




# Usefulness of Percutaneous Pedicle Screw Fixation for Treatment of Lower Lumbar Burst (A3-A4) Fractures: Comparative Study with Thoracolumbar Junction Fractures

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## Abstract

**Background** Percutaneous pedicle screw fixation (PPSF) without fusion has been recently recommended in the treatment of thoracolumbar fracture to reduce the adverse effects associated with the conventional open approaches and to restore range of motion. However, those studies report on the thoracolumbar junction, and there is no report on lower lumbar fracture.

**Purpose** To assess effectiveness of PPSF without fusion for treating lower lumbar burst (A3 and A4) fractures.

**Methods** A retrospective analysis was made to evaluate consecutive 50 patients with AO type A3 and A4 thoracolumbar fracture underwent PPSF. Patients were divided into a thoracolumbar junction (TLJ) group (T11-L2) and lower lumbar (LL) group (L3-5). The following items were measured and compared between the two groups. Vertebral height and consolidation, retropulsed fragment, sagittal curve and fixation failure were assessed with certain interval regularly.

**Results** The average height at pre- and post-reduction were 56.2% (36.2–74.3), 95.3% (84.2–98.3) in TLJ group and 65.7% (45.7–86.2), 91% (73.1–100) in LL group. The average canal area occupancy rate at pre- and post-reduction were 46.1% (37.4%–67.5%), 38.1% (31.3%–40.8%) in TLJ group and 40.4% (15.0–65.7), 19.3% (9.4–26.6) in LL group. Consolidation was completed within 12 months after surgery in both groups. There was no significant difference between two groups in clinical and radiographic parameters except Cobb angle loss.

**Conclusion** Patients with lower lumbar fracture can be effectively managed with PPSF without fusion. PPSF following the implant removal can restore the movement of the lower lumbar spine, which is essential for daily life.

**Keywords** Lower lumbar spine · Burst fracture · Minimal invasive technique · Percutaneous pedicle screw fixation

## Introduction

Thoracolumbar burst fractures (AO type A3 and A4) are treated equally on basis of severity and stability of fracture conservatively or surgically despite the differences of sagittal curvature in thoracolumbar junction and lower lumbar spine. In the past, conventional posterior short-segment pedicle

screw fixation was most widely used for the treatment of thoracolumbar fracture around the world [1–5]. However, patients who underwent the conventional operation suffered from many sequelae such as soft tissue and muscle disruption and severe pain due to wide incision. Recently, many studies have reported that percutaneous pedicle screw fixation (PPSF) is an effective treatment for minimal soft tissue injury, shortens hospitalization and recovery period, and reduces perioperative complication [6–9]. Numerous studies [10–15], including present authors' work [16], showed comparable functional and radiographic outcomes for fusion and non-fusion in surgically treated burst fracture. In addition, in the case of the non-fusion group, it was reported that local segmental ranges of motion (ROM) restored through the removal of instruments [5, 12–14, 16]. However, to our knowledge, no study has investigated clinical outcomes and ROM after implant removal following PPSF for lower lumbar fracture. Burst fracture of the lower lumbar

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spine (L3-5) represent a small portion of all thoracolumbar fracture. Because of its rarity, most of study regarding the ideal treatment for thoracolumbar burst fracture concerns the thoracolumbar junction, rather than the lower lumbar level. However, clinically, restoration and/or maintenance of the mobility of the lower lumbar spine is very important. Especially, essential for the Asians' way of daily floor sitting living.<sup>17</sup> Therefore, this study conducted a comparative study with the thoracolumbar Junction (T11-L2) fracture surgery group to verify the clinical and radiological results of PPSF without fusion in lower lumbar (L3-5) fracture. We assessed the effectiveness of reduction and restoration of sagittal alignment, fracture consolidation, and the fate of the unfused cranial and/or caudal injured motion segments of the fractured vertebra.

## Material and Methods

This study was approved by our institutional review board and patient consent was exempted from ethics committee due to minimal risk of the study (IRB No. 2022-L10-01). Among all the AO type A3 and A4 thoracolumbar fracture patients without neurologic deficit, 50 patients underwent PPSF were subjected to this study. There were 7 type A3 and 43 type A4 fracture. They were treated at Cheju Halla General Hospital, Jeju between April 2011 and December 2021. The mean age of patients in TLJ group (18 men, 14 woman) was 47 years and in LL group (8 men, 10 women) 51 years. The fracture levels were 3 cases of T11, 5 cases of T12, 11 cases of L1, 13 cases of L2, 7 cases of L3 9 cases of L4 and 2 cases of L5 fracture. Authors carefully observed the posterior column damage which is indicative of instability. The fracture type and stability were assessed by plain radiograms, computed tomography (CT), and magnetic resonance imaging (MRI).

## Surgical Indication and Technique

Fracture kyphosis over 30°, vertebral height loss over 40%, canal compromise over 50%, three column injury were subjected to surgery, that is surgical indication recognized by National Health Insurance Corporation of Korea. Metastatic and/or primary spinal lesions, previous spinal surgery, rheumatic diseases, spinal infection, osteoporotic fracture were excluded.

Under general anaesthesia, the patient was placed in the radiolucent operating table. C-arm X-ray image intensifier was used to identify the fracture site and the correct entry point. About 20 mm incision was made, and a guide wire was placed the pedicle under fluoroscopic guidance. For ligamentotaxis and stabilization, short vertebral fixation construct was adopted. Three or four vertebral bodies (3

points) fixation were performed: one or two cephalad vertebra (CEV) + fractured vertebra (FV) + one caudal vertebra (CAV) construct. The rod derotation technique was used to provide consistent anatomic and lordotic distraction loads across the longitudinal axis, and corrected the collapsed vertebral body and disc height, and displaced intracanal fragment. The authors aimed to restore the lumbar lordosis up to 35–45° of Cobb's angle. Thus, the pre-bending rods were used to meet the normal lumbar lordotic curve. The ligamentotaxis was performed by derotating the contoured rods as a first step in the inserted screw slots, and the gentle minimal axial distraction was added as second step to complete the reduction [17]. Through these step-by-step ligamentotaxis, over-distraction of the collapsed vertebral height and disc by over-stretch of the ligaments could be avoided. Also, by these step procedures, an effort was made to prevent the later screw toggling in the bone and screw failure.

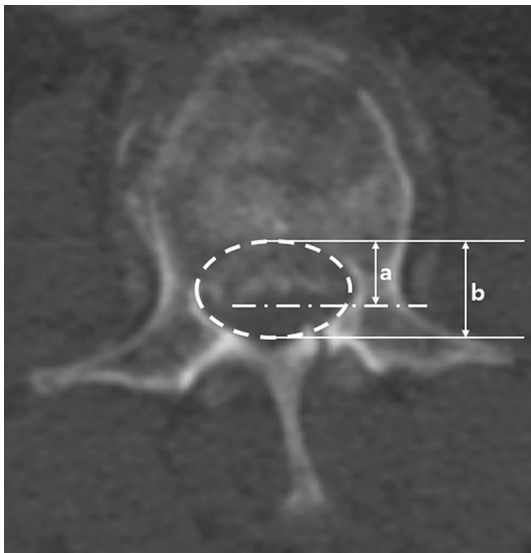
## Postoperative Management

The patients were braced by a thoracolumbar orthosis (TLSO) 10 to 12 weeks. Postoperatively, the patients were allowed to ambulate on the second day after surgery. Up to one week after surgery, the patient utilized a walker and subsequently progressed to full load walking without assistance. Plain radiographs taken every 2 weeks up to 2 months, every 4 weeks by 3–4 month, every 3 months up to 12 months, every 6 months up to 18–24 months and thereafter once a year. The CT scan was examined immediately after surgery to confirm the location of the pedicle screws and fracture reduction and was examined 12 months after surgery to confirm fracture consolidation and spinal canal remodeling. Preoperatively, the necessity and proper time of the removal of the fixation instrument were explained to all the patients, and the patients' consent was obtained in advance related with the proper time of instrument removal.

## Outcome Assessment

Postoperative follow-up ranged from 16–36 months. Back pain was quantified with a visual analogue scale (VAS). Measurements of radiologic factors listed below were performed at pre- and postoperative zero (immediate postoperative), 3, 6, and 12 months.

- (1) Accuracy of fracture reduction (percentile reduction)
- (2) Postoperative changes in vertebral body height till complete fracture consolidation,
- (3) Time of complete fracture consolidation,
- (4) Pre- and postoperative chronological changes of the intracanal fragment:
- (5) Degree of posterior displacement of the retropulsed fragment,



**Fig. 1** The canal occupying ratio was defined as the ratio of the maximal retropulsed fragment thickness (a) to the anteroposterior spinal canal diameter (b) on CT axial imaging

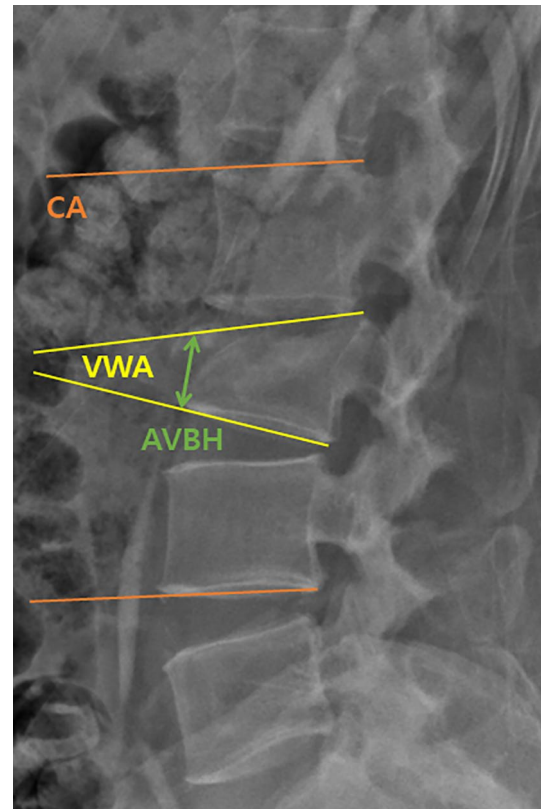
- (6) Canal occupying ratio by the retropulsed fragment (Fig. 1).
- (7) Changes in vertebral wedge angle (VWA), and sagittal lumbar curve (Cobb angle; CA) (Fig. 2) [11].

### Measuring Devices for Result Assessment

The time of complete consolidation was defined when there was no further vertebral recollapse. Kyphotic angles of the fractured vertebrae and lumbar lordosis were measured. Vertebral height and anteroposterior diameter of the canal on radiographs were measured by the measuring gauge (precision measurement, 0.01 mm, Mitutoyo, Paramus, NS, USA) [17, 18]. Also axial CT was used in measuring the anteroposterior canal diameter and canal dimension. For the canal measurement, scaled screen tablet (1mm<sup>2</sup> size) was used. All measurements were carried out by two independent observers.

### Statistical Analysis

All the statistical tests were performed using the statistical software SPSS version 26 (IBM Corp., Armonk, NY, USA). Paired *t*-test and Mann–Whitney *U* test were used to determine the significance of intergroup differences. Statistical differences were considered significant when the  $p < 0.05$ .



**Fig. 2** Radiological assessment on lateral view of plain radiograph in a patient with AO type A3 fracture. CA cobb angle, VWA vertebral wedge angle, AVBH anterior vertebral body height

### Results

In TLJ group, the average preoperative body height of the fractured vertebrae was 56.2% (36.2–74.3) and postoperatively improved by 95.3% (84.2–98.3). The average preoperative displacement of intracanal fragment was 46.1% (37.4–67.5) and postoperatively improved by 38.1% (31.3–40.8%) of the normal anteroposterior diameter (Table 1). In LL group, the average preoperative body height of the fractured vertebrae was 65.7% (45.7–86.2) and postoperatively improved by 91% (73.1–100). The average preoperative displacement of intracanal fragment was 40.4% (15.0–65.7) and postoperatively improved by 31.1% (13.8–38.7) of the normal anteroposterior diameter (Table 2). The fractured vertebral body began to consolidate at postoperative 10 weeks on average (range 8–15 weeks) and fracture consolidation was completed within 12 months after surgery in both groups, and no cases of nonunion occurred. In TLJ group, VWA at pre- and postoperative zero and final follow-up were 31° (range 21°–35°), 3° (range 1°–6°), and 3° (range 1°–6°) on average, respectively. In LL group, VWA at pre- and postoperative zero and final follow-up were 21° (range 16°–36°), 7°

(range 1°–15°), and 8° (range 4°–18°) on average, respectively. After implant removal, there was no recollapse of vertebral bodies and discs, and sagittal lumbar alignment was maintained in both groups (Fig. 3). No screw failures

were observed. On flexion–extension motion radiograms, no abnormal motion at the injured level was observed (Fig. 4). There was no significant difference between the

**Table 1** Radiological assessment for TLJ group ( $n=32$ ), mean (range)

Parameters	Preoperative	Postoperative month			
		0	3 mo	6 mo	12 mo
Percentile vertebral height against normal height <sup>a</sup>	56.2% (36.2–74.3)	95.3% (84.2–98.3)	94.3% (84.3–97.2)	94.02% (86.1–96.1)	94% (87.5–96.7)
Vertebral wedge angle	31' (21–35)	3' (1–6)	3' (1–6)	3' (1–6)	3' (1–6)
Cobb angle	19' (10–28)	3' (1–6)	4' (2–10)	4' (2–8)	4' (1–8)
Displacement of retro-pulsed fragment (occupancy rate <sup>b</sup> )	46.1% (37.4–67.5)	38.1% (31.3–40.8)			21.3% (16.7–22)

TLJ thoracolumbar junction

<sup>a</sup>AVBH of FV/(AVBH of CEV + AVBH of CAV/2) × 100

<sup>b</sup>(Thickness of the retropulsed fragment/anteroposterior diameter of the spinal canal) × 100

**Table 2** Radiological assessment for LL group ( $n=18$ ), mean (range)

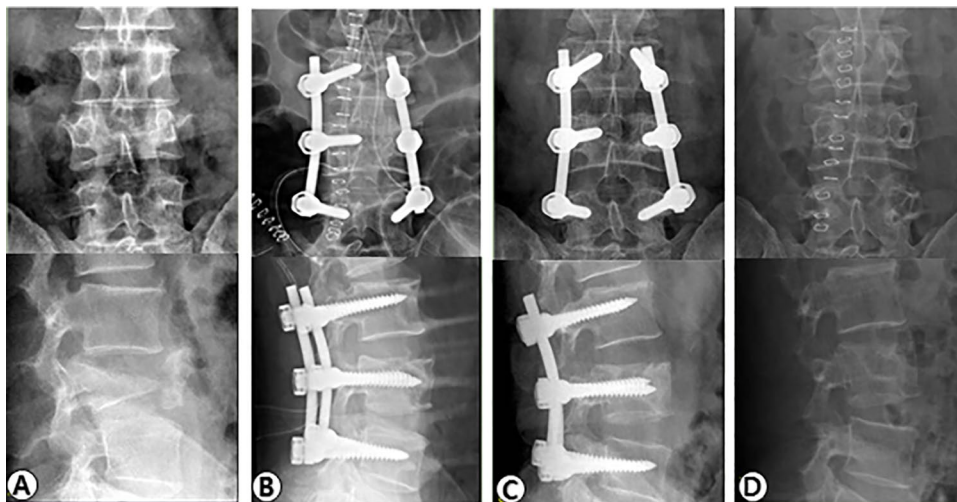
Parameters	Preoperative	Postoperative month			
		0	3 mo	6 mo	12 mo
Percentile vertebral height against normal height <sup>a</sup>	65.7% (45.7–86.2)	91% (73.1–100)	90.6% (75.5–99)	90.5% (71.7–99)	90.4% (71.5–99)
Vertebral wedge angle	23' (16–36)	8' (1–17)	8' (2–17)	7' (3–18)	7' (3–18)
Cobb angle	15' (1–25)	–4' (–16 to 5)	–3' (–17 to 7)	–3' (–17 to 8)	–2' (–18 to 9)
Displacement of retro-pulsed fragment (occupancy rate <sup>b</sup> )	40.4% (15.0–65.7)	31.1% (13.8–38.7)			19.3% (9.4–26.6)

LL lower lumbar

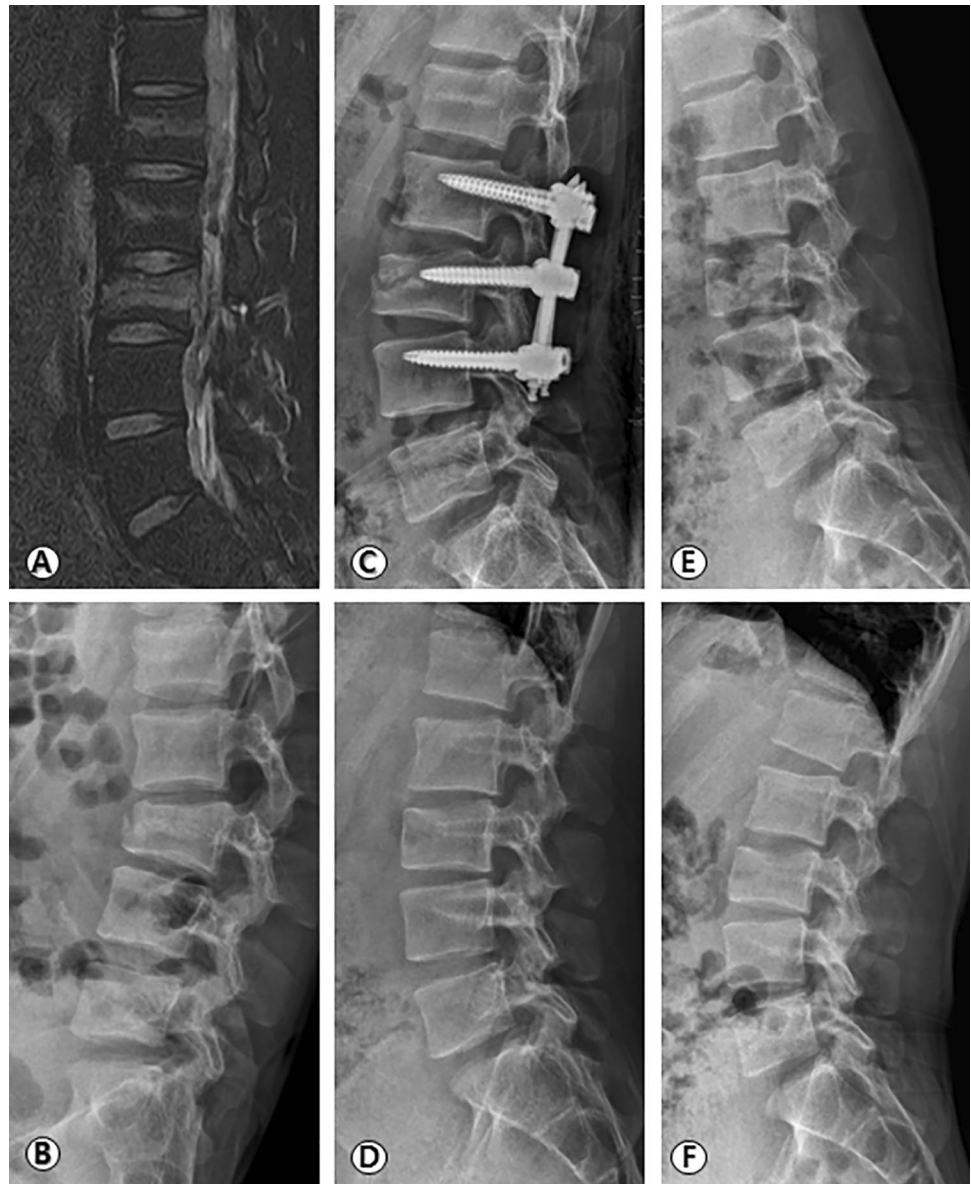
<sup>a</sup>AVBH of FV/(AVBH of CEV + AVBH of CAV/2) × 100

<sup>b</sup>(Thickness of the retropulsed fragment/anteroposterior diameter of the spinal canal) × 100

**Fig. 3** A 47-year-old man with L4 AO type A4 fracture. Severe wedging of the posterior 4/5 of vertebral body (A) is seen, which is well-reduced and maintained until fracture consolidation (B, C). After removal of the implant, vertebral body and disc height are well maintained (D)



**Fig. 4** A 20-year-old man with L3 AO type A3 fracture and L1, 2 AO type A1 fracture. Preoperative MRI image (A) and plain radiograph (B) showing L2-3 facet joint injury and fracture kyphosis 30°. C Immediate postoperative plain radiograph showing restoration of vertebral wedge angle and Cobb angle. After removal of the implant, vertebral body and disc height are well maintained (D). On flexion E extension F motion radiographs, no abnormal motion at the injured level was observed



two groups in clinical and radiographic parameters except cobb angle loss ( $p > 0.05$ ) (Table 3).

## Discussion

Spinal fractures represent a frequent condition today. According to an epidemiological study by Hu et al., the average annual incidence of spinal fracture is 64 per 100,000, with the average annual hospitalized rate being 29 per 100,000 [19]. Gold standard for surgical management of unstable thoracolumbar burst fracture is still controversial. However, nowadays, with advances in instruments and surgical techniques, minimally invasive techniques for PPSF have been developed to avoid disadvantage of open technique

including larger surgical scars, soft tissue damage, denervation of posterior musculature and postoperative pain. In many studies, including prospective study [20] and meta-analysis study [7], showed that there were no differences in clinical, functional, and radiological results between open fixation with fusion and PPSF without fusion, but complications such as bleeding, operation time and postoperative pain were significantly decreased [6–8, 11, 13, 15, 16, 20]. Some authors have shown that PPSF without fusion followed by implant removal after fracture consolidation can alleviate pain and discomfort caused by the hardware and preserve mobility and flexibility [14, 21, 22]. A systematic review and meta-analysis by Khew et al. also demonstrated that routine planned implant removal in younger patients who undergo posterior fixation for thoracolumbar burst fractures results

**Table 3** Comparison of Clinical and Radiological Findings between Groups

Parameters	Group	Mean $\pm$ SD	<i>p</i> Value
VAS (Postoperative 12mo)	TLJ	1.2 $\pm$ 0.7	> 0.05
	LL	1.1 $\pm$ 0.9	
Cobb angle loss ( $^{\circ}$ ) <sup>a</sup>	TLJ	1 $\pm$ 0.9	< 0.05
	LL	3 $\pm$ 1.7	
AVBH loss (%) <sup>b</sup>	TLJ	1.8 $\pm$ 1.2	> 0.05
	LL	1.1 $\pm$ 1.3	
Occupancy rate improvement <sup>c</sup> (%)	TLJ	22.3 $\pm$ 10.3	> 0.05
	LL	21.8 $\pm$ 9.8	

VAS visual analog scale, TLJ thoracolumbar junction, LL lower lumbar, AVBH anterior vertebral body height

<sup>a</sup>(Postoperative 12 mo Cobb angle – Postoperative zero Cobb angle)

<sup>b</sup>(Postoperative 12 mo AVBH – Postoperative zero AVBH)

<sup>c</sup>(Preoperative Occupancy rate – Postoperative 12mo Occupancy rate)

in improved quality of life. The study found no significant difference in decremting kyphotic correction loss between implant retention and removal [12].

To our knowledge, it is not known whether these results also apply to lower lumbar burst fractures. Studies on new minimally invasive therapeutic approaches for spinal fractures have been focused on the thoracolumbar junction and accepted guidelines or consensus for the lower lumbar spine fractures have not been reported. For the lower lumbar spine fracture, limited instrument-aided segmental stabilization without fusion is very important. Fixation of a certain mobile segment affects not only the mobile adjacent segments (load and motion concentration), but also the lumbar-pelvic rhythm.<sup>16,17</sup> However, motion preservation surgery was rarely tried, though its importance is well-known. This could be attributed to the infrequent occurrence of lower lumbar burst fractures and the potential concerns regarding mechanical stress due to the distinct biomechanical characteristics of the lower lumbar spine as compared to the thoracolumbar junction. The lower lumbar spine has a wider range of motion, allowing for flexion, extension, lateral flexion, and rotation, whereas the thoracolumbar junction has limited motion due to the attachment of the ribs to the thoracic spine. This increased range of motion places greater stress on the lower lumbar vertebrae, which is further exacerbated by the fact that the lumbar spine supports a larger portion of the body's weight as compared to the thoracolumbar junction. Specifically, the lumbar spine carries approximately 40% of the body's weight, while the thoracolumbar junction carries only about 20%. As a result, the lower lumbar vertebrae and discs are subjected to greater stress due to the increased weight they support [23–25]. However, from a biomechanical point of view, the application of PPSF without fusion to lower lumbar burst fractures seems feasible as

the fracture collapse pattern in this area is unlikely to cause significant kyphosis deformity leading to implant failure. In the more lordotic middle and lower lumbar spine where the compression forces act more posteriorly, no implant failures occurred with the “one above one below” construct [16, 26, 27]. The current authors achieved successful fracture consolidation and deformation correction through three-point fixation (3 vertebral body fixation including fracture vertebra) and contoured rod bending. Mahar et al. and Moon et al. reported that in achieving short-segment fixation of burst fracture the placement of pedicle screws into the fractured vertebral body generated a segmental construct which demonstrated improved biomechanical stability compared with a non-segmental construct [16, 17]. Also Mahar et al. stated that biomechanical testing in a cadaveric model showed that axial torsion stability was improved by twofold [17]. There are trend towards increased stability in flexion–extension and lateral bending, though not statistically significant.

The findings of current study are in line with the previous studies, indicating that PPSF is a safe and effective surgical approach for appropriately selected patients with thoracolumbar burst fractures. Furthermore, the results of this study confirm that PPSF can be similarly effective and safe when used to manage lower lumbar burst fractures. In current study, sagittal deformity and canal dimension were improved after surgery in both groups. The correction was well maintained with slight losses of AVBH (In TLJ group, preoperatively, 56.2%; postoperatively, 95.3%; and at last follow-up, 94%, In LL group, preoperatively, 65.7%; postoperatively, 91%; and at last follow-up, 90.4%) and CA (In TLJ group, preoperatively, 19 $^{\circ}$ ; postoperatively, 3 $^{\circ}$ ; and at last follow-up, 4 $^{\circ}$ , In LL group, preoperatively, 15 $^{\circ}$ ; postoperatively, –4 $^{\circ}$ ; and at last follow-up, –3 $^{\circ}$ ) until the last follow-up after implant removal. It was difficult to confirm the reason for the delayed correction loss because we did not check follow-up MRI after implant removal. In previous studies of kyphosis and vertebral collapse, intervertebral disc collapse was identified as the main cause of postoperative kyphosis. The intrusion of the disc into the vertebral depression via the central depression of the end plate may potentially contribute to vertebral collapse and kyphosis [22, 28, 29]. Decreased height and creeping of the intervertebral disc can be speculated to be the cause of the greater cobb angle loss in LL group than in TLJ group, where the intervertebral disc plays a relatively greater role in the cobb angle. We suggest that despite the observed subtle losses, there may be limited clinical significance. This is supported by the facts that fracture consolidation was completed within 12 months after surgery in both groups without nonunion complication and patients did not report discomfort or limitations in their daily lives, such as back pain and stiffness, following implant removal. It is believed that aforementioned findings could be clearly demonstrated through a long-term follow-up study

after implant removal. Further study is already designed to address these issues.

As limitation of this study, short-term survey, small case numbers, lack of control group (open screw fixation with fusion) can be listed. To validate our hypothesis, which was based on a retrospective monocentric study, it is recommended that an observational multicentre study be conducted.

## Conclusion

The current study showed that PPSF without fusion in the treatment of lower lumbar burst fracture (type A3 and A4) is safe and offers firm construct stability. The maintenance of reduction and consolidation of fractures were not impacted by fusionless stabilization. Moreover, the utilization of contoured rods with three-point fixation was deemed beneficial. All immobilized segments could restore painless motion after implant removal.

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**Data availability** The data are not publicly available due to their containing information that could compromise the privacy of research participants.

## Declarations

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical standard statement** This article does not contain any studies with human or animal subjects performed by the any of the authors.

**Informed consent** For this type of study informed consent is not required.

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