



Comparison of Outcomes between Minimal Invasive Spine Stabilization and Open Conventional Approach in Thoracolumbar Traumatic Spine Fractures

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ABSTRACT

Background: Thoracolumbar traumatic spine fractures represent one of the most frequent spinal injuries, often necessitating surgical stabilization. While open conventional fixation has been the established method, minimally invasive spine stabilization (MISS) has gained attention due to its potential advantages in reducing surgical morbidity. This study aimed to compare outcomes between MISS and the open conventional approach in patients with thoracolumbar traumatic fractures.

Methods: A quasi-experimental study was conducted in the Department of Neurosurgery, Sheikh Zayed Hospital, Rahim Yar Khan, from January to May 2025. Seventy-six patients meeting eligibility criteria were enrolled and equally assigned to MISS or open conventional fixation groups (38 each). Outcomes assessed included operative time, postoperative pain (Numerical Rating Scale, day seven), hospital stay, and mobilization time. Data were analyzed using independent t-tests, Chi-square tests, and stratified subgroup analyses, with significance set at $p < 0.05$. **Results:** Baseline demographic and clinical characteristics were comparable between groups ($p > 0.05$). The mean operative time was significantly shorter in the MISS group (82.4 ± 14.8 min) compared to the open group (93.7 ± 16.5 min, $p = 0.002$). Postoperative pain scores were also lower in MISS (3.2 ± 0.9) versus open surgery (4.7 ± 1.1 , $p < 0.001$). Hospital stay was reduced in MISS patients (13.8 ± 2.7 days) compared to open surgery (15.9 ± 3.1 days, $p = 0.002$). Mobilization occurred earlier in the MISS group (3.4 ± 1.2 days) than in the open group (4.8 ± 1.5 days, $p < 0.001$). Subgroup analyses confirmed consistent benefits of MISS across most age, gender, and ASA strata. **Conclusion:** MISS demonstrated superiority over open stabilization in reducing operative time, postoperative pain, hospital stay, and mobilization delay in thoracolumbar traumatic spine fractures.

INTRODUCTION

The thoracolumbar junction, a region marked by the transition from the mobile lumbar spine to the rigid thoracic spine, has been identified as a particularly vulnerable site for traumatic injuries. In urban environments, young adults frequently sustain trauma to this area, with epidemiological data indicating that such injuries constitute of more than 50% of spine fracture [1,2]. The biomechanical interplay at this junction, involving the axial transfer of kinetic energy, results in a heightened susceptibility to fractures [3].

Surgical intervention is the cornerstone of management for these fractures, aimed at restoring spinal stability, alignment, and decompression of neural elements. Traditional open stabilization with pedicle screws has been the established modality, endorsed for its efficacy in maintaining structural integrity even in patients

devoid of neurological deficits. This approach has garnered support for its radiological and clinical efficacy in the treatment of thoracolumbar burst fractures with concomitant posterior ligamentous complex injuries [4]. However, the evolution of surgical techniques has introduced minimally invasive surgery (MIS) as a formidable alternative. MIS techniques, focusing on pedicle screw instrumentation, have demonstrated a reduction in soft tissue damage, intraoperative blood loss, and improved postoperative pain profiles when juxtaposed with conventional methods [5,6].

Xu et al. [7] reported that patients treated with minimally invasive percutaneous fixation had better outcomes than those undergoing traditional open surgery, with advantages in operative efficiency, hospital stay, postoperative pain, and complication rates. Afolabi et al. [8] found comparable hospital stays and mobilization

times between the two groups but noted that minimally invasive surgery significantly reduced operative duration. Murans et al. [9] demonstrated that minimally invasive treatment was associated with improved functional scores and lower postoperative back pain compared with the open approach.

The trajectory of surgical management for thoracolumbar spine trauma is at a crossroads with innovations in minimally invasive techniques. Despite the reported benefits of reduced operative times, lower intraoperative blood loss, and improved postoperative pain outcomes associated with minimally invasive spine stabilization (MISS), discrepancies persist in the literature. These inconsistencies fuel an ongoing debate, underscoring a literature gap that necessitates further investigation. It is imperative to conduct rigorous comparative analyses to validate the efficacy and safety of MISS relative to conventional open surgical approaches. This study aimed to address this gap, providing clarity on the optimal surgical intervention for thoracolumbar traumatic spine fractures, thereby influencing future clinical decision-making and potentially enhancing patient care.

MATERIAL AND METHOD

This quasi-experimental study was conducted at the Department of Neurosurgery, Sheikh Zayed Hospital, Rahim Yar Khan, over a period of six months following approval from the institutional review board. The study was designed to compare the outcomes of minimally invasive spine stabilization (MISS) with those of the open conventional approach in the management of thoracolumbar traumatic spine fractures. The sample size was calculated using published data, keeping the level of significance at 5%, power at 80%, and expected mean operative time of 80.89 ± 15.69 minutes for MISS versus 91.19 ± 16.27 minutes for the open approach. The required sample size was 76 patients, with 38 patients in each group [7]. A non-probability consecutive sampling technique was employed.

Patients aged between 18 and 65 years, of either gender, who were diagnosed with a single-level thoracolumbar traumatic fracture between T11 and L5, with less than 30% canal compromise and no features of spinal cord compression on MRI, were eligible for inclusion. Patients classified as American Society of Anesthesiologists (ASA) class I–III were included. Exclusion criteria comprised patients with non-traumatic fractures (such as osteoporotic, neoplastic, or tuberculous lesions), prior spinal surgeries at any level, pre-existing spinal deformities, multilevel traumatic fractures, or associated traumatic cerebral edema. Patients with chronic neurological or orthopedic conditions that could interfere with mobility or pain assessment, those requiring decompression due to neurological deficits, and those with severe hepatic, renal, or hematological dysfunction were also excluded. Patients unable to provide informed consent were not considered for enrollment. Written informed consent was obtained from all eligible participants. Baseline assessments included age, gender, comorbidity status, ASA classification (confirmed by a

consultant anesthesiologist), and fracture details verified through MRI. All participants were assigned into one of two groups. Group A underwent MISS, while Group B underwent open conventional stabilization.

MISS was performed by inserting pedicle screws under fluoroscopic guidance through small transverse incisions made along Langer's lines. The paraspinal musculature was traversed bluntly after fascial incision, and rods were introduced through proximal or distal entry points. Fracture reduction was first attempted passively through prone positioning and further optimized using distraction, compression, or sagittal alignment correction with the implant system's reduction instruments. In the open conventional approach, a standard midline incision was used with subperiosteal exposure extended to the transverse processes. Pedicle screws were inserted under fluoroscopic guidance, and fracture reduction was achieved using the same biomechanical principles as in the MISS group. Fusion was performed by opening the facet joints with a chisel, decorticating the laminae, and applying allograft bone chips. All procedures were performed by consultant neurosurgeons with at least three years of independent surgical experience.

Postoperative care protocols were standardized across both groups. The primary outcomes were operative time (minutes), postoperative pain measured on day seven using the Numerical Rating Scale (0–10), length of hospital stay (days, counted from the first postoperative day to discharge), and mobilization time (days from the first postoperative day until first ambulation, including sitting, standing, or walking). Discharge criteria included hemodynamic stability, discontinuation of intravenous medications, absence of nursing dependency, and ability to perform basic activities with or without minimal assistance.

All data were collected using a structured proforma, ensuring confidentiality and anonymization of patient information. Data analysis was performed using SPSS version 26. Quantitative variables, including age, operative time, postoperative pain scores, hospital stay, and mobilization time, were expressed as mean \pm standard deviation. Categorical variables, including gender, ASA status, and comorbidity presence, were presented as frequencies and percentages. Group comparisons for continuous variables were conducted using the independent samples t-test, while categorical variables were compared using Chi-square test. Stratification of outcomes was performed according to age, gender, ASA status, and comorbidities to assess effect modification, with post-stratification significance tested by unpaired t-test. A p-value ≤ 0.05 was considered statistically significant.

RESULTS

During the six-month study period, 76 patients with thoracolumbar traumatic spine fractures were enrolled and equally allocated into two groups: 38 patients underwent minimal invasive spine stabilization (MISS) and 38 received the open conventional approach. All enrolled patients completed the study protocol without loss to follow-up.

Table 1
Demographic and Clinical Characteristics of Study Population

Variables	MISS Group (n=38)	Open Conventional Group (n=38)	p-value
Age (years), mean ± SD	42.3 ± 11.7	44.1 ± 10.9	0.482
Gender, n (%)			
Male	26 (68.4%)	24 (63.2%)	0.627
Female	12 (31.6%)	14 (36.8%)	
ASA Status, n (%)			
Class I	15 (39.5%)	13 (34.2%)	0.734
Class II	18 (47.4%)	20 (52.6%)	
Class III	5 (13.1%)	5 (13.2%)	
Fracture Location, n (%)			
T11	3 (7.9%)	4 (10.5%)	0.892
T12	8 (21.1%)	7 (18.4%)	
L1	14 (36.8%)	13 (34.2%)	
L2	9 (23.7%)	11 (29.0%)	
L3	2 (5.3%)	2 (5.3%)	
L4	1 (2.6%)	1 (2.6%)	
L5	1 (2.6%)	0 (0.0%)	
Comorbidities Present, n (%)	11 (28.9%)	13 (34.2%)	0.621

The baseline characteristics demonstrated no statistically significant differences between the two groups (p>0.05), confirming adequate randomization and comparable populations for analysis.

Table 2
Comparison of Primary Outcomes Between MISS and Open Conventional Groups

Outcome Variables	MISS Group (n=38)	Open Conventional Group (n=38)	Mean Difference (95% CI)	p-value
Operative Time (minutes), mean ± SD	82.4 ± 14.8	93.7 ± 16.5	-11.3 (-18.5 to -4.1)	0.002
Postoperative Pain (NRS), mean ± SD	3.2 ± 0.9	4.7 ± 1.1	-1.5 (-2.0 to -1.0)	<0.001
Hospital Stay (days), mean ± SD	13.8 ± 2.7	15.9 ± 3.1	-2.1 (-3.4 to -0.8)	0.002
Mobilization Time (days), mean ± SD	3.4 ± 1.2	4.8 ± 1.5	-1.4 (-2.0 to -0.8)	<0.001

The MISS group showed significantly shorter operative time, lower postoperative pain scores, reduced hospital stay, and earlier mobilization compared with the open conventional group. These differences were statistically significant and indicated clear clinical advantages of the minimally invasive approach in terms of perioperative efficiency, patient comfort, and recovery.

Table 3
Stratified Analysis of Operative Time by Potential Confounders

Stratification Variable	MISS Group mean ± SD (n)	Open Group mean ± SD (n)	p-value
Age Group			
18-40 years	79.8 ± 13.2 (16)	91.3 ± 15.8 (14)	0.037
41-65 years	84.3 ± 15.7 (22)	95.2 ± 16.9 (24)	0.026
Gender			
Male	83.1 ± 15.2 (26)	94.8 ± 17.1 (24)	0.014
Female	80.9 ± 14.1 (12)	91.9 ± 15.3 (14)	0.067
ASA Status			
Class I-II	81.2 ± 14.3 (33)	92.4 ± 16.2 (33)	0.004
Class III	90.2 ± 15.8 (5)	102.4 ± 16.9 (5)	0.276
Comorbidity			

Present	86.7 ± 16.2 (11)	97.3 ± 17.8 (13)	0.147
Absent	80.6 ± 13.9 (27)	91.8 ± 15.7 (25)	0.008

Stratified analysis for operative time revealed consistent superiority of MISS across most subgroups. The advantage persisted regardless of age category, with younger patients (18-40 years) showing a mean difference of 11.5 minutes (p = 0.037) and older patients (41-65 years) demonstrating a 10.9-minute reduction (p = 0.026). Gender stratification indicated significant differences in males (p = 0.014), while females showed a trend toward significance (p = 0.067). Patients with ASA Class I-II showed significant operative time reduction with MISS (p = 0.004), whereas Class III patients, though showing numerical improvement, did not reach statistical significance, likely due to small sample size.

Table 4
Stratified Analysis of Postoperative Pain (NRS) by Potential Confounders

Stratification Variable	MISS Group mean ± SD (n)	Open Group mean ± SD (n)	p-value
Age Group			
18-40 years	3.0 ± 0.8 (16)	4.4 ± 1.0 (14)	<0.001
41-65 years	3.4 ± 0.9 (22)	4.9 ± 1.1 (24)	<0.001
Gender			
Male	3.3 ± 0.9 (26)	4.8 ± 1.1 (24)	<0.001
Female	3.0 ± 0.8 (12)	4.5 ± 1.0 (14)	<0.001
ASA Status			
Class I-II	3.1 ± 0.9 (33)	4.6 ± 1.0 (33)	<0.001
Class III	3.8 ± 0.8 (5)	5.2 ± 1.3 (5)	0.068
Comorbidity			
Present	3.5 ± 0.9 (11)	5.0 ± 1.2 (13)	0.002
Absent	3.1 ± 0.9 (27)	4.5 ± 0.9 (25)	<0.001

DISCUSSION

The present study compared outcomes between minimally invasive spine stabilization (MISS) and open conventional stabilization in thoracolumbar traumatic spine fractures. In this study, MISS reduced operative duration by a mean of 11.3 minutes compared with the open approach (82.4 vs 93.7 minutes, p=0.002). These findings are in line with those reported by Xu et al., who observed significantly shorter operative times in minimally invasive fixation compared with open techniques in 98 patients with thoracolumbar fractures [7]. Similarly, Afolabi et al. documented a mean reduction of almost 50 minutes when MISS was employed, reflecting the efficiency of limited exposure and targeted instrumentation [8]. A meta-analysis by McAnany et al. also confirmed shorter operative times in MISS across multiple comparative studies [6].

Conversely, certain reports have indicated longer operative times in early experiences with MISS, particularly when surgeons were in the learning phase [10]. Wang et al. observed prolonged operative durations during the initial implementation of MISS, largely attributable to fluoroscopic navigation and smaller surgical corridors [11]. These variations highlight the importance of surgeon experience and institutional familiarity with minimally invasive techniques in achieving consistent time efficiency. In the current study, operative time superiority of MISS remained consistent across younger and older patients, and across gender and ASA strata, supporting its robustness as an efficient surgical approach.

Postoperative pain was significantly lower in MISS patients, with a mean NRS score of 3.2 compared to 4.7 in the open group ($p < 0.001$). This difference, representing a 1.5-point reduction, is clinically meaningful and correlates with the reduced muscle dissection and tissue trauma inherent to minimally invasive procedures. Murans et al. reported similar findings, demonstrating lower patient-reported pain and Oswestry Disability Index (ODI) scores in the MISS group compared to the open approach [9]. Carazzo et al., in a systematic review, concluded that MISS consistently results in improved pain outcomes due to preservation of posterior musculature [5]. These results are also supported by clinical trials and meta-analyses. Li et al. observed significantly reduced pain scores at both early and late follow-up in MISS-treated patients [12]. Phan et al. highlighted reduced analgesic requirements and faster resolution of acute postoperative pain in minimally invasive fixation compared to open stabilization [13].

The average hospital stay was reduced by 2.1 days in the MISS group compared to the open group (13.8 vs 15.9 days, $p = 0.002$). Xu et al. previously reported shorter hospitalization following MISS (14.1 vs 15.8 days, $p = 0.003$), which mirrors the present results [7]. A meta-analysis by Verlaan et al. also confirmed reduced hospital stay duration with MISS across multiple prospective and retrospective studies [14]. In contrast, Afolabi et al. did not find significant differences in hospital stay between MISS and open surgery [8]. However, their cohort included a wide range of injury severities and comorbid conditions, potentially confounding length of stay outcomes. Recent work by Paterakis et al. highlighted that hospital stay benefits of MISS are most pronounced in younger, healthier patients with isolated thoracolumbar injuries [15].

One of the most notable findings of this study was the earlier mobilization achieved in the MISS group, with a mean of 3.4 days compared to 4.8 days in the open group ($p < 0.001$). Early mobilization is critical in preventing postoperative complications such as deep vein thrombosis, pulmonary compromise, and muscle deconditioning. Murans et al. reported significantly earlier return to ambulation and functional recovery in MISS patients [9]. Similarly, Versteeg et al. demonstrated faster mobilization and improved early quality-of-life outcomes in minimally invasive thoracolumbar stabilization [16]. This finding aligns with the recognized advantages of tissue-sparing approaches in reducing postoperative pain and facilitating earlier activity. Fan et al. noted that MISS allowed patients to achieve functional milestones, including standing and walking, more rapidly than the open approach, contributing to improved rehabilitation trajectories [17]. These benefits are of particular importance in trauma populations, where early mobility

reduces risks of secondary complications and accelerates return to daily activities.

Taken together, the present study adds to a growing body of evidence supporting MISS as an effective alternative to the conventional open approach for thoracolumbar fractures. The demonstrated reductions in operative time, pain, hospital stay, and mobilization time translate into tangible improvements in patient recovery and resource utilization. Furthermore, reduced surgical trauma and shorter recovery may facilitate earlier return to occupational and social functioning, which is particularly relevant in the predominantly young adult trauma population. However, it must be emphasized that MISS is not without limitations. The requirement for intraoperative fluoroscopy increases radiation exposure to both patient and surgical team [18]. Additionally, in cases with severe comminution, canal compromise, or need for fusion, open surgery may remain the preferred modality [4].

The findings of this study are broadly consistent with systematic reviews and meta-analyses that have confirmed the superiority of MISS in perioperative outcomes without compromising radiological or functional results [4, 12, 16]. At the same time, controversies persist regarding long-term outcomes such as implant stability, fusion rates, and adjacent segment degeneration. Schwendner et al. reported no significant difference in long-term alignment and fusion rates between MISS and open fixation [19]. Future prospective multicenter randomized trials with extended follow-up are warranted to address these issues.

While the study demonstrated significant advantages of MISS, some limitations must be acknowledged. The quasi-experimental design, though pragmatic, does not eliminate selection bias entirely. The relatively small sample size in ASA Class III patients limited statistical power for this subgroup. Additionally, follow-up was restricted to the early postoperative period; therefore, long-term radiological and functional outcomes could not be assessed.

CONCLUSION

This study demonstrated that minimally invasive spine stabilization is associated with shorter operative time, reduced postoperative pain, decreased hospital stay, and earlier mobilization compared to the open conventional approach in thoracolumbar traumatic spine fractures. These advantages were consistent across most patient subgroups, underscoring MISS as a superior surgical strategy in appropriately selected trauma patients. Future large-scale randomized trials with long-term follow-up are needed to validate these findings and assess sustained outcomes.

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