

Exploring the Efficacy of Minimally Invasive Spine Fixation in Thoracolumbar Spinal Injuries

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ABSTRACT

Background: Thoracolumbar spinal injuries pose significant challenges in orthopedic practice, often requiring surgical stabilization to restore alignment and neurological function. Minimally invasive techniques have emerged as alternatives to traditional open surgery, potentially reducing perioperative morbidity while achieving comparable outcomes. **Objective:** To evaluate the efficacy of minimally invasive pedicle screw fixation in thoracolumbar spinal injuries. **Methods & Materials:** This retrospective cohort study included patients who underwent minimally invasive pedicle screw fixation for thoracolumbar fractures between July 2023 and June 2025 at the NITOR, Bangladesh. Thirty patients were enrolled. We collected and analyzed data on demographics, injury characteristics, neurological status, surgical outcomes, and functional recovery using descriptive statistics. **Results:** A total of 30 patients (21 males, 9 females; mean age 35 years) were included. Most injuries resulted from falls. Fractures involved the thoracic spine in 50%, the lumbar spine in 33%, and the thoracolumbar junction in 17%. Neurological deficits were present on admission in 40%, with 75% demonstrating postoperative improvement. Mean hospital stay was 6 days. Postoperative regional sagittal alignment was satisfactory in 100% of patients (Cobb angle correction to $\leq 10^\circ$). At final follow-up, 90% reported no or mild pain (VAS ≤ 3), and 80% achieved good functional outcomes (ODI ≤ 20). **Conclusion:** Minimally invasive pedicle screw fixation is a safe and effective option for thoracolumbar spinal injuries, with outcomes comparable to open surgery and reduced perioperative morbidity. It yields rapid improvements in pain, Frankel grade, functional status, and regional sagittal alignment.

Keywords: Functional outcome, Minimally invasive surgery, Sagittal alignment, Spine fixation, Thoracolumbar injuries

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INTRODUCTION

Thoracolumbar spinal injuries represent a significant portion of all spinal trauma, often resulting from high-energy mechanisms such as falls and motor vehicle accidents [1]. The unique biomechanical transition zone between the rigid thoracic spine and the mobile lumbar spine makes this region particularly vulnerable to fracture [2]. Epidemiological data indicate an annual incidence of approximately 30 per 100,000 inhabitants, with a rising trend observed in the elderly population due to low-velocity falls [3]. In developing countries, high-energy trauma from road traffic accidents and falls from height remain the predominant causes [1]. These injuries can lead to devastating consequences, including neurological deficits, chronic pain, and long-term disability, placing a substantial burden on healthcare systems and society [4]. The primary goals of surgical management for thoracolumbar fractures are to restore spinal stability, decompress neural

elements when indicated, correct deformity, and facilitate early mobilization [5]. Traditional open surgical approaches, while effective, are associated with significant approach-related morbidity, including extensive muscle dissection, substantial blood loss, and prolonged postoperative recovery [6]. These drawbacks have driven the development and adoption of minimally invasive spine surgery (MISS) techniques, which aim to achieve comparable clinical and radiological outcomes while minimizing surgical trauma [7]. Among the various MISS techniques, percutaneous pedicle screw fixation has emerged as a widely utilized method for stabilizing thoracolumbar fractures [8]. This technique involves the insertion of pedicle screws through small skin incisions under fluoroscopic guidance, thereby preserving the paraspinal musculature and reducing tissue damage [9]. The theoretical advantages of percutaneous fixation include reduced intraoperative blood loss,

shorter operative times, less postoperative pain, and faster recovery compared to traditional open surgery [10]. A recent meta-analysis of 35 cohort studies demonstrated that patients undergoing percutaneous approaches experienced significantly less intraoperative blood loss, shorter hospital stays, and lower infection rates than those treated with open approaches [11]. Despite these promising benefits, the adoption of minimally invasive techniques for thoracolumbar trauma has been accompanied by certain challenges. These include a reliance on intraoperative fluoroscopy with associated radiation exposure, a potentially steep learning curve for surgeons, and concerns regarding the adequacy of decompression and fusion in select cases [12]. Furthermore, the evidence base for MISS in the context of trauma is still evolving, with many studies being retrospective and heterogeneous in their patient populations and outcome measures [7]. There is a particular paucity of data from South Asian countries, including

Bangladesh, where the burden of spinal trauma is high, and healthcare resources are often limited [13]. In Bangladesh, the management of thoracolumbar fractures has traditionally involved open surgical techniques. The feasibility and outcomes of minimally invasive fixation in this setting require careful evaluation, considering the unique patient demographics, injury patterns, and resource constraints [4]. Previous work from the National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR) has demonstrated the effectiveness of short-segment fixation for unstable thoracolumbar burst fractures, highlighting the potential for specialized care in the country [13]. However, the specific role of minimally invasive percutaneous fixation in this population remains underexplored. Given this knowledge gap, the present study was undertaken to evaluate the efficacy of minimally invasive pedicle screw fixation in patients with thoracolumbar spinal injuries. We hypothesized that this technique would yield satisfactory clinical and radiological outcomes with reduced perioperative morbidity.

METHODS & MATERIALS

This retrospective cohort study included all patients who underwent minimally invasive

pedicle screw fixation for thoracolumbar fractures between July 2023 and June 2025 at the National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Bangladesh. A total of 30 patients were enrolled.

Inclusion criteria: Patients with traumatic thoracolumbar fractures (T10-L2) confirmed on imaging, aged 18-70 years, who underwent MIS pedicle screw fixation, and had complete medical records with a minimum follow-up of 6 months were included.

Exclusion criteria: Patients with pathological fractures, previous spinal surgery, severe comorbidities precluding surgery, or incomplete follow-up data were excluded.

Study procedure: Data were retrieved from medical records, including demographics, injury mechanism, fracture level, and neurological status. Neurological function was assessed using the Frankel grade [14]. Pain was evaluated using the Visual Analogue Scale (VAS) [15]. Functional outcome was measured using the Oswestry Disability Index (ODI) [16]. Radiological parameters included the regional Cobb angle for sagittal alignment.

Surgical details, hospital stay, and complications were recorded.

Data analysis: Data were analyzed using SPSS version 26.0. Descriptive statistics were expressed as frequencies, percentages, means, and standard deviations. The paired t-test was used to compare preoperative and postoperative continuous variables. A p-value <0.05 was considered statistically significant.

RESULT

A total of 30 patients who underwent minimally invasive pedicle screw fixation for thoracolumbar fractures were included. The demographic and clinical characteristics are presented in *Table I*. The mean age was 35 years, with a male predominance (70.0%). Falls from height were the most common mechanism of injury (60.0%), followed by road traffic accidents (33.3%). Fractures involved the thoracic spine in 50.0% of cases, the lumbar spine in 33.3%, and the thoracolumbar junction in 16.7%. According to the AO Spine classification, type A fractures were most common (56.7%). Neurological deficits were present on admission in 40.0% of patients.

Table I
Demographic and clinical characteristics of the study population (n=30).

Characteristics	n	%
Age (years), Mean ±SD	35.0 ± 11.2	
Sex		
Male	21	70.0
Female	9	30.0
Mechanism of injury		
Fall from height	18	60.0
Road traffic accident	10	33.3
Others	2	6.7
Fracture Level		
Thoracic spine (T10-T12)	15	50.0
Lumbar spine (L1-L2)	10	33.3
Thoracolumbar junction (T12-L1)	5	16.7
AO Spine classification		
Type A	17	56.7
Type B	9	30.0
Type C	4	13.3
Neurological status on admission (Frankel Grade)		
Grade E (Normal)	18	60.0
Grade D	4	13.3
Grade C	5	16.7
Grade B	3	10.0

Data were expressed as frequency (percentage) or mean ±SD.

The surgical parameters and perioperative outcomes are summarized in *Table II*. The mean operative time was 95.5 ± 22.4 minutes, and the mean intraoperative blood

loss was 85.3 ± 30.6 mL. The mean hospital stay was 6.0 ± 1.8 days. Postoperative complications were minimal, with wound infection and screw

misplacement each occurring in 3.3% of patients.

Table II
Surgical parameters and perioperative outcomes.

Characteristics	Values
	Mean ± SD/n (%)
Surgical parameters	
Operative time (minutes)	95.5 ± 22.4
Intraoperative blood loss (mL)	85.3 ± 30.6
Number of screws inserted	6.2 ± 1.4
Hospital stays (days)	6.0 ± 1.8
Complications	
Wound infection	1 (3.3)
Screw misplacement	1 (3.3)

Data were expressed as mean ±SD or frequency (percentage).

The clinical outcomes at final follow-up are presented in Table III. Neurological improvement was observed in 75.0% of patients with preoperative deficits. At final follow-up, 90.0% reported no or mild pain (VAS ≤3), and 80.0% achieved good functional outcomes (ODI ≤20). The mean VAS score improved from 7.2 ± 1.5 preoperatively to 2.1 ± 1.2 (p<0.001). The mean ODI score improved from 52.4 ± 12.6 to 16.8 ± 8.4 (p<0.001).

Table III
Clinical outcomes at final follow-up.

Parameters	Preoperative	Final follow-up	p-value
VAS score, Mean ±SD	7.2 ± 1.5	2.1 ± 1.2	<0.001*
ODI score, Mean ±SD	52.4 ± 12.6	16.8 ± 8.4	<0.001*
Pain category, n (%)			
No or mild pain (VAS ≤3)	0 (0.0)	27 (90.0)	
Moderate pain (VAS 4-6)	8 (26.7)	3 (10.0)	
Severe pain (VAS ≥7)	22 (73.3)	0 (0.0)	
Functional outcome (ODI), n (%)			
Good (ODI ≤20)	0 (0.0)	24 (80.0)	
Moderate disability (ODI 21-40)	5 (16.7)	5 (16.7)	
Severe disability (ODI >40)	25 (83.3)	1 (3.3)	
Frankel grade improvement, n (%)			
Improved by 1 grade		5 (41.7)	
Improved by 2 grades		4 (33.3)	
No improvement		3 (25.0)	

Data were expressed as mean±SD or frequency (percentage). Paired t-test was performed. *Significant.

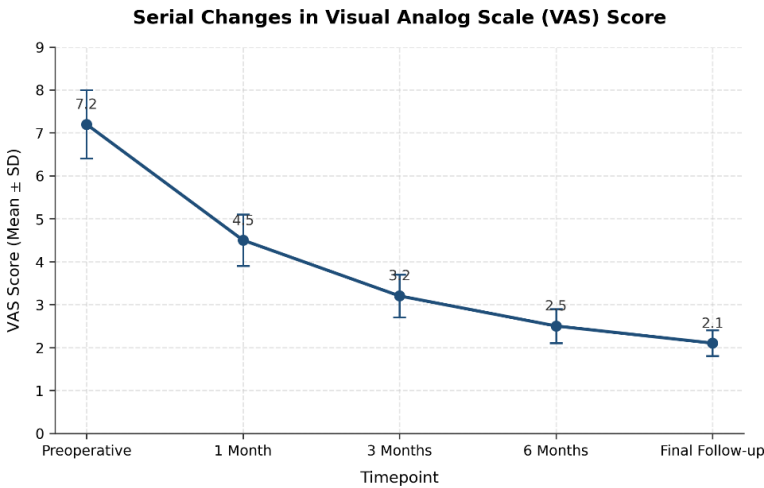


Figure 1 Line diagram showing serial changes in VAS score from preoperative to final follow-up.

Figure 1 demonstrates the progressive reduction in pain intensity following surgery. The mean VAS score decreased from 7.2 ± 1.5 preoperatively to 2.1 ± 1.2 at final follow-up, with the most substantial improvement observed within the first three months postoperatively.

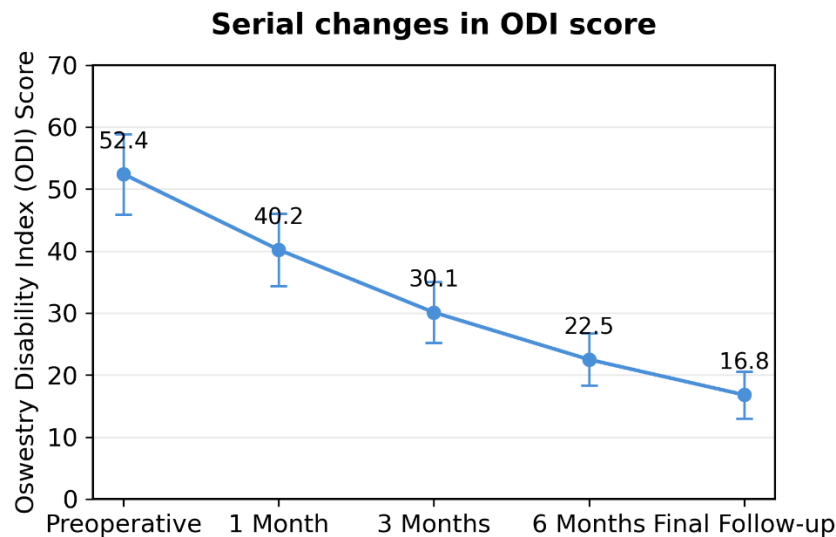


Figure 2 Line diagram showing serial changes in ODI score from preoperative to final follow-up.

Figure 2 illustrates the significant improvement in functional status following surgery. The mean ODI score decreased from 52.4 ± 12.6 preoperatively to 16.8 ± 8.4 at final follow-up, indicating a transition from severe to minimal disability in the majority of patients.

The radiological outcomes are presented in Table IV. The mean regional Cobb angle improved from $18.5 \pm 6.2^\circ$ preoperatively to $4.2 \pm 3.1^\circ$ immediately postoperatively ($p < 0.001$), with maintenance of correction at final follow-up ($5.1 \pm 3.4^\circ$). All patients (100%) achieved satisfactory postoperative

regional sagittal alignment (Cobb angle $\leq 10^\circ$). Loss of correction at final follow-up was minimal (mean $0.9 \pm 0.8^\circ$).

Table IV
Radiological outcomes of the participants.

Parameters	Preoperative	Immediate postoperative	Final follow-up	p-value
Regional Cobb angle (°), Mean $\pm$ SD	18.5 $\pm$ 6.2	4.2 $\pm$ 3.1	5.1 $\pm$ 3.4	<0.001*
Satisfactory alignment (Cobb $\leq$ 10°),n (%)	0 (0.0)	30 (100.0)	30 (100.0)	
Loss of correction (°), Mean $\pm$ SD			0.9 $\pm$ 0.8	

Data were expressed as mean $\pm$ SD or frequency (percentage). Paired t-test was performed. *Significant.

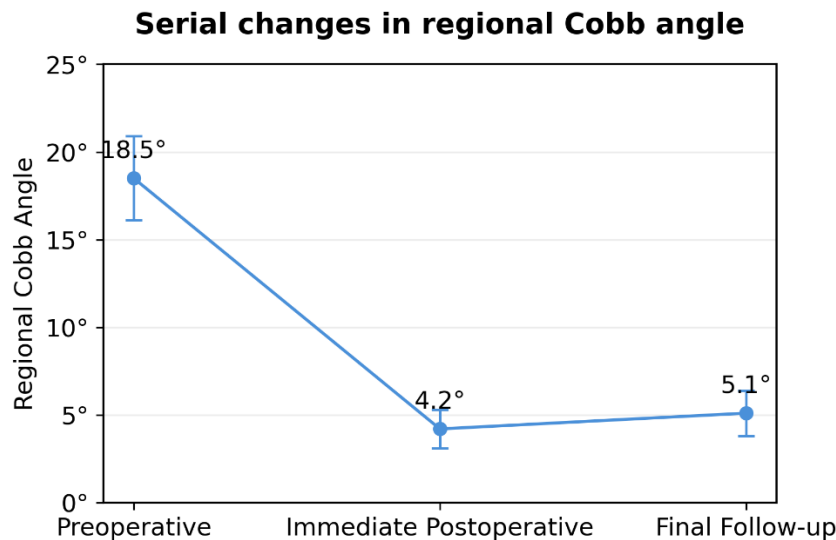


Figure 3 Line diagram showing serial changes in regional Cobb angle from preoperative to final follow-up.

Figure 3 demonstrates the significant improvement in regional sagittal alignment following surgery. The mean Cobb angle

improved from $18.5 \pm 6.2^\circ$ preoperatively to $4.2 \pm 3.1^\circ$ immediately postoperatively,

with sustained correction ($5.1 \pm 3.4^\circ$) at final follow-up.

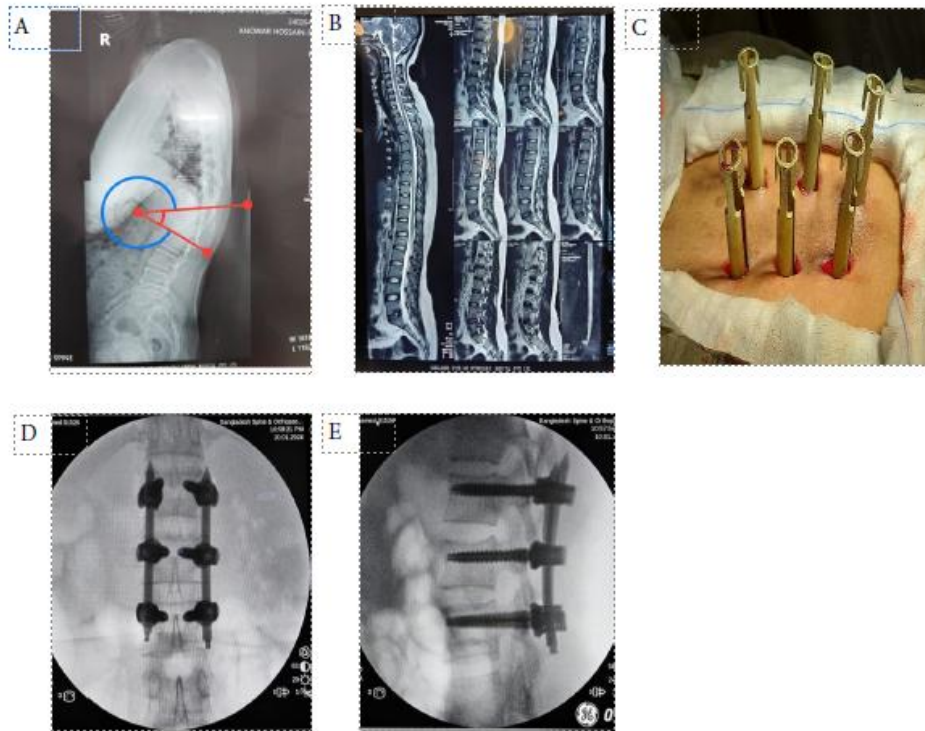


Figure 4 Preoperative imaging and intraoperative workflow for minimally invasive spinal fusion.

Preoperative imaging and intraoperative workflow for minimally invasive spinal fusion (Figure 4). (A) Preoperative lateral radiograph displaying Cobb angle measurement for kyphotic deformity assessment. (B) Preoperative sagittal T2-weighted MRI illustrating spinal cord compression and disc pathology. (C) Intraoperative photograph of percutaneous extender towers positioned through six bilateral stab incisions on the patient's lower back. (D, E) Intraoperative anteroposterior and lateral fluoroscopic images confirming symmetrical bilateral pedicle screw trajectories, optimal screw length within the vertebral bodies, and longitudinal rod assembly across three vertebral levels.

DISCUSSION

The present study was undertaken to evaluate the efficacy of minimally invasive pedicle screw fixation in patients with thoracolumbar spinal injuries. Our findings demonstrate that this technique yields satisfactory clinical and radiological outcomes, with significant improvements in pain, functional status, and regional sagittal alignment, alongside a low complication rate and reduced perioperative morbidity. These results add to the growing evidence supporting the adoption of minimally invasive techniques in the management of thoracolumbar trauma. The perioperative outcomes observed in our study a mean operative time of 95.5 minutes, intraoperative blood loss of 85.3 mL, and hospital stay of 6.0 days compare favorably with published

data. A comparative study of percutaneous versus open fixation reported operative duration of 93.8 versus 109.4 minutes, blood loss of 131.1 versus 442.2 mL, and postoperative stay of 8.7 versus 15.1 days, respectively [17]. Another comparative study found significantly less intraoperative blood loss, shorter operative duration, and shorter hospital stay with percutaneous fixation compared to open surgery, all with statistical significance [18]. These findings collectively confirm that the minimally invasive approach substantially reduces surgical trauma and accelerates recovery without compromising surgical efficacy. The significant improvement in neurological status observed in our study, with 75% of patients showing postoperative improvement in Frankel grade, is consistent with previous reports. A single-center experience of 125 patients undergoing MIS fixation for thoracolumbar fractures found that more than 10% presented with neurological deficits on admission, with 75% demonstrating postoperative improvement [19]. A separate study reported that more than 80% of patients with neurological deficits showed postoperative improvement according to Frankel grading [20]. These findings suggest that MIS fixation not only provides stability but also facilitates neurological recovery, likely through indirect decompression and restoration of spinal alignment. Regarding radiological outcomes, our study demonstrated a significant improvement in regional Cobb angle from 18.5° preoperatively to 4.2° immediately postoperatively, with

sustained correction at final follow-up. However, a prospective cohort study of 78 patients reported that while significant reduction of traumatic kyphotic deformity was achieved immediately postoperatively, a significant loss of sagittal alignment was observed at follow-up, with no correlation between loss of reduction and subjective outcome [21]. This finding suggests that the primary goal of MIS fixation may be the prevention of complete vertebral body collapse rather than long-term restoration of anatomical alignment. Nonetheless, the satisfactory alignment achieved in our cohort, with 100% of patients demonstrating Cobb angle $\leq 10^\circ$ at final follow-up, indicates that adequate correction can be maintained. Functional outcomes in our study were excellent, with a mean ODI improvement from 52.4 to 16.8 and VAS improvement from 7.2 to 2.1 ($p < 0.001$ for both). These results are consistent with a meta-analysis of 35 cohort studies demonstrating that patients undergoing percutaneous approaches experienced significantly less intraoperative blood loss, shorter hospital stays, and lower infection rates than those treated with open approaches [22]. Another randomized controlled trial found that percutaneous fixation was comparable to open fixation in improving ODI scores at 12 months but showed earlier improvement at 6 months and reduced blood loss [18]. A retrospective comparative study also reported a better Oswestry index in the percutaneous group at one day and three months postoperatively [23]. The complication rate in our study was low,

with wound infection and screw misplacement each occurring in 3.3% of patients. A systematic review of pedicular screw fixation techniques identified poor positioning of pedicle screws as the most common cause of complications, while noting that minimally invasive techniques have contributed to reducing surgical trauma and complications [24]. The low complication rate in our cohort supports the safety profile of MIS fixation when performed with adequate fluoroscopic guidance.

LIMITATIONS

The study is limited by its retrospective design, small sample size of 30 patients, absence of a control group undergoing open surgery, relatively short follow-up period, and single-center setting, which may limit the generalizability of findings to broader populations.

CONCLUSION

Minimally invasive pedicle screw fixation is a safe and effective treatment option for thoracolumbar spinal injuries, yielding outcomes comparable to open surgery with reduced perioperative morbidity. The technique facilitates rapid improvements in pain, Frankel grade, functional status, and regional sagittal alignment, with a low complication rate. It represents a valuable approach in appropriately selected patients, particularly where minimizing surgical trauma and accelerating recovery are prioritized.

RECOMMENDATION

Future prospective randomized controlled trials with larger sample sizes, control groups undergoing open surgery, and longer follow-up periods are recommended to confirm these findings. Multicenter studies would enhance generalizability and further validate the efficacy of minimally invasive fixation in thoracolumbar trauma.

CONFLICT OF INTEREST

The authors declare no conflicts of interest. No funding was received for this study. The corresponding author had full access to all data and final responsibility for the decision to submit for publication.

AI DECLARATION

Artificial intelligence tools contributed marginally to manuscript preparation and development. All core scientific content was human-verified.

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ETHICAL APPROVAL

The study was approved by the Institutional Ethics Committee

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