) in our study experienced kyphosis recurrence after undergoing one-segment fixation above

the injured segment, and this result could be attributed to insufficient stabilization of the upper segments. This patient should be treated with two-segment fixation in the cranial segments and one-segment fixation in the caudal segments. Three-segment fixation, including two segments above and one segment below, has been widely used in the treatment of thoracolumbar fractures.<sup>35</sup> In B2 fractures with upper endplates and fractures, the disc lesion increases the instability of the spine, and two-segment fixation should be performed in the upper levels rather than the lower levels.

Damage to the intervertebral disc may accelerate disc degeneration and influence clinical outcomes after surgery. Heyde *et al.*<sup>36</sup> investigated 18 intervertebral disc specimens from 17 patients with thoracolumbar spine injuries and three healthy intervertebral disc specimens, and the findings suggested that in the affected intervertebral disc, the induced early apoptosis of IVD cells was induced by thoracolumbar fractures. Animal experiments have also demonstrated degenerative changes in the disc caused by vertebral endplate injuries.<sup>37</sup> In a clinical study, Wang *et al.*<sup>38</sup> found that thoracolumbar burst fractures led to disc degeneration at levels adjacent to the fractured endplate. Moreover, although spontaneous fusion of facet joints and intervertebral discs has been observed after trauma,<sup>28,39</sup> due to the poor self-repair ability of the intervertebral disc *in vivo*, lesions of intervertebral discs hinder the stability of the spine after trauma.<sup>40,41</sup> In that case, involvement of the endplate and disc leads to recollapse of the vertebral body, implant failure, and eventually postoperative kyphosis in patients with thoracolumbar AO Type B2 fractures.<sup>42</sup>

### Surgical Strategies

Currently, posterior fixation is the most commonly performed surgical treatment,<sup>17,43,44</sup> and Joseph *et al.*<sup>45</sup> reported good short-term outcomes in type B2 flexion distraction thoracolumbar fractures using posterior pedicle screw instrumentation alone. Unfortunately, the sample size of the study was too small (18 cases), and MRI findings were not reported. We compared the clinical radiological outcomes between the two groups and found that patients with disc injuries in the fracture segment suffered more correction loss and kyphosis progression (Figs 4–7). Similarly, as previously reported in other studies,<sup>24,42</sup> kyphotic changes were also found in injured discs. In addition, the disc injury appears to be associated with a higher risk of complications. This may be because endplate and disc involvement suggest high injury severity and an increased risk of postoperative complications, such as implant failure. Our findings suggested that a disc injury near the fractured vertebral body was associated with kyphosis progression after posterior fixation for type B2 injuries.

To the best of our knowledge, this case series was the first to investigate the relationship between adjoining disc injuries and treatment efficacy in patients with thoracolumbar AO type B2 fractures. These findings draw our attention to the importance of interbody fusion or long

segment fixation for disc injury patients. It must be acknowledged that long-segment fixation, which includes pedicle screws and rod fixation at two levels above and below the fracture segment, has a large impact on the motion of the segments. However, this drawback could be overcome by implant removal.<sup>46</sup> In the disc injury intragroup comparison, the difference between the incidences of long-segment fixation failed to reach statistical significance ( $P = 0.117$ ), therefore, long-segment fixation has not been confirmed to prevent implant failure, even though it could be an alternative procedure in cases in which short-segment fixation has failed (Fig. 7). Fürderer *et al.*<sup>47</sup> suggested that only obvious morphological alterations in injured intervertebral discs are relative indications for interbody fusion. In a retrospective study,<sup>24</sup> the mean Cobb angle correction loss was  $10.8^\circ$ , and the mean local kyphosis correction loss was  $3.0^\circ$ , but for patients with flexion-distraction injuries, the losses of correction were much higher in patients with disc injuries ( $11.9$  vs  $10.8^\circ$ ,  $5.3$  vs  $3.0^\circ$ , respectively). In the past, B2 injuries were usually treated by conservative management because of the high healing potential of the bone tissue.<sup>11,14</sup> This study provides supportive evidence for the idea of “delayed instability” as mentioned in previous literature.<sup>48</sup> According to this concept, even a mild fracture, such as bony Chance-type fracture without malalignment, could lead to delayed healing, long-term pain, or even progression to deformity. Even though callus formation was noted after a vertebral body fracture, there is minimal improvement in biomechanical strength for this type of bone healing.<sup>49,50</sup> Therefore, it is important for implants to stabilize the fracture effectively.

In the intragroup comparison (Table 4), we found that there was significant difference in terms of the incidence of interbody fusion between patients with or without postoperative complications. This result showed that when disc injury occurs, the implants provide more stability of the B2 fracture, and posterior fixation alone may be inadequate. According to this, interbody fusion can, potentially, enhance the stability of the fixation, and prevent implant failure. The use of an interbody cage depends on the specific conditions of the endplates. However, when the endplate is fractured,

the interbody cage implant increases the risk of endplate collapse.<sup>51</sup> In our study, nine patients with disc and endplate injuries underwent cage implantation, and all the patients achieved solid fusion without cage subsidence. It may be that these patients benefited from long segment fixation. In patients with severe endplate fractures in which the interbody cage is inherently difficult to implant, bone grafting alone would be alternative.<sup>52</sup> In addition, because long segment posterior fixation or additional anterior surgery after posterior fixation may be options,<sup>53</sup> further studies are needed to determine the optimal surgical strategy of thoracolumbar AO type B2 fracture patients with traumatic disc lesions.

### Limitations

The limitations of this study are that this was a retrospective study. The number of patients was small, and the mean follow-up time was short. Furthermore, because the patients were surgically treated by different surgeons in one medical center, there was selection bias regarding surgical preference by different surgeons regarding the indications of long segment fixation and interbody fusion, and the incidence of interbody fusion in the disc injury group was significantly higher than that in the no disc injury group. Therefore, more high-quality studies, especially large-sample randomized controlled trials, are required to support our findings.

### Conclusion

Patients with combined intervertebral disc lesions are at a higher risk for complications, such as implant failures. These results suggest that MRI should be considered to confirm adjacent disc injuries in patients with B2 injuries. Interbody fusion with posterior fixation by pedicle screws and rods should be considered in patients with B2 injuries and adjoining disc lesions, rather than conservative treatment or posterior short-segment fixation alone. As increasing attention has been drawn on the effect of disc injury, more studies with long-term follow-up and large sample sizes are required to provide further evidence.

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