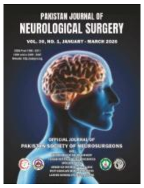
PAKISTAN JOURNAL OF NEUROLOGICAL SURGERY (QUARTERLY) – OFFICIAL JOURNAL OF PAKISTAN SOCIETY OF NEUROSURGEONS

Original Research

Biomechanical Outcome of Short Segment Trans-pedicular Fixation at Thoraco-Lumbar Junction Fractures with Incorporation of Screws at Fractured Level

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ABSTRACT

Objective: Despite consensus on the surgical management of thoracolumbar fractures, considerable controversy exists regarding the correction of kyphotic deformity. This study is to evaluate the extent of correction of kyphotic deformity in 6S short-segment TP Fixation (6S-SSF) with incorporation of Screws into fractured vertebrae in Thoracolumbar Junction Fractures (TLJ).

Material and Methods: This retrospective cohort study analyzed 34 patients with unstable thoracolumbar fractures (T10-L3) treated with six-screw short-segment transpedicular fixation between March 2019 and February 2021. Primary outcomes included correction of kyphotic deformity and maintenance of reduction at 12-month follow-up. Secondary outcomes encompassed vertebral height restoration and functional scores.

Results: The cohort comprised 25 males (73.5%) and 9 females (26.5%) with a mean age of 37.2 ± 9.8 years. L1 fractures predominated (41.2%), followed by T12 fractures (29.4%). Mean preoperative kyphotic angle measured 16.3° ± 4.2°, improving to 7.6° ± 3.1° postoperatively. At 12-month follow-up, the kyphotic angle measured 8.1° ± 3.4°, representing minimal correction loss of 0.5° ± 1.2°.

Conclusion: The Six-screw short-segment transpedicular fixation in thoracolumbar fractures, including the fractured vertebra, demonstrates superior biomechanical stability with effective kyphotic correction and minimal loss of reduction as compared to traditional four-screw constructs.

Keywords: Short segment fixation, kyphotic angle, thoracolumbar fractures, thoracolumbar injury classification and scoring system (TLICS).

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Date of Submission: 02-11-2025
Date of Revision: 01-03-2026
Date of Acceptance: 12-03-2026

Date of Online Publishing: 15-3-2026
Date of Print: 31-3-2026

DOI: 10.36552/pjns.v30i1.1111

INTRODUCTION

The Thoracolumbar spine fractures represent 60–70% of all traumatic spinal injuries. The region between T-10 and L-3, a biomechanical transition zone, is particularly at risk. This junction, where the rigid thoracic spine meets the flexible lumbar spine, creates a critical stress point during traumatic loading. When a fracture at this junction occurs, accompanied by neurological injury, particularly involving the cauda equina or conus medullaris, patients face significant disability and long-term morbidity.[3]

Although there have been significant advancements in spinal imaging and surgical techniques, there is ongoing debate on achieving consensus on optimal surgical approach and the degree of kyphosis correction, which is paramount to improving clinical and biomechanical outcomes.[4]

The Thoraco-lumbar Injury Classification and Severity Score (TLICS) offers a structured evaluation based on three key parameters that include the neurological status and injury morphology, as well as the integrity of the posterior ligamentous complex of the patient. The TLICS scores provide clear treatment guidance: scores of 3 or less typically indicate non-operative management, scores of 5 or higher favor surgical intervention, while scores of 4 occupy a "gray zone" requiring individualized clinical decision-making based on patient-specific factors.[6 7 8] The discrepancies between classification systems, particularly in the context of neurological deficits or posterior ligamentous complex injuries, highlight the need for a more nuanced approach to fracture management.[9,10]

The goal of an optimal surgical intervention is threefold: restore spinal alignment, decompress neural structures, and achieve sufficient stability while preserving intervertebral motion. The traditional four-screw short-segment fixation has gained widespread adoption because it is technically straightforward and causes less surgical morbidity than anterior approaches. However, biomechanical analysis reveals a fundamental limitation: approximately 80 - 90% of axial loads traverse the anterior vertebral body and intervertebral disc, with only 10–20% passing through posterior elements. This load distribution pattern is why four-screw constructs fail when the anterior column sustains significant injury, leading to progressive kyphotic deformity and implant failure.[11 12]

Short-segment trans-pedicular fixation is a promising surgical option for thoracolumbar fractures.[13,14] Recent studies have reported improved biomechanical outcomes and stability. However, the studies regarding this technique are limited, and there is variation and inconsistency among these studies.[10,3 ,4]

The scope of this study is to encompass the biomechanical outcome of six-screw short-segment fixation (SSF), including fractured vertebrae in thoracolumbar junction injuries, specifically analyzing kyphotic deformity correction and maintenance of reduction over a 12-month follow-up. This will help provide valuable insights into the role of this surgical approach as a potential management technique for thoracolumbar spine fractures.

MATERIALS & METHODS

Study Design & Setting

A retrospective cohort study took place at the Department of Neurosurgery at Sheikh Zayed Hospital, located in Rahim Yar Khan, Pakistan. The research protocol was thoroughly reviewed and subsequently approved by the Institutional Review Board (Ref No. 558/IRB/SZMC/SZH) dated 28/10/2022.

Ethical Approval

All ethical standards were ensured. Before participation, informed consent was obtained from all individuals for participation in this study and for the publication of clinical data accompanying radiological images. Patient confidentiality was maintained throughout the study period, with all personal and medical data secured according to institutional protocols. Data from a total of 34 patients were collected from the department between March 2019 and February 2021.

Inclusion Criteria

Patients with thoracolumbar injuries who were treated with six-screw short-segment transpedicular fixation made up the population at Sheikh Zayed Hospital. Patients between the ages of 20 and 60 who had unstable thoracolumbar burst fractures between the T10 and L3 vertebrae were included in the study population. Patients with substantial spinal deformities, defined as kyphotic angulation of 20 degrees or more or vertebral body height loss of 50% or more, were included. Furthermore, patients had to have MRI examinations showing evidence of significant canal impairment, namely, more than 50% spinal canal compression. These standards were chosen to guarantee that individuals with unstable injuries that were clinically severe and required surgery were included.

Exclusion Criteria

Since osteoporotic bone disease considerably affects biomechanical characteristics and surgical outcomes, patients with osteoporotic bone disease (defined as a T-score less than −2.5 on bone density measurement) were excluded from the study. Excluded were cases with pedicle fractures that would prevent safe screw implantation, pure distraction mechanisms, and fracture-dislocation injuries. Pathological fractures (secondary to malignancy or other systemic disease), multilevel consecutive fractures, complete spinal cord injury, and any prior surgical intervention at the injured spinal level were also excluded. These exclusion criteria were implemented to create a homogeneous cohort with isolated unstable thoracolumbar fractures amenable to the six-screw short-segment fixation technique.

Data Collection and Radiographic Assessment

Every patient included in the study underwent a thorough imaging assessment, which comprised anteroposterior and lateral X-ray radiographs, as well as Magnetic resonance imaging (MRI) and computed tomography (CT) Scans. MRI was performed using standard 1.5T protocols with T1-weighted, T2-weighted, and STIR sequences in both sagittal and axial planes to assess soft tissue injury, spinal cord integrity, and ligamentous complex disruption. CT scans included thin-slice (1-2mm) axial reconstructions with coronal and sagittal reformation to precisely identify fracture morphology, pedicle integrity, and vertebral body involvement. Level confirmation was performed

Figure 1: *Intraoperative placement of transpedicular screws at three levels (one level above, at fracture level, and one level below) using the free-hand technique. Informed consent was obtained from the patient for the publication of clinical data and associated radiological images.* ***Figure 1(left)*** *pre-operative radiograph,* ***Figure 1 (top right)*** *lateral radiograph,* ***Figure1(bottom right)*** *anterior-posterior radiograph.*

by: (1) counting vertebrae from the sacrum superiorly, (2) identifying anatomical landmarks, and (3) comparing sagittal and axial images to ensure consistent level identification. Sagittal imaging defined kyphotic deformity and compression, while axial imaging assessed canal compromise and retropulsion. All imaging was reviewed independently by two senior surgeons to prevent wrong-level error, with discrepancies resolved by consensus." Specifically focused on the thoracolumbar region of the spine. Biomechanical parameters (decrease in vertebral height, kyphotic angle, and thecal sac compression) were measured from the scans, and the type of fracture was assessed. Kyphotic angle was measured by Cobb's method between the superior endplate of the upper intact vertebra and the inferior endplate of the lower intact vertebra. Loss of correction was measured as a reduction of immediate, post-operative, and 12-month follow-up kyphotic angles.

Operative Setup

All procedures were performed under general anesthesia. Patients were placed in the prone position with careful padding strategies to prevent pressure ulcers and nerve compression injuries. Specific positioning measures included gel padding placed under all bony prominences; both eyes protected with lubricating ointment and protective tape to prevent corneal abrasion; both axillae padded with soft material to prevent axillary nerve compression, with arms positioned alongside the trunk; thoracic and lumbar regions properly aligned by adjusting table breaks to maintain neutral spinal alignment; endotracheal tube secured to avoid compression against the lip or teeth; and all pressure points reassessed after positioning changes. This positioning approach minimizes perioperative morbidity, including brachial plexus injury, pressure ulcers, rhabdomyolysis, and visual loss from prone positioning.

A systematic hardware verification checklist was completed by the surgical nursing staff and verified by the primary surgeon. Components verified included: quantity and size of pedicle screws confirmed to match preoperative templating, they were inspected for the thread and head integrity; diameter and curvature of titanium rods verified as matching surgical plan; quantity and compatibility of set screws and connectors was confirmed; expiration date, sterilization status, and quantity verified of sutures, hemostatic agents, and wound closure products was confirmed. A count of all implants was performed before and after insertion, documented in the operative record, and reconciled with the inventory system.

The correct vertebral level was identified by AP fluoroscopy, counting from the sacrum, lateral fluoroscopy confirming anatomical features of the target level, and placement of a marker at the proposed incision site with confirmation imaging. The vertebral body at the fracture level was cross-referenced with preoperative imaging (CT/MRI) for absolute confirmation. This dual-plane fluoroscopic verification was performed by both the primary surgeon and surgical assistant independently, with verbal confirmation before incision.

Surgical Technique

Trans-pedicular screws were inserted after a posterior midline approach at the three levels (one-above, one-below, and fractured-level) by free-hand technique in pedicles of the vertebra (Figure 1), except for the broken pedicle, where no screws were placed. Screws were selected corresponding to the vertebra dimensions. Screw-heads at the fractured level were placed slightly projecting to serve as a push-point. This allows for kyphosis reduction. An overall reduction of kyphosis or normal vertebral height was achieved. Additionally, a laminectomy for decompression was performed in patients who had a pre-operative neurological deficit of more than 50%. Stitches from the surgical wound were removed according to a standardized technique after 2 weeks. Patients were mobilized after 24 hours with a thoracolumbar brace; however, the patient was allowed to sit up after 2 weeks. Patients underwent imaging to assess kyphosis correction post-operatively and at 12-month follow-up.

All procedures included multimodal intraoperative neuromonitoring to detect real-time neural compromise. The monitoring protocol consisted of Somatosensory Evoked Potentials (SSEP), Motor Evoked Potentials (MEP), and Electromyography (EMG), along with a technical person monitoring the changes and reporting to the surgical team.

Hemostasis was achieved with topical hemostatic agents (thrombin-soaked gauze, hemostatic matrix), monopolar cauterization of bleeding vessels, and irrigation with normal saline. Meticulous hemostasis reduced operative blood loss and postoperative hematoma risk. After confirming hemostasis and hardware position with final fluoroscopic imaging, the fascia was closed with running 0-Vicryl sutures, subcutaneous tissue with running 2-0 Vicryl, and skin with staples. A sterile dressing was applied. All instruments and sponges were counted and confirmed.

Outcome Measures

Postoperative neurological assessment was performed using standardized and validated measures as part of routine clinical care, including serial motor, sensory, bladder, reflex, and gait evaluations at 6 hours postop, 24 hours postop, discharge, and 12-month follow-up, with clear protocols for urgent imaging and re-exploration in cases of neurological deterioration. These assessments were systematically documented in standardized operative records. Clinical and Injury details were assessed to evaluate the patient's health. Kyphotic correction was evaluated using radiological imaging.

Statistical Analysis

The data was collected from the patient's health records. Then it was analyzed using SPSS version. 25.0. As per the standard, mean and standard deviation were used for quantitative variables, whereas qualitative variables were reported with numbers and percentages. The chi-square test was used to assess associations, with a p-value of less than 0.05 considered statistically significant. Student's t-test was used to compare pre-operative and post-operative parameters to determine if there were statistically significant differences. This test helps to evaluate the effect of the surgical intervention by analyzing changes in measured variables before and after the procedure.

RESULTS

Patient Demographics

The study included 34 patients meeting all inclusion criteria. Among the patients, 25 (73.5%) were male and 9 (26.6%) were female. Mean age of the cohort was 37.21 ± 9.20 (ranging from 21 – 58 years); however, 32.4% (11) patients were between 30 to 39 years, and 29.4% (10) were between 40-49 years. The age distribution of the patients is shown in Figure 2. All the patients were assessed in the emergency department, of which 41.2% (14)

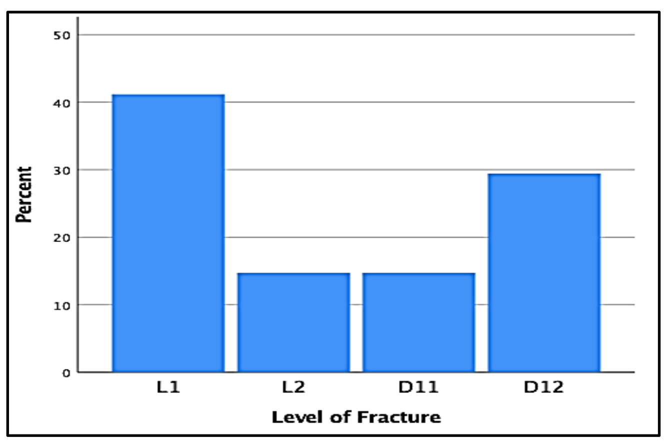


Figure 2: *Distribution of fracture levels (L1 and D12) in the study population.*

had an L1 fracture, and 29.4% (10) had a D12 fracture (Figure 3). The patients were taken to surgery within a maximum of 10 days, with a mean of 3.59 days after presenting in the emergency department.

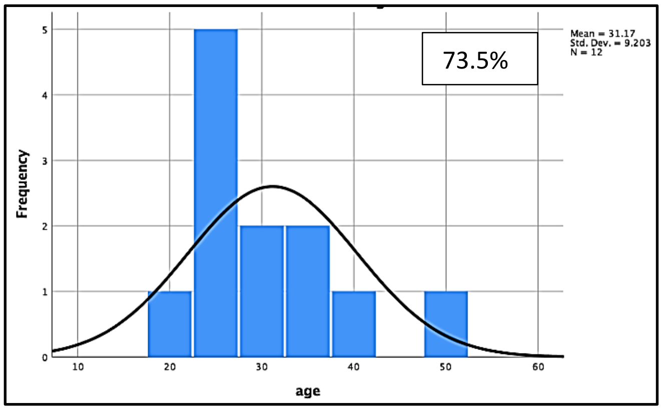


Figure 3: *Age distribution of 34 patients with thoracolumbar fractures managed with six-screw short-segment fixation.*

Operative Details

All 34 patients in the study underwent six-screw short-segment fixation with intermediate screw placement. Among these, three-level fixation was carried out in the majority of patients, specifically 29 individuals, representing 85.3% of the total study population. In contrast, 5 patients, accounting for 14.7%, required a more extensive four-level fixation due to the presence of pathology at an adjacent spinal level. Additionally, decompressive laminectomy was performed in 9 patients, which corresponds to 26.5% of the cohort, as these individuals presented with pre-operative neurological deficits necessitating this surgical intervention.

Operative Parameters

Mean operative time: 118 ± 36 minutes.

Mean estimated blood loss: 270 ± 95 mL.

Mean hospital stays: 7 ± 4 days.

Radiographical Imaging Outcomes

The sagittal kyphotic angle was determined using Cobb’s method, measuring between the superior endplate of the vertebra above and the inferior endplate of the vertebra below the injured segment, as illustrated in Figure 4.

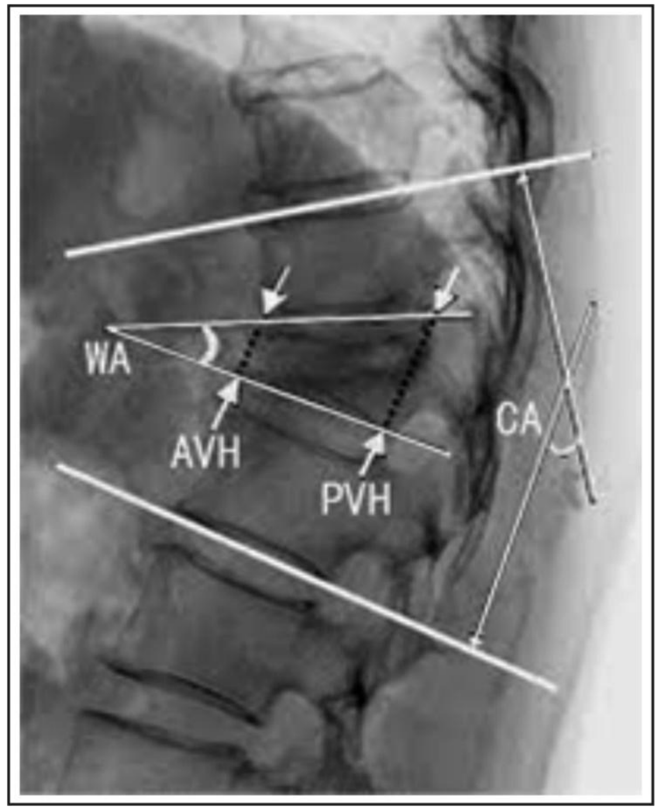
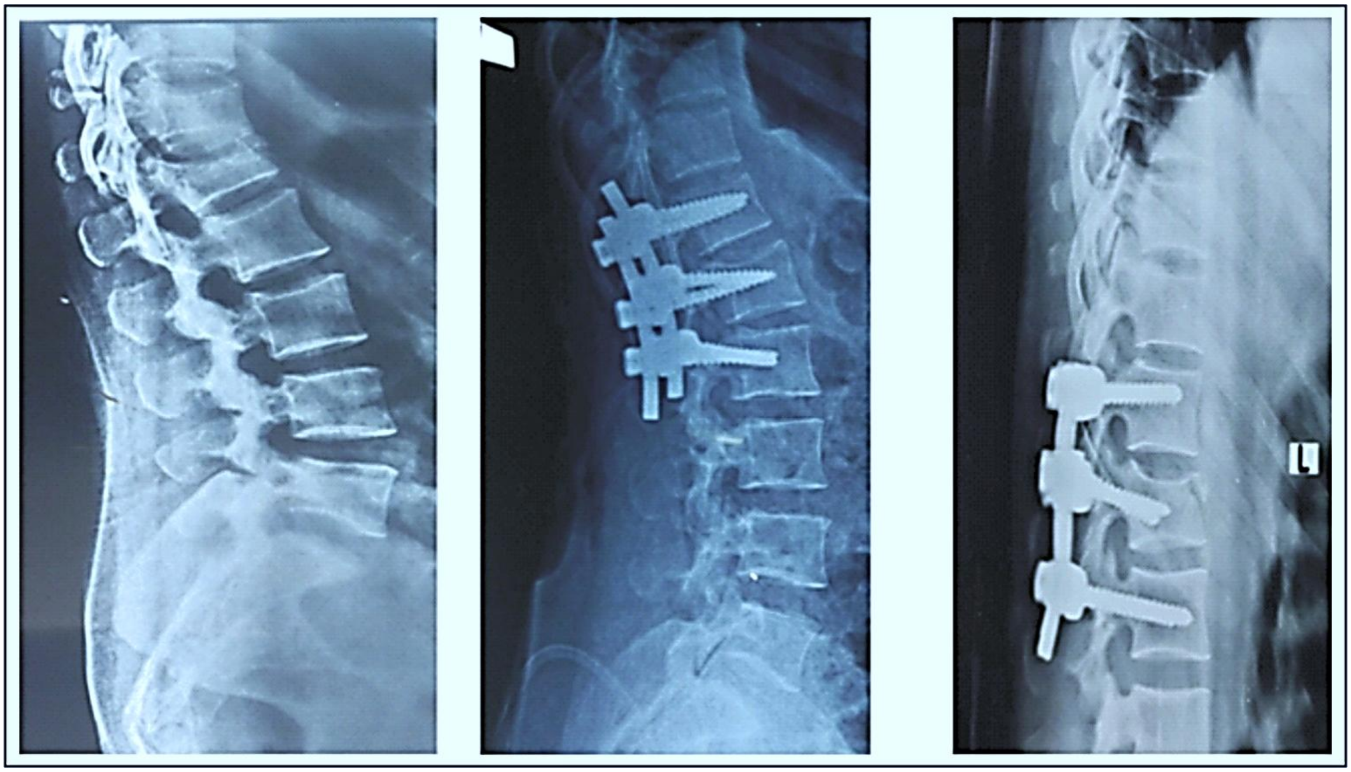


Figure 4: *Measurement of sagittal kyphotic angle using Cobb's method between the superior endplate of the vertebra above and the inferior endplate of the vertebra below the injured segment. Informed consent was obtained from the patient for the publication of clinical data and associated radiological images.*

The mean of preoperative kyphotic angle was 16.34 ± 4.2° (ranging from 13-22), improved significantly to 7.62 ± 3.1° immediately postoperatively, representing a mean correction of 8.7° ± 3.8°. At 12-month follow-up, the mean of the kyphotic angle measured was 8.1° ± 3.4°, indicating minimal correction loss of 0.5° ± 1.2°. The maintained correction at final follow-up was

Table 1: *Summary of Biomechanical Outcomes: Pre-operative, Post-operative, and 12-Month Follow-up Measurements.*

Time Point	Mean Kyphotic Angle (°) (n=34)	Std. Deviation (°) (n=34)	Range/Clinical Notes
Pre-operative	16.34	4.2	13–22
Immediate post-operative	7.62	3.1	Mean Correction: 8.7 ± 3.8°
12-Month Follow-up	8.1	3.4	Correction Loss: 0.5 ± 1.2°
Final Maintained Correction	8.2	3.6	vs. Pre-operative



(a): **(b):** **(c):**

Figure 6: *Kyphotic angles demonstrating minimal correction loss. Informed consent was obtained from the patient for the publication of clinical data and associated radiological images.* ***Figure 6(a)*** *pre-operative radiograph,* ***6(b)*** *immediate post-operative radiograph, and* ***6(c)*** *12-month follow-up radiograph.*

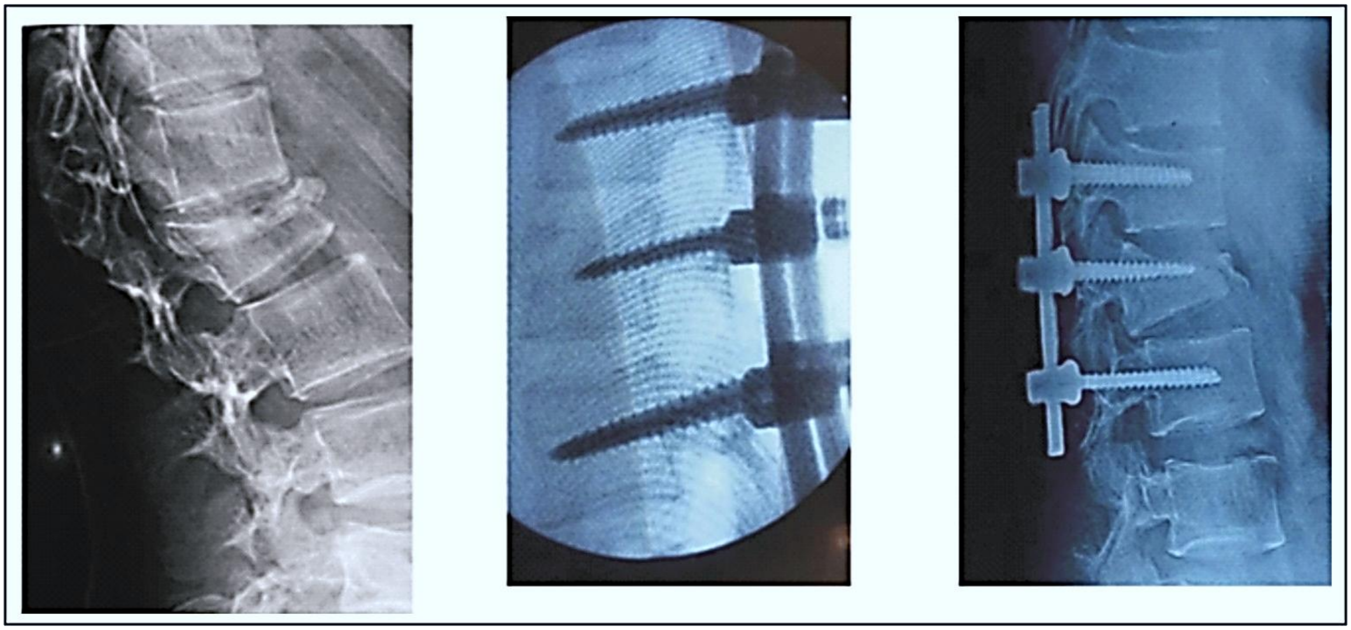
8.2° ± 3.6° compared to preoperative values. These measurements are summarized in Table 1 and illustrated radiologically in Figures 6 and 7, respectively.

COMPLICATIONS

In 05 cases (14.7%), dural tear caused by the initial injury was encountered after laminectomy. It was sutured primarily, and in 02 patients, we used fibrin glue to seal CSF leakage. CSF did not leak postoperatively in any case. No wound infections and systemic complications related to the surgery occurred.

DISCUSSION

Among the cohort observed in this study, there were no failures of implant reported, which reflects the efficacy of intermediate screws in short-segment constructs. Numerous studies have shown good results of fracture level screws,



(a): **(b):** **(c):**

Figure 7: *Serial radiological images showing progressive healing and maintenance of fracture reduction. Informed consent was obtained from the patient for the publication of clinical data and associated radiological images.* ***Figure 7(a)*** *pre-operative radiograph**, 7(b)*** *immediate post-operative radiograph**, and 7(c) 1***2-month follow-up radiograph.*

especially in unstable fractures, underlining their success in reducing correction loss and hardware failure.[15,16]

The four-screw short segment fixation did not ensure adequate mechanical stability, as it does not support the axial-load sharing, which potentially leads to hardware failure. It does provide the benefit of increased mobility and is a simpler technique, but it does not impede kyphosis progression. These outcomes are injunction of defective weight-bearing at the anterior column of the spine.[17]

When the body is in an upright posture, the anterior section of the vertebral body and intervertebral disc bear approximately 85% of the axial load, whereas the posterior articular process bears only approximately 15%. Failure of the four-screw technique to bring favorable biomechanical outcomes necessitates long-segment posterior or anterior screw fixation.

Enhanced pullout strength provided by the additional fixation points and the preservation of anatomical continuity between pedicles and posterior elements, along with the improved construct stiffness protecting against anterior column loads, makes six-screw constructs more stable than four-screw constructs. It also maintains the anatomic continuity that generally exists between the pedicles of the vertebra and the pars interarticularis. As a result, the screws that anchor in the pedicles of the vertebra at the fracture site are not left “unsupported”. They are allowed to transfer loads to the neighboring vertebrae through the posterior elements. The screw constructs placed at the fracture level are capable of attaining and sustaining the correction of kyphotic deformity.[18,19] This effectively enhances structural strength, improves construct rigidity, and protects the fractured vertebral body from anterior loading forces.[16]

Intermediate screw constructs yield superior results across all categories of thoracolumbar fractures. A systematic review reported in 2024 drew a conclusion from 102 studies about thoracic and lumbar fractures. The study deduced that posterior percutaneous methods incorporating intermediate screws are the safest and most practical approach for managing type A3/A4 burst fractures in patients without significant neurological impairment.[20] Additionally, recent finite element analyses confirm comparable biomechanical properties between different intermediate screw configurations.[21]

Biomechanical research shows that incorporating intermediate screws at the fracture site enhances construct stiffness by 31% relative to standard short-segment fixation. [22] They function through a three-point fixation mechanism, where they act as a central support point between the upper and lower pedicle screws. This configuration distributes loads more effectively across the construct and reduces stress concentration at individual screw-bone interfaces. The screws essentially create an internal splint that supports the fractured vertebral body from collapse during healing.

This study reviewed 34 patients in whom the mean correction of kyphotic angle was 8.7° ± 3.8° with minimal correction loss of 0.5° ± 1.2°. The maintained correction at final follow-up was 8.2° ± 3.6° compared to preoperative values. This result supports the efficacy of the intermediate screw construct. A similar study reported in 2021, which was a comparative study by Farghaly et al, reported significantly higher correction (13.3° vs 5.1°) and lower correction loss with intermediate screw constructs.[23] Similarly, a 2025 analysis of 277 patients demonstrated equivalent efficacy between 6S-SSF and long-segment fixation while preserving motion segments.[24]

The use of posterior intermediate screws maintains greater spinal mobility than long-segment fixation. The six-screw short segment fixation (SSF) offers a significant advantage over long segment fixation (LSF) by preserving more motion segments during surgical fusion, potentially eliminating the need for removal of the implant at a later stage to enhance mobility in non-fusion surgeries. Among the three constructs, the intermediate screws technique (6S SSF) creates the least stress around the pedicle screws, which helps reduce complications like implant failure. Interestingly, it induces greater stress in the vertebral body that is fractured compared to LSF and 4-screw SSF, which, according to Wolff's law, may actually stimulate bone healing.[25]

When treating thoraco-lumbar fractures, the addition of intermediate screws at the fracture level not only results in a reduction in correction loss but also has been reported with less post-operative pain and better mobility. Ultimately, this six-screw fixation has proven to be not only a motion segment-saving procedure but also cost-effective, with less blood loss and operative time. [26-30]

Furthermore, the use of polyaxial screws can enhance the effectiveness of short-segment fixation. Where monoaxial screws may lack sufficient biomechanical support and long-segment fixations can be excessively invasive, polyaxial screws (with inclined angles) provide a stable construct. This makes polyaxial-screws an applicable surgical preference, particularly for patients with Denis type B TL fractures.[31] Another promising approach currently being investigated involves fixation using screws placed one level below and two levels above the injury. This method involves pedicle screw fixation combined with decompression, a hybrid technique, for the management of unstable thoracolumbar fractures.[32] This can be further studied and practiced to provide an insight into its effects on biomechanical outcomes.

CONCLUSION

Six-screw short-segment transpedicular fixation incorporating the fractured vertebra is a good alternative to traditional four-screw constructs. It provides superior stability while preserving motion segments compared to long-segment fixation. The intervention appears particularly beneficial for unstable thoracolumbar fractures with significant kyphotic deformity. However, prospective randomized controlled trials that have longer follow-up of patients during the course of recovery are required to establish superiority definitively to confirm long-term clinical benefits.

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Additional Information

Disclosures: The authors report no conflict of interest.

Ethical Review Board Approval: The study was approved by the Institutional Review Board of Sheikh Zayed Medical College/Hospital, Rahim Yar Khan (Reference No. 558/IRB/SZMC/SZH) dated 28/10/2022.

Human Subjects: Informed and written consent was obtained from all patients/participants in this study for participation and for publication of clinical data and radiological images.

Conflicts of Interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following:

Financial Relationships: All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work.

Other Relationships: All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

Data Availability Statement: For data sharing, interested researchers can contact the corresponding author.

Funding: None.

AUTHOR CONTRIBUTION

Sr.#	Author's Full Name	Intellectual Contribution to Paper in Terms of:
1.	Muhammad Farooq	Idea Conception, study design, methodology, manuscript review, and quality Insurer.
2.	Muhammad Saad Asif	Study Design, data collection, data analysis, paper write-up and editing, manuscript submission and correction and referencing.
3.	Hafiz Mohammad Maaz	Manuscript writing and editing.
4.	Mohammad Sufyan	Study design and editing.
5.	Usama Yaseen	Data collection and editing.