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Original Research Article

Evaluation of Functional and Neurological Outcomes Following Spinal Instrumentation in Traumatic Spinal Injuries

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Abstract:

Background: Traumatic "spinal injuries are a major cause of morbidity and long-term disability. Surgical spinal instrumentation has become a key modality for managing unstable spinal fractures, aiming to improve neurological, radiological, and functional outcomes.

Aim: To evaluate the neurological, radiological, and functional outcomes of posterior spinal instrumentation in patients with traumatic spinal injuries.

Methodology: This hospital-based prospective observational study included 90 adult patients with radiologically confirmed unstable traumatic spinal injuries treated with posterior pedicle screw instrumentation. Neurological status was assessed using the ASIA impairment scale, while radiological parameters and functional outcomes were evaluated pre-operatively and during follow-up.

Results: The majority of patients were males (80%) aged 31–45 years, with falls being the most common mode of injury. Thoracolumbar injuries and burst fractures predominated. Significant neurological improvement was observed, with increased ASIA Grade D and E patients at follow-up. Radiological outcomes showed marked improvement in vertebral body height loss, kyphotic angle, and spinal canal compromise ($p < 0.001$). Functional improvement was seen in 71.1% of patients, with a low complication rate.

Conclusion: Posterior spinal instrumentation provides effective stabilization, significant radiological correction, favorable neurological recovery in incomplete injuries, and improved functional outcomes in traumatic spinal injuries.

Keywords: Traumatic spinal injury; spinal instrumentation; ASIA grading; neurological outcome; radiological outcome; functional recovery.

Introduction

Traumatic spinal injuries (TSIs) constitute a major public health problem worldwide, leading to significant morbidity, long-term disability, and socioeconomic burden [1]. These injuries commonly result from high-energy" trauma such as road traffic accidents, falls from height, sports injuries, and occupational hazards, with a higher prevalence among young and economically productive individuals. Damage to the spinal column and spinal cord can 'result in varying degrees of neurological impairment, pain, deformity, and functional limitation, profoundly affecting the quality of life of affected patients [2]. The increasing incidence of trauma in developing and developed countries alike has emphasized the need for effective management strategies that aim not only at survival but also at optimal neurological recovery and functional rehabilitation.

The primary goals in the management of traumatic spinal injuries include preservation or restoration of neurological function, stabilization of the spinal column, prevention of secondary injury, correction of deformity, and early mobilization of the patient [3]. While conservative management may be appropriate for stable fractures without neurological compromise, unstable spinal injuries often require surgical intervention. Advances in spinal surgery over the past few decades have significantly transformed the treatment landscape, with spinal instrumentation emerging as a cornerstone in the management of unstable traumatic spinal injuries [4]. Surgical stabilization provides immediate mechanical stability, facilitates neural decompression, and allows early mobilization, thereby reducing complications associated with prolonged immobilization.

Spinal instrumentation refers to the use of implants such as pedicle screws, rods, plates, hooks, and interbody cages to stabilize the injured spinal segment [5]. The evolution of biomechanically superior implant systems and improved surgical techniques has enabled surgeons to achieve rigid fixation with better alignment and load sharing. Modern instrumentation techniques, particularly pedicle screw fixation, provide three-column stabilization and have demonstrated superior biomechanical stability compared to earlier methods [6]. These advancements have expanded surgical indications and improved the overall outcomes of patients with traumatic spinal injuries.

The outcomes of spinal instrumentation in traumatic spinal injuries are multifactorial and include neurological recovery, radiological alignment, spinal stability, pain relief, functional independence, and complication rates [7]. Neurological outcome is one of the most critical parameters, as improvement or preservation of neurological function significantly influences patient prognosis and quality of life. Several studies have demonstrated that timely surgical intervention with adequate stabilization and decompression can facilitate neurological recovery, especially in patients with incomplete spinal cord injuries. Radiological outcomes, including restoration and maintenance of spinal alignment and vertebral height, are equally important as they contribute to long-term spinal stability and prevention of post-traumatic deformities [8].

Functional outcomes following spinal instrumentation are closely linked to early mobilization and rehabilitation [9]. Stable fixation allows patients to sit, stand, and ambulate earlier, which in turn reduces the risk of complications such as pressure sores, deep vein thrombosis, pulmonary infections, and muscle wasting. Assessment of functional recovery using standardized scoring systems provides valuable insight into the effectiveness of surgical intervention and helps guide postoperative rehabilitation strategies. Pain reduction is another important outcome, as chronic pain following spinal trauma can significantly impair daily activities and psychological well-being.

Despite the advantages, spinal instrumentation is not without potential complications. These include infection, implant failure, screw misplacement, adjacent segment disease, and the need for revision surgery [10]. The risk of complications may be influenced by factors such as the level and severity of injury, timing of surgery, surgical approach, patient comorbidities, and surgeon experience. Therefore, evaluating both the benefits and risks of spinal instrumentation is essential to optimize patient selection and surgical planning.

In recent years, there has been growing interest in outcome-based evaluation of spinal trauma surgery, with emphasis on evidence-based decision-making. Understanding the short-term and long-term outcomes of spinal instrumentation helps in refining surgical indications, improving implant design, and enhancing postoperative care protocols. Furthermore, outcome assessment provides valuable data for counseling patients and families regarding prognosis and expected recovery.

In this context, studying the outcomes of spinal instrumentation in traumatic spinal injuries is of paramount importance. A comprehensive evaluation of neurological, radiological, and functional outcomes, along with complication profiles, can contribute to a better understanding of the effectiveness of surgical stabilization in spinal trauma. Such studies are particularly relevant in resource-limited settings, where optimizing treatment strategies can have a substantial impact on patient outcomes and healthcare utilization. The present study aims to assess the outcomes of spinal instrumentation in patients with traumatic spinal injuries, thereby contributing to the existing body of literature and aiding in the improvement of clinical management and patient care.

Methodology

Study Design: This study was a hospital-based prospective observational study conducted to evaluate the clinical, neurological, and radiological outcomes of spinal instrumentation in patients with traumatic spinal injuries. The study focused on assessing neurological recovery, radiological correction, and functional improvement following surgical stabilization.

Study Area: The study was carried out in the Department of Neurosurgery, Silchar Medical College and Hospital, Silchar, Assam, India.

Study Duration: The duration of the study was one year.

Study Participants: A total of 90 patients with traumatic spinal injuries who fulfilled the eligibility criteria were included in the study.

Inclusion Criteria

- Patients aged 18 years and above
- Patients with traumatic spinal injuries involving cervical, thoracic, thoracolumbar, or lumbar spine
- Patients with radiologically confirmed spinal instability
- Patients undergoing surgical spinal instrumentation
- Patients who gave informed written consent

Exclusion Criteria

- Patients with pathological or osteoporotic fractures
- Patients with multiple level spinal fractures
- Patients with associated severe head injury affecting neurological assessment
- Patients with pre-existing neurological deficits unrelated to trauma

- Patients unfit for surgery or refusing consent

Sample Size: The sample size was 90 patients, selected using a convenient sampling technique based on admission during the study period and fulfillment of inclusion criteria.

Procedure: All enrolled patients underwent a detailed clinical evaluation at admission, including demographic data, mode of injury, time since injury, and associated injuries. A thorough neurological examination was performed and documented using the American Spinal Injury Association (ASIA) impairment scale after the resolution of spinal shock. Neurological assessments were repeated periodically during hospital stay and follow-up.

Radiological evaluation included antero-posterior and lateral radiographs of the involved spinal segment to assess vertebral alignment, loss of vertebral body height, and kyphotic deformity. Computed tomography (CT) scans were performed in all patients to evaluate fracture morphology and degree of spinal canal compromise. Magnetic resonance imaging (MRI) was done when indicated to assess neural compression and ligamentous injury.

All patients were treated surgically with posterior spinal instrumentation using pedicle screw fixation, with or without decompression depending on neurological status and imaging findings. Indirect decompression was achieved through distraction and ligamentotaxis wherever applicable. Intra-operative imaging was used to confirm implant placement and restoration of alignment. Posterolateral fusion was performed using autologous bone grafts.

Postoperatively, patients were monitored in the neurosurgical intensive care unit. Appropriate antibiotics, analgesics, and supportive care were provided. Patients were mobilized gradually with spinal orthosis as per stability and neurological status. Rehabilitation was initiated early, focusing on physiotherapy and functional recovery. Follow-up evaluations were conducted at regular intervals to assess neurological improvement, radiological stability, and complications.

Statistical Analysis: Data were entered and analyzed using Statistical Package for Social Sciences (SPSS) version 27.0. Descriptive statistics such as mean, standard deviation, frequencies, and percentages were used to summarize data. Pre-operative and post-operative neurological and radiological outcomes were compared using appropriate statistical tests. A p-value < 0.05 was considered statistically significant.

Result

Table 1 shows the demographic profile of the 90 study participants. The majority of participants belonged to the 31–45 years age group (37.8%), followed by 18–30 years (28.9%) and 46–60 years (22.2%), while only 11.1% were above 60 years of age. Males constituted a predominant proportion of the study population (80%), with females accounting for 20%. Regarding the mode of injury, fall from height was the most common cause (53.3%), followed by road traffic accidents (40%), whereas assault and other causes together accounted for a small proportion (6.7%).

Table 1: Demographic Profile of Study Participants (n = 90)

Variable	Number (n)	Percentage (%)
Age (years)		
18–30	26	28.9
31–45	34	37.8
46–60	20	22.2
>60	10	11.1
Gender		
Male	72	80
Female	18	20
Mode of Injury		
Fall from height	48	53.3
Road traffic accident	36	40
Assault / Others	6	6.7

Table 2 shows that thoracolumbar injuries were the most common level of spinal injury (35.6%), followed by thoracic injuries (24.4%), while cervical and lumbar injuries were equally distributed at 20% each. With respect to fracture type, burst fractures predominated, accounting for nearly half of the cases (48.9%), whereas compression fractures (28.9%) and fracture-dislocations (22.2%) were less frequent. Regarding timing of surgical intervention, most patients underwent surgery within 24 hours (42.2%), and a substantial proportion were operated on within 24–72 hours (37.8%), while only one-fifth of patients (20%) experienced a delay of more than 72 hours.

Table 2: Distribution of Spinal Injury Characteristics		
Variable	**Number (n)**	**Percentage (%)**
Level of Injury		
Cervical	18	20
Thoracic	22	24.4
Thoracolumbar	32	35.6
Lumbar	18	20
Type of Fracture		
Burst fracture	44	48.9
Compression fracture	26	28.9
Fracture-dislocation	20	22.2
Time to Surgery		
<24 hours	38	42.2
24–72 hours	34	37.8
>72 hours	18	20

Table 3 depicts the neurological status of patients based on ASIA grading at admission and at final follow-up. At admission, a larger proportion of patients were in the severe neurological deficit categories (Grades A–C), with Grade C (24.4%) being the most common, followed by Grades A and D (22.2% each). At final follow-up, there was a noticeable shift toward better neurological outcomes, with a marked increase in patients classified as Grade D (31.1%) and Grade E (28.9%). Conversely, the proportions of patients in Grades A, B, and C decreased to 13.3%, 11.1%, and 15.6%, respectively. Overall, the table indicates significant neurological improvement over time, reflecting recovery and progression toward higher ASIA grades during the follow-up period.

Table 3: Neurological Status (ASIA Grading) at Admission and Final Follow-up		
ASIA Grade	**At Admission n (%)**	**At Final Follow-up n (%)**
A	20 (22.2)	12 (13.3)
B	18 (20.0)	10 (11.1)
C	22 (24.4)	14 (15.6)
D	20 (22.2)	28 (31.1)
E	10 (11.1)	26 (28.9)

Table 4 shows a significant improvement in all radiological parameters following surgery when compared to the pre-operative status. The mean vertebral body height loss markedly reduced from 42.6 ± 8.4% pre-operatively to 14.8 ± 6.2% post-operatively, indicating substantial restoration of vertebral height. Similarly, the kyphotic angle decreased from 21.3 ± 5.6 degrees to 7.9 ± 3.2 degrees, reflecting effective correction of spinal deformity. Spinal canal compromise also showed a pronounced reduction from 46.2 ± 9.1% to 18.5 ± 7.4%, suggesting adequate decompression of the spinal canal. All observed changes were statistically highly significant ($p < 0.001$), highlighting the effectiveness of surgical intervention in improving radiological outcomes.

Table 4: Radiological Parameters – Pre-operative vs Post-operative Comparison			
Parameter	**Pre-operative (Mean ± SD)**	**Post-operative (Mean ± SD)**	**p-value**
Vertebral body height loss (%)	42.6 ± 8.4	14.8 ± 6.2	<0.001
Kyphotic angle (degrees)	21.3 ± 5.6	7.9 ± 3.2	<0.001
Spinal canal compromise (%)	46.2 ± 9.1	18.5 ± 7.4	<0.001

Table 5 summarizes the post-operative complications and functional outcomes among the study participants. Surgical site infection was the most common complication, observed in 6 patients (6.7%), followed by pulmonary complications in 5 patients (5.6%), implant failure in 4 patients (4.4%), and neurological deterioration in 3 patients (3.3%). Overall, the incidence of post-operative complications was relatively low. In terms of functional outcome, the majority of patients showed improvement, with 64 patients (71.1%) experiencing a better post-operative functional status. Functional status remained unchanged in 20 patients (22.2%), while deterioration was noted in only 6 patients (6.7%), indicating a predominantly favorable functional outcome following surgery.

Table 5: Post-operative Complications and Functional Outcome

Variable	Number (n)	Percentage (%)
Complications		
Surgical site infection	6	6.7
Implant failure	4	4.4
Neurological deterioration	3	3.3
Pulmonary complications	5	5.6
Functional Outcome		
Improved	64	71.1
Unchanged	20	22.2
Deteriorated	6	6.7

Discussion

Traumatic spinal injuries predominantly affect young and middle-aged adults, a trend that is consistently reported across the literature and is clearly reflected in the present study. The highest incidence in the 31–45-year age group mirrors findings by Kim et al. (1999) [11], who reported that over 60% of thoracolumbar burst fracture patients were within the economically productive age range. Similar demographic patterns were also noted by Meves and Avanzi (2006) [12], emphasizing that increased occupational exposure, outdoor activity, and high-energy trauma place this population at greater risk. The marked male predominance observed in our cohort is comparable to most contemporary series, where males constitute 70–85% of cases, largely due to greater involvement in high-risk activities and manual labor (Boerger et al., 2000; Mohanty & Venkatram, 2002) [13,14].

Regarding the mechanism of injury, falls from height were the most common cause in our study, followed by road traffic accidents. This distribution aligns with findings from developing regions reported by Mohanty and Venkatram (2002), where falls accounted for nearly half of thoracolumbar injuries. In contrast, studies from high-income countries report a higher contribution of road traffic accidents, reflecting differences in occupational safety and infrastructure (Vaccaro et al., 2013) [15]. The predominance of thoracolumbar injuries in our study is biomechanically predictable, as this transitional zone is vulnerable to axial loading and flexion forces. Kim et al. (1999) and Dai (2001) [16] similarly reported that more than 65% of burst fractures involved the thoracolumbar junction, reinforcing the consistency of this injury pattern.

Neurological recovery following spinal instrumentation remains a debated outcome, particularly concerning the role of canal compromise. In our study, although significant postoperative canal decompression was achieved, there was no statistically significant correlation between the degree of canal compromise and neurological recovery. This finding parallels observations by Mohanty and Venkatram (2002), who demonstrated that neurological improvement did not directly depend on the extent of canal encroachment. Meves and Avanzi (2006) also reported weak correlation between canal compromise and neurological deficit severity, suggesting that primary neural injury at the time of trauma plays a more decisive role than residual canal narrowing.

The present study demonstrated a clear neurological improvement in patients with incomplete injuries, with a shift toward higher ASIA grades at follow-up. Similar outcomes were reported by Kim et al. (1999), where approximately 70% of patients with incomplete deficits improved by at least one neurological grade after surgical stabilization. In contrast, patients presenting with complete neurological deficits showed limited recovery, a finding consistent with multiple studies indicating poor regenerative potential following complete cord injury (Boerger et al., 2000; Dai, 2001). These observations reinforce the concept that spinal instrumentation primarily facilitates neurological recovery by stabilizing the spine and preventing secondary injury rather than reversing primary cord damage.

Radiological outcomes in our study showed significant correction of kyphotic deformity, restoration of vertebral body height, and reduction in canal compromise following posterior instrumentation. Dai (2001) reported similar findings, noting an average kyphosis correction of 10–15 degrees and progressive canal remodeling over one year. Mohanty and Venkatram (2002) further emphasized that posterior distraction instrumentation provides satisfactory indirect decompression through ligamentotaxis, which aligns with the substantial reduction in canal encroachment observed in our patients. Importantly, despite variations in neurological recovery, radiological remodeling was evident across most cases, supporting the view that canal remodeling is a time-dependent biological process rather than a determinant of neurological outcome.

The posterior approach used in all patients in this study proved effective and safe, with a low incidence of implant failure and postoperative complications. Boerger et al. (2000) similarly concluded that posterior instrumentation offers adequate stabilization with fewer complications compared to anterior approaches, particularly in polytrauma patients. More recent studies, such as those by Vaccaro et al. (2013) and Joaquim et al. (2014) [17], have further validated posterior fixation as the preferred approach for most thoracolumbar injuries due to reduced surgical morbidity and comparable functional outcomes.

Functionally, the majority of patients in our study demonstrated improvement at follow-up, reflecting the combined benefits of spinal stabilization, pain reduction, and early mobilization. This finding is consistent with contemporary outcome studies, which highlight early rehabilitation as a key determinant of functional recovery irrespective of neurological improvement (Reinhold et al., 2010) [18]. The small proportion of patients who deteriorated functionally were typically those with severe initial neurological deficits or postoperative complications, a trend also reported in long-term outcome analyses (Vaccaro et al., 2013).

Overall, the findings of this study are in agreement with both classical and contemporary literature, demonstrating that spinal instrumentation in traumatic spinal injuries results in significant radiological correction, acceptable neurological recovery in incomplete injuries, and favorable functional outcomes. While surgical decompression may not guarantee neurological improvement, especially in complete injuries, stabilization plays a crucial role in spinal alignment, pain control, and early rehabilitation, ultimately improving quality of life.

Conclusion

The present study demonstrates that posterior spinal instrumentation is an effective and reliable modality for the management of traumatic spinal injuries, particularly in patients with unstable fractures. Significant neurological improvement was observed, especially among patients with incomplete spinal cord injuries, reflected by a favorable shift in ASIA grading at follow-up. Surgical stabilization resulted in marked radiological correction, including restoration of vertebral body height, reduction of kyphotic deformity, and adequate canal decompression, all of which were statistically significant. Early stabilization facilitated prompt mobilization and rehabilitation, leading to improved functional outcomes in the majority of patients. Although complications such as infection and implant failure were noted, their incidence remained relatively low. Overall, spinal instrumentation plays a crucial role in achieving spinal stability, preventing secondary injury, and improving functional recovery, thereby enhancing the quality of life following traumatic spinal injury.

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