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Factors associated with quality of life after traumatic thoracolumbar spine injury: a narrative review

Abstract

Background: Traumatic thoracolumbar spine injuries are a major cause of persistent pain, functional limitation, and reduced quality of life (QoL), even in the absence of severe neurological impairment. Although numerous studies have examined individual aspects of outcome after these injuries, the determinants of long-term QoL remain fragmented across the literature. This review aimed to analyse and systematise factors associated with QoL and functional outcomes in adult patients following traumatic thoracolumbar spine injury.

Methods: This study was conducted as a narrative review with a structured literature search. PubMed, Embase, and the Cochrane Library were searched using database-specific strategies focused on thoracolumbar fractures, quality of life, functional outcome, deformity, sagittal balance, and other clinically relevant sequelae. Titles, abstracts, and full texts were screened, with eligibility assessment performed independently by three reviewers and disagreements resolved by consensus. Articles published in English were considered eligible. Given the marked clinical and methodological heterogeneity of the available evidence, a quantitative meta-analysis was not performed; instead, the data were synthesised narratively.

Results: A total of 154 publications were included. For analytical synthesis, all factors associated with QoL after thoracolumbar spine injury were grouped into five domains: demographic and baseline factors, clinical factors, radiological factors, treatment-related factors, and psychosocial/rehabilitation-related factors. The most consistent adverse predictors of long-term outcome were initial neurological deficit, limited neurological recovery, persistent pain, and functional disability. Additional influential factors included age, comorbidity, osteoporosis, injury severity, sagittal alignment, treatment complications, return to work, psychological status, and the broader psychosocial context. Radiological success alone did not reliably correspond to patient-perceived recovery. Surgical treatment generally provided faster short-term improvement, but its long-term superiority over conservative treatment in stable fractures without neurological deficit remained unproven.

Conclusions: Quality of life after traumatic thoracolumbar spine injury is multifactorially determined and cannot be explained by any single clinical, radiological, or technical parameter. Long-term outcome reflects the interaction between injury severity, treatment effectiveness, residual symptoms, and the patient's capacity for functional, psychological, and social adaptation. These findings support a personalised, multidisciplinary approach to treatment planning and outcome assessment, with greater emphasis on patient-reported outcomes alongside radiological and technical results.

Keywords: thoracolumbar spine injury, spinal fractures, quality of life, functional outcome, neurological recovery, sagittal balance, kyphosis, rehabilitation, patient-reported outcomes, treatment outcome

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Introduction

Traumatic injuries of the spine remain among the most challenging and clinically consequential problems in modern trauma surgery, orthopaedics, and neurosurgery. A particularly important subset involves the thoracolumbar junction (Th11–L2), a biomechanically vulnerable transition zone between the relatively rigid thoracic spine and the more mobile lumbar segment. According to published literature, this region accounts for 50–70% of all spinal fractures.[1] In younger and middle-aged patients, such injuries typically result from high-energy mechanisms-road traffic accidents, falls from height, and occupational trauma-whereas in elderly patients with underlying osteoporosis, comparable fractures can occur even after low-energy events.[1–6]

The clinical importance of thoracolumbar injuries extends well beyond the immediate risk of neurological deterioration or the need for surgical stabilization. Even in the absence of major neurological deficits, a substantial proportion of patients continue to experience chronic pain, functional limitations, reduced physical activity, difficulties with social and occupational reintegration, and psychological disturbances- all of which contribute to a lasting decline in quality of life. For this reason, evaluating outcomes in this patient group cannot be limited to imaging data, the degree of deformity correction, or the achievement of bony union.

In the context of spinal trauma, quality of life (QoL) is a multidimensional, patient-centred construct encompassing physical, psychological, and social functioning after injury and treatment. Clinical research typically employs both generic instruments such as the SF-36 and EQ-5D and more condition-specific scales focused on pain intensity and functional disability, including the ODI, RMDQ, and VAS. Even with standardised tools, however, interpreting long-term results remains challenging: neurological status, pain, post-

traumatic deformity, residual sagittal imbalance, treatment modality, age, comorbidities, osteoporosis, and psychosocial factors all influence QoL simultaneously.

Despite a large body of published work on thoracolumbar injuries, the available evidence remains fragmented and heterogeneous. Some studies focus predominantly on radiological parameters and mechanical stability; others examine neurological recovery or compare surgical versus conservative approaches. The factors that determine long-term QoL are frequently analysed in isolation, and their relative contribution to final functional outcomes remains a matter of debate. This makes it difficult to build a coherent picture of prognostically relevant determinants of recovery and limits opportunities for individualising treatment decisions.

The aim of this review is to analyse and systematise the factors associated with quality of life and functional outcomes in adult patients following traumatic thoracolumbar spine injuries, with a focus on clinical, radiological, treatment-related, and psychosocial predictors of long-term results.

Materials and methods

This work was conducted as a narrative literature review with a structured search strategy and synthesis of results. The objective was to identify and analyse factors associated with quality of life, functional outcomes, and long-term results in adult patients with traumatic thoracolumbar spine injuries.

The literature search was conducted in the PubMed, Embase, and Cochrane Library electronic databases. The PubMed search strategy was as follows: ("Spinal Fractures"[MeSH Terms] OR fracture[Title/Abstract]) AND (thoracolumbar[Title/Abstract] OR ("Thoracic Vertebrae"[MeSH Terms] AND "Lumbar Vertebrae"[MeSH Terms])) AND ("Quality of Life"[MeSH Terms] OR "Treatment Outcome"[MeSH Terms] OR kyphosis[Title/Abstract] OR "loss of correction"[Title/Abstract] OR "sagittal balance"[Title/Abstract] OR "functional outcome"[Title/Abstract] OR outcome[Title/Abstract] OR functional[Title/Abstract]) NOT (child[MeSH Terms] OR adolescent[MeSH Terms] OR neoplasms[MeSH Terms]). Comparable search strategies were developed for Embase and the Cochrane Library using the corresponding controlled vocabulary and database-specific syntax. The search aimed to identify publications addressing outcomes after thoracolumbar fractures, including quality of life, functional recovery, post-traumatic deformity, loss of correction, sagittal alignment, and other clinically relevant sequelae.

Initial screening was based on title and abstract review. Publications considered potentially relevant were subsequently assessed by full-text analysis. An additional hand-search of reference lists from selected full-text articles was performed to identify publications not captured by the primary search. Only articles published in English were eligible for inclusion.

Eligibility assessment was conducted independently by three reviewers, with disagreements resolved by discussion and consensus. This approach was intended to minimise the risk of subjective bias in study selection.

Studies were included if they enrolled adult patients with traumatic thoracolumbar spine injuries and reported on clinical, functional, radiological, or patient-reported outcomes-including quality of life, pain, neurological status, post-traumatic deformity, loss of correction, sagittal balance parameters, and results of surgical or conservative treatment. Original clinical studies, literature reviews, and additional relevant publications identified through manual reference searches were all considered.

Excluded from the review were studies focused exclusively on paediatric or adolescent populations, publications on neoplastic spinal lesions, and works that provided no data relevant to quality of life, functional recovery, or long-term outcomes following thoracolumbar injury.

Given the considerable clinical and methodological heterogeneity among the available publications-reflecting differences in patient populations, injury types, treatment approaches, follow-up duration, and outcome measurement instruments-a formal quantitative meta-analysis was not performed. Data synthesis was carried out using a narrative approach: results from individual studies were compared, recurring patterns were identified, contradictions were noted, and the clinical relevance of each discussed factor was assessed.

Results

After a structured literature search, screening, and full-text assessment, 154 publications were included in the review. The main characteristics of the included studies are presented in Supplementary Table S1. For the subsequent analytical synthesis, all factors associated with quality of life after thoracolumbar spine injury were grouped into five thematic domains: demographic and baseline factors, clinical factors, radiological factors, treatment-related factors, and psychosocial and rehabilitation-related factors.

Demographic and baseline factors

Age

Age is one of the most influential demographic variables affecting long-term outcomes and quality of life after thoracolumbar spine injury. Its effects are multifactorial, reflecting both biological and clinical realities. Older patients typically have diminished tissue regenerative capacity, higher rates of osteoporosis, sarcopenia, and comorbid illness- all of which impair their ability to tolerate injury, constrain treatment options, complicate rehabilitation, and increase the risk of mechanical and systemic complications.[3–7] Even when anatomical or radiological outcomes are formally adequate, functional recovery in elderly patients is frequently less complete.[3,4,8]

The literature broadly supports the association between advancing age and less favourable functional outcomes. Soultanis et al.,[8] in a retrospective study of 75 patients treated conservatively for vertebral compression fractures, found a statistically significant correlation between age and higher ODI disability scores at 3.5 years of follow-up (p=0.01). Chen et al.,[9] analysing predictors of kyphotic deformity recurrence after implant removal in 67 patients, also noted the effect of age, although it did not retain independent predictive value in a multivariate model. Belmont et al.,[2] studying a relatively young and physically fit cohort of military aviators, reported high rates of return to professional duties—an indirect indicator that younger, healthier populations tend to recover more fully.

That said, the independent contribution of age should be interpreted with some caution. In many cases, its effect likely operates through closely associated factors: reduced bone mineral density, comorbid illness, diminished muscle reserve, limited rehabilitation potential, and the different injury profile typical of older patients.[3–6] When studies control for neurological status, deformity severity, comorbidities, or surgical characteristics, the independent role of age may diminish accordingly.[7,9] Watanabe et al.,[7] for example, found no

clear difference in certain clinical outcomes between patients with Parkinson's disease who underwent spinal surgery and those without, despite a higher complication rate—highlighting how age and its associated conditions can exert complex, mediated effects rather than a straightforward direct influence.

Age is best understood not as a simple demographic variable but as a composite marker of reduced physiological reserve, compromised bone quality, and diminished recovery potential.[3–5] In practice, this has implications for risk stratification, treatment selection, determining the appropriate extent of fixation, setting realistic rehabilitation goals, and framing expectations about long-term quality of life.[2,8,9]

Sex

The role of sex in shaping long-term outcomes after thoracolumbar spine injury has received considerably less attention than age, neurological status, or deformity severity. In most cases, its influence appears to be indirect, mediated through differences in injury mechanism, patient age, bone quality, comorbid conditions, and individual patterns of pain perception and psychological adaptation. Men are overrepresented among high-energy injury patients, while women-particularly postmenopausal women-are more vulnerable to osteoporosis and its adverse mechanical and functional consequences.[2,10]

Direct comparative data on sex differences in quality of life after traumatic thoracolumbar injury are sparse. Belmont et al.,[2] studying military aviators, noted a marked male predominance reflecting the epidemiology of high-energy trauma rather than illuminating any sex-specific effect on outcomes. Hallberg et al.,[10] in a prospective seven-year study of women with osteoporotic vertebral fractures, demonstrated a persistent decline in QoL across most SF-36 domains compared to a reference population. However, these findings speak more to the vulnerability of a specific clinical subgroup-older women with fragility fractures-than to the independent role of sex per se.[10]

On current evidence, sex should be regarded as a contextual rather than an independent prognostic factor, one that is closely intertwined with age, injury mechanism, bone quality, and population characteristics.[2,10] Its clinical relevance is most meaningful when considered alongside associated variables-particularly osteoporosis risk in older women and the typical differences in injury mechanism between sexes. At present, the available data are insufficient to confidently identify sex as a standalone predictor of long-term QoL after thoracolumbar injury.

Comorbidity

Comorbid conditions represent an important cluster of factors that can significantly affect the course of treatment, rehabilitation potential, and long-term outcomes in patients with thoracolumbar spine injuries. Their adverse effects operate on multiple levels. Cardiovascular, pulmonary, and endocrine pathologies—including diabetes—can raise anaesthetic and surgical risk, increase perioperative complications, delay tissue healing, and limit participation in active rehabilitation. Beyond this, a pre-existing reduction in somatic reserve is itself associated with poorer physical functioning and lower QoL; a subsequent traumatic injury can then further destabilise an already fragile baseline.[4–7]

Available data consistently indicate that comorbidity affects primarily the safety of treatment and the rate of complications. The most illustrative evidence comes from Watanabe et al.,[7] who compared surgical outcomes in patients with and without Parkinson's disease. The presence of this serious neurodegenerative comorbidity was associated with a higher rate of perioperative complications, including delirium and pneumonia. Yet at two-year follow-up, ODI and VAS scores did not differ significantly between groups.[7] This suggests that comorbidity may have a greater impact on treatment tolerability and perioperative risk than on the ultimate functional trajectory.

In a number of studies, comorbidity manifests not only as a catalogue of chronic diseases but as a background state of heightened vulnerability to injury and its consequences. This is especially visible in research on elderly patients with osteoporosis, where reduced bone quality, age-related systemic impairment, and limited compensatory capacity create a clinical profile of elevated risk.[4–6] In this context, osteoporosis might be seen not merely as an isolated variable but as part of a broader comorbid burden-one that can compromise fixation stability, increase the risk of correction loss, and complicate postoperative recovery.[4–6]

On balance, the available evidence fairly consistently links comorbidity to a more complicated perioperative and rehabilitative course, though its direct effect on final QoL outcomes appears variable and likely depends on the specific pattern of comorbid disease, injury severity, treatment approach, and quality of perioperative management.[4–7] From a practical standpoint, assessing the comorbid background is essential for risk stratification, determining the appropriate scope of intervention, anticipating complications, and setting realistic expectations regarding functional recovery. A similar logic applies to other conditions that compromise consolidation potential and mechanical durability-including diffuse idiopathic skeletal hyperostosis, where even apparently stable low-energy fractures may unite poorly and carry higher rates of malunion.[11]

Osteoporosis and bone mineral density

Osteoporosis and reduced bone mineral density (BMD) rank among the most clinically significant factors affecting treatment outcomes in patients with thoracolumbar spine injuries. Their influence is twofold: osteoporosis increases fracture susceptibility even after low-energy trauma, and it substantially complicates subsequent management. Reduced bone mass and disrupted microarchitecture impair the holding power of pedicle screws, raising the risk of loosening, migration, and construct failure—which can lead to loss of correction, deformity progression, pseudarthrosis, and unsatisfactory functional recovery.[3–6] These considerations often necessitate longer instrumentation constructs, cement augmentation, or other technical modifications, making treatment more complex and potentially more invasive.[3,4]

The available literature consistently shows that an osteoporotic background substantially shapes the choice of treatment strategy and the nature of surgical stabilisation. Hu et al.,[3] in a retrospective study of 43 elderly patients with osteoporotic burst fractures, demonstrated that short-segment posterior fixation augmented with pedicle screws at the fractured vertebra combined with kyphoplasty can deliver reliable and safe results. The very existence of such purpose-built protocols reflects the need to adapt surgical strategy to compromised screw purchase in osteoporotic bone.[3] Komadina et al.,[4] Rajasekaran et al.,[5] and Schnake et al.,[6] all emphasise that osteoporotic vertebral fractures should be regarded as a distinct clinical category, requiring a tailored approach to diagnosis, risk stratification, and the choice between conservative, minimally invasive, and open surgical treatment.[4–6] Additional case series in patients with osteoporotic fractures and neurological deficits show that even in older age groups, surgical stabilisation and decompression—when technically adapted to bone quality-can yield meaningful pain relief, ODI improvement, and neurological recovery.[12]

What the literature debates, however, is not whether osteoporosis poses a problem-this is taken as given-but rather how best to account for it in the treatment plan. The main points of contention concern the choice between conservative therapy and surgical stabilisation, the indications for vertebroplasty or kyphoplasty, the need for cement augmentation, and the optimal construct length and configuration.[4–6] Osteoporosis, in other words, does not merely represent an unfavourable background; it can fundamentally reshape the architecture of the clinical decision. An additional layer of complexity arises from the fact that certain comorbid conditions-Parkinson's disease among them-may be associated with secondary bone density loss, further elevating the risk of mechanical complications.[7]

Osteoporosis and reduced BMD should therefore be considered key determinants of treatment complexity, the risk of mechanical failure, and the prospects for long-term functional recovery.[3–7] In practical terms, timely identification of compromised bone quality is essential for selecting the appropriate treatment strategy, modifying surgical technique, and reducing the likelihood of correction loss, fixation failure, and the need for revision surgery.

Smoking

Smoking is a potentially important adverse factor that may worsen treatment outcomes after thoracolumbar spine injuries through a combination of systemic and local effects on tissue repair. Nicotine and other components of tobacco smoke impair microcirculation and tissue oxygenation, disrupt osteoblast function and bone remodeling, and may thereby retard fracture consolidation and increase the risk of nonunion. Smoking is also associated with higher rates of infectious, thromboembolic, and respiratory complications, which can adversely affect both the tolerance of surgical treatment and the pace of functional recovery.

Direct studies specifically examining the effect of smoking on QoL after thoracolumbar injury are limited within the reviewed literature. The most relevant evidence comes from Vorlat et al.,[13] who analysed socioeconomic predictors of outcome following conservative treatment of compression fractures and identified smoking as one of the strongest adverse predictors of recovery. Although the study was not exclusively focused on patient-reported QoL measures, its findings clearly point to an association between tobacco use and a less favourable recovery trajectory.[13] Belmont et al.,[2] while not directly examining smoking in their military aviator cohort, described a population that was relatively young and physically fit with high rates of occupational return-suggesting, indirectly, that the absence of significant behavioural and somatic risk factors, including smoking, may facilitate better functional outcomes.[2]

Interpreting the available data requires caution. The specific evidence base for traumatic thoracolumbar injuries is limited, and part of the understanding of smoking's adverse role draws on broader spinal surgery literature-particularly regarding bone fusion and pseudarthrosis risk. Nevertheless, even within the reviewed sources, smoking emerges as a factor capable of impairing recovery not only through its biological effects on tissue healing but also through a general reduction in somatic reserve and a heightened susceptibility to complicated treatment courses.[13]

Smoking should be regarded as a clinically significant and potentially modifiable risk factor-one that may adversely affect healing, complication rates, and, indirectly, long-term functional outcomes and quality of life.[2,13] This gives particular weight to smoking cessation counselling, especially in patients planned for surgical treatment that requires reliable bony consolidation.

Clinical factors related to injury

Neurological status

Initial neurological deficit

Initial neurological status is among the most powerful clinical determinants of long-term outcomes after thoracolumbar spine injury. Its prognostic importance stems from the fact that damage to the spinal cord, conus medullaris, or cauda equina roots directly affects motor, sensory, and autonomic functions-and thereby the patient's independence, mobility, capacity for self-care, and ability to reintegrate professionally and socially. Severe neurological deficit is associated not only with higher rates of disability but with a pronounced decline in quality of life driven by persistent motor impairment, bladder and bowel dysfunction, neuropathic pain, spasticity, and the secondary complications of prolonged inactivity.[14–18]

The literature consistently confirms the close relationship between the severity of the initial neurological deficit, injury severity, and prognosis. Kim et al.,[14] in a retrospective study of 148 patients, showed that posterior osseous element disruption was associated with a significantly higher rate of initial neurological deficit compared to injuries without this component. Verlaan et al.,[15] in a systematic review of 5,748 patients, found that groups treated with anterior surgical approaches had more severe neurological deficits at baseline, while neurologically intact patients were more frequently found in posterior fixation cohorts-reflecting not any superiority of one approach but rather that the severity of neurological deficit is itself a key driver of treatment selection.[15]

This relationship is most striking in the most severe injury patterns. Sandquist et al.,[16] describing a case of traumatic spondyloptosis, emphasised that profound neurological deficit-including ASIA A status-is a characteristic feature of such catastrophically unstable injuries. Tezer et al.,[18] reporting on a series of patients with flexion-distraction fractures treated with combined approaches, noted pre-existing neurological deficits in all patients. Further evidence of prognostic significance comes from the prospective study by Goulet et al.,[17] in which baseline AIS status proved to be one of the few clinical parameters significantly associated with poor neurological recovery among patients with severe deficits following burst fractures.

The evidence for initial neurological deficit is arguably the most consistent and least controversial among the clinical predictors reviewed.[14–18] While individual studies differ in their assessment of which morphological features are associated with neurological injury, the role of initial neurological status as a principal determinant of functional recovery and long-term QoL is not seriously in doubt. In practical terms, this single factor does much to determine the urgency and extent of intervention, rehabilitation expectations, and the realistic prognosis for independence and quality of life.

Neurological recovery

The degree of neurological recovery after thoracolumbar spine injury carries independent clinical significance: it is this-rather than the initial deficit alone-that ultimately determines the extent to which impaired neurological function is translated into real functional independence. While the initial neurological status defines the starting severity, the subsequent trajectory of motor, sensory, and autonomic recovery reflects the patient's actual rehabilitation potential. Even modest improvement on ASIA or Frankel scales can translate into clinically meaningful gains in mobility, self-care, and social participation.[14,15,17–20]

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The literature broadly supports the view that patients with incomplete deficits have the greatest recovery potential. Verlaan et al.,[15] demonstrated in their review that partial deficits may carry a high potential for improvement regardless of the surgical approach chosen. Tezer et al.,[18] reported Frankel scale improvement in 8 of 11 patients with preoperative deficits following combined fixation. Similarly, Zahra et al.,[20], analysing outcomes of anterior corpectomy in patients with incomplete deficits, noted at least one-grade AIS improvement in 30% of patients. These findings are consistent with the clinical principle that an incomplete neurological injury provides more favourable conditions for subsequent functional recovery.[15,18,20]

The literature also makes clear that the trajectory of neurological recovery depends not only on the initial degree of deficit but on the morphological features of the injury. Goulet et al.,[17] found that beyond baseline AIS status, several radiological features-including displacement of the posterior-inferior vertebral body corner, the presence of a retropulsed comminuted fragment, and a complete laminar fracture-were independently associated with recovery potential. Interestingly, Kim et al.,[14] observed that posterior element disruption, despite being associated with more severe initial injury, was simultaneously linked to a higher likelihood of neurological improvement. The authors attributed this to a possible effect of relative spontaneous decompression of neural structures in certain injury configurations.[14] Such observations underscore the point that recovery prognosis emerges from a complex interplay between initial deficit severity, injury morphology, and the conditions for neural decompression.

The principal debate in the literature concerns not whether neurological recovery matters-that is self-evident-but rather the factors that promote or limit it, and the means of optimising its extent. Questions about the optimal timing of decompression, the choice of surgical approach, and the need for direct anterior column reconstruction remain actively discussed. Oner et al.,[19] concluded in their review that, for burst fractures with incomplete deficits, no single surgical approach demonstrates a clear or universal advantage in terms of neurological recovery-implying that timing, adequacy of decompression, injury severity, and the patient's biological recovery potential may matter more than the approach itself.[19] Analogously, in severe fracture-dislocations and flexion-distraction injuries, neurological recovery following reconstructive surgery remained the principal determinant of subsequent functional outcome.[21]

Neurological recovery trajectory must be considered a central component of long-term outcome in patients with spinal trauma.[14,15,17–20] The degree and completeness of recovery largely determine subsequent functional independence, rehabilitation potential, and ultimate quality of life. Practically, this makes estimating the likelihood of neurological improvement one of the most important considerations in treatment planning, prognostic counselling, and setting rehabilitation priorities.

Injury severity

Polytrauma and ISS

The severity of concomitant injury is an important clinical factor with the potential to significantly affect treatment course, rehabilitation potential, and long-term QoL in patients with thoracolumbar spine injuries. In polytrauma, the overall burden is defined not only by the vertebral fracture itself but by the cumulative impact of multiple injuries affecting vital organs and other anatomical regions. Traumatic brain injury, chest or abdominal trauma, long bone fractures, and other components of combined injury can independently contribute to lasting disability, impede early mobilisation, and delay return to functional independence. Moreover, severe overall injury may limit the feasibility of timely and optimal surgical treatment for the spinal component, while prolonged intensive care, staged interventions, and physiological strain further slow rehabilitation.[15,17]

The available data confirm the unfavourable role of high overall injury severity. Goulet et al.,[17] in a prospective study of patients with burst fractures and neurological deficits, found that a high ISS-alongside baseline neurological status-was one of the few clinical factors independently associated with poor neurological recovery. This is particularly noteworthy because it directly links polytrauma severity to one of the key components of subsequent QoL: the potential for neurological deficit to resolve.[17] Verlaan et al.,[15] similarly found that patients requiring more aggressive surgical stabilisation strategies had higher rates of polytrauma than those managed with less extensive posterior constructs, suggesting that polytrauma tends to accompany a more severe initial clinical profile and frequently co-occurs with more complex injury morphology.[15]

Polytrauma probably affects outcomes not through a single pathway but through several interacting mechanisms: elevated complication risk, constrained treatment options in the acute phase, delayed active rehabilitation, and an amplification of functional deficit from the sum of extra-spinal injuries.[15,17] It is therefore important, when interpreting outcomes, to recognise that a high ISS reflects not just a background characteristic but the total biological cost of trauma-a cost that can impair both neurological recovery and the patient's long-term physical and social adaptation.

Polytrauma and a high ISS should be considered clinically significant adverse prognostic factors in patients with thoracolumbar spine injuries.[15,17] Accounting for them is essential for risk stratification, prioritising acute-phase management, interpreting functional outcomes, and forming prognostic estimates regarding subsequent quality of life.

Fracture type and AO/magerl morphology

The fracture type according to the AO/Magerl classification is one of the key injury characteristics, as it reflects the mechanism of trauma, the degree of biomechanical instability, and the likelihood of involvement of different structural columns. Type A compression and burst fractures predominantly affect the anterior column; type B injuries involve a distraction component with posterior ligamentous disruption; and type C fractures carry the highest instability due to rotational displacement and three-column involvement. This gradation has direct clinical relevance: as morphological severity increases, so does the risk of secondary displacement, deformity progression, persistent pain, neurological complications, and the need for more rigid and extensive stabilization-all of which can ultimately affect functional outcomes and QoL.[2,22,23]

In the available literature, fracture type is more commonly used as a determinant of treatment strategy and risk profile than as a direct predictor of QoL in its own right. Medici et al.,[22] in a prospective study, showed that patients with type A1/A2 fractures achieved better outcomes with percutaneous stabilisation than with conservative treatment, highlighting the relevance of injury morphology in selecting the optimal approach. Verlaan et al.,[15] noted that more severe type B and C injuries were more frequently found in long-segment and combined fixation groups, reflecting the need for more aggressive stabilisation in the context of pronounced instability. Fracture morphology thus substantially determines not only the extent of intervention but also the inherent complexity of the clinical situation.[2,22]

The prognostic value of morphological classification is further illustrated in specific clinical contexts. Mayle et al.,[23] describing a Chance fracture in a patient with ankylosing spondylitis, emphasised that even relatively low-energy mechanisms can produce catastrophically unstable injuries when spinal biomechanics are already compromised. This underscores the point that the prognostic significance of fracture morphology is inseparable from the characteristics of the underlying spinal segment and any background pathology.[23]

The AO/Magerl classification carries important prognostic and practical weight, though its influence on QoL in most studies operates primarily indirectly-through its determination of instability, complication risk, and treatment strategy.[2,22,23] From a clinical perspective, fracture type serves as one of the fundamental reference points for assessing injury severity, stratifying risk, and selecting the extent of stabilisation, which makes it a meaningful element in forecasting the long-term functional result.

Posterior ligamentous complex injury

Posterior ligamentous complex (PLC) injury is one of the defining features of spinal instability in thoracolumbar trauma. The PLC-comprising the supraspinous and interspinous ligaments, the ligamentum flavum, and the facet joint capsular structures-plays a critical role in resisting flexion and distraction loads. Its disruption, particularly in flexion-distraction injuries, produces pronounced mechanical instability, increases the risk of progressive kyphotic deformity, and can contribute to chronic pain driven by micromotion and, in some cases, to neurological deterioration. This is why PLC integrity occupies a central place in modern decision algorithms for choosing between conservative and surgical management.[19,24]

The available data consistently emphasise the high clinical significance of PLC disruption. Oner et al.,[19] in a systematic review, concluded that complete disruption of the posterior ligamentous complex should be regarded as a strong argument for surgical treatment of thoracolumbar burst fractures. Although this conclusion is based on a limited evidence base, it reflects a stable clinical consensus: instability caused by PLC rupture rarely allows for reliable outcomes with conservative management alone.[19] Tanasansomboon et al.,[24] also stress that PLC integrity assessment is a defining component of classification systems—particularly the TLICS-where its disruption significantly raises the total score and thus substantially influences the treatment recommendation.[24]

The importance of posterior structural disruption is further supported by studies examining the relationship between injury morphology and neurological status. Kim et al.,[14] demonstrated that posterior element rupture was associated with more severe initial neurological deficit but simultaneously with a higher potential for neurological improvement-a finding that illustrates the interpretive complexity of injury morphology. The posterior component may signal both greater initial severity and a specific configuration that favours neural decompression.[14] In practice, however, the key point remains: PLC disruption is a marker of instability that demands particularly careful consideration in treatment planning.[14,19,24]

PLC injury should be regarded as one of the most significant morphological features influencing treatment strategy, the risk of deformity progression, and long-term functional outcome.[14,19,24] The main debates in the literature concern not the importance of the PLC itself but the accuracy of diagnosing the extent of its injury-particularly in cases of partial or equivocal MRI findings. From a clinical standpoint, assessing PLC integrity remains one of the central elements of instability stratification and outcome prediction.

Additional clinical factors affecting quality of life

Beyond the principal injury characteristics discussed above, a number of additional clinical factors can meaningfully influence long-term functional outcomes and quality of life. Suzuki et al.,[25] showed that a history of prior vertebral fractures was associated with higher disability scores and lower EQ-5D values following a new acute fracture, underscoring the relevance of pre-existing structural vertebral damage as an adverse background.[25] Mayle et al.,[23] drew attention to the particular vulnerability of patients with ankylosing spondylitis, in whom altered spinal biomechanics predispose to unstable fractures even after relatively low-energy trauma.[23] Thormann et al.,[26] demonstrated that clinical signs reflecting the functional state of the spine and paraspinal soft tissues-including tenderness on palpation, paraspinal muscle tension, finger-to-floor distance, and the Schober test-are also associated with quality of life.[26] Miyakoshi et al.,[27,28] found that spinal mobility and extensor muscle strength were in some cases more closely correlated with QoL than the presence of fractures per se, particularly in patients with osteoporotic spinal involvement.[27,28] Krishnakumar et al.,[29] described a rare but clinically important variant of severe post-traumatic deformity with abdominal compression requiring surgical correction to improve functional status and quality of life.[29] Finally, Bing et al.,[30] demonstrated that neuropathic pain in the lower extremities-related primarily to nerve root injury-is an independent factor substantially worsening quality of life after fracture.[30] Taken together, these findings make clear that clinical outcomes after thoracolumbar injury are shaped not only by fracture type and neurological status, but by a broader spectrum of structural, functional, and symptomatic characteristics.

Radiological factors

Radiological parameters reflect the structural consequences of injury, the degree of instability, the effectiveness of deformity correction, and the quality of subsequent spinal segment restoration. Their relationship to clinical outcomes and quality of life remains actively debated, since radiological improvement does not always correlate directly with the patient's functional recovery.

Kyphotic deformity

Local kyphotic angle/ Cobb angle

Residual kyphotic deformity after thoracolumbar injury has traditionally been considered one of the most significant radiological factors with the potential to affect long-term clinical results and quality of life. Its relevance stems from the fact that increasing local kyphosis alters sagittal biomechanics, shifts the body's centre of gravity anteriorly, and requires constant compensatory activity of the paraspinal musculature to maintain upright posture. Over time, this can lead to chronic muscular fatigue, pain, adjacent segment overloading, and accelerated degenerative change. In severe deformity, kyphosis can produce not only functional limitations but also a visible cosmetic deficit and, in the most extreme cases, secondary visceral complications-making it a clinically meaningful determinant of QoL.[29,31–33]

The influence of local kyphosis on quality of life, however, is one of the most actively contested questions in the literature-and for good reason. A number of studies demonstrate a statistically significant relationship between the degree of residual deformity and poorer functional outcomes. Schulz et al.,[31] studying patients after 360°

fixation, found a significant correlation between residual kyphosis and ODI and Hannover score results, with worse outcomes seen when kyphosis exceeded 12°. Freslon et al.,[32] similarly noted an association between residual kyphotic deformity and ODI-based functional impairment. Hitchon et al.,[34] analysing predictors of conservative treatment failure, showed that patients with unfavourable courses had more pronounced initial kyphotic deformity. Suzuki et al.,[33] demonstrated that severe fracture deformity was associated with greater pain, disability, and reduced quality of life at long-term follow-up. Moreover, in many studies comparing surgical techniques, the degree of kyphosis correction and its subsequent loss are used as primary radiological benchmarks.[1,15,22,35–41] In postoperative series and studies of various reconstructive strategies, this parameter retained its central role as a marker of construct durability.[42–51] D'Oria et al.,[52] for instance, showed that less kyphosis progression in the vertebroplasty group was accompanied by better clinical results than in the conservative arm.[52]

On the other hand, a meaningful number of studies have failed to confirm a direct relationship between post-traumatic kyphosis and quality of life. Soultanis et al.,[8] in a cohort treated conservatively, found no significant correlation between the degree of post-traumatic kyphosis and either VAS pain scores or ODI. Briem et al.,[53] comparing different fixation strategies, detected no statistically significant association between the Cobb angle and SF-36 quality of life scores. Defino et al.,[54] similarly found no reliable correlation between radiological and clinical-functional outcomes, while Andress et al.,[42] observed that postoperative correction loss was not necessarily accompanied by clinical deterioration. Thomas et al.,[55] in a systematic review, concluded that the available evidence does not unequivocally link post-traumatic kyphosis to clinical outcomes.[42,54,55] Additional observations in conservatively treated patients also suggest that deformity progression is level-dependent: thoracolumbar junction fractures tend to lose correction more than fractures at more caudal levels.[56]

The discordance between these findings likely reflects several compounding factors. Study populations differ considerably in age, injury type, initial instability, neurological status, and treatment approach. Different studies use different radiological parameters and different endpoints-ranging from pain and ODI to generic QoL questionnaires. And the relationship between local kyphosis and clinical consequences does not appear to be strictly linear. A plausible inference is that moderate residual deformity within the spine's compensatory range does not always translate into clinically meaningful functional decline, whereas beyond a certain threshold-probably in the vicinity of 15–20°-the risk of chronic pain, fatigue, and functional limitation increases considerably.[8,31–34,42,53–55] Finally, it is worth considering that local kyphotic angle may be an insufficiently sensitive surrogate measure when evaluated in isolation from global sagittal balance, the functional state of paraspinal musculature, and the broader clinical context.

Residual kyphotic deformity undoubtedly retains important radiological and clinical significance, but its direct impact on quality of life cannot be considered definitively established across all clinical scenarios.[8,31–34,42,53–55] Additional clinical series also suggest that outcome depends on the durability of correction and the severity of residual deformity, although the strength of this association varies across populations.[57–64] The most defensible position is that the clinical relevance of kyphosis depends on its magnitude, the injury context, and the patient's capacity to compensate for any resultant sagittal imbalance. In practice, correcting kyphotic deformity remains a primary surgical goal-but it should be interpreted alongside functional and patient-reported outcomes rather than in isolation.

Global sagittal balance

Global sagittal balance is a more integrative characterisation of post-traumatic deformity than local kyphotic angle, as it reflects not only the geometry of the injured segment but the capacity of the entire musculoskeletal system to compensate for any resulting misalignment. The most widely used measure is the position of the C7 plumb line relative to the posterosuperior corner of S1; a positive sagittal vertical axis (SVA) is generally interpreted as a sign that compensatory mechanisms have been exhausted. Under these circumstances, maintaining upright posture requires additional adaptive strategies-modification of thoracic kyphosis, augmentation of lumbar lordosis, pelvic retroversion, and compensatory knee flexion-all of which carry energetic costs, produce chronic muscle loading, contribute to pain, and degrade functional status. This makes global sagittal balance a potentially important determinant of quality of life.[65–68]

The available data suggest that preserving or restoring a balanced sagittal profile is associated with more favourable clinical results. Hoffmann et al.,[65] in long-term follow-up of patients after minimally invasive anterior fusion, noted that a balanced sagittal profile was maintained in all assessed patients, and this was accompanied by good clinical outcomes. Koller et al.,[67] analysing conservative treatment results, demonstrated that post-traumatic kyphosis combined with reduced lumbar lordosis-factors that directly affect the global sagittal profile—has a significant impact on clinical outcome. These observations support the view that long-term functional well-being depends not only on local fracture correction but on maintaining overall sagittal harmony.[65,67]

Correction of local deformity, however, does not automatically restore global balance. Lazennec et al.,[66] evaluating outcomes of wedge osteotomy for post-traumatic kyphosis, showed that even substantial correction of the local angle does not necessarily restore lumbar lordosis or the overall sagittal profile. This observation is practically important, as it highlights the limitations of assessing local kyphosis in isolation and the need for a broader analysis of spinal and pelvic spatial relationships.[66] Similarly, Iwata et al.,[68] demonstrated that signs of global sagittal imbalance-including increased DSVA and significant PI-LL mismatch-were associated with specific patterns of osteoporotic fracture consolidation, indirectly pointing to the clinical relevance of global alignment for subsequent recovery.[68]

Global sagittal balance should be considered one of the most clinically relevant radiological factors determining long-term functional outcomes after thoracolumbar spine injury.[65–68] Unlike local kyphosis, its significance is tied not just to the deformity itself but to the limits of the patient's compensatory capacity. While some of the conceptual framework here derives from the degenerative deformity literature, the available post-traumatic observations also point to the importance of assessing the global sagittal profile when interpreting treatment outcomes and planning deformity correction.

Spinal canal compromise and remodelling

Spinal canal compromise by retropulsed bony fragments is one of the most significant morphological consequences of burst fractures and other unstable thoracolumbar injuries. Its primary clinical importance lies in the risk of neural injury and neurological deficit. In the acute phase, more severe canal narrowing typically reflects greater injury severity and is associated with a higher likelihood of motor, sensory, and autonomic impairment. Over the longer term, however,

the significance of residual compromise is not always determined by its absolute magnitude alone: the clinical outcome also depends on initial neurological status, fracture morphology, the dynamics of reduction, and the canal's capacity for subsequent remodelling.[14,17,69]

The available data confirm an association between the degree of canal compromise and the severity of neurological impairment. Kim et al.,[14] showed that the mean degree of canal narrowing was significantly greater in patients with initial neurological deficits than in neurologically intact patients. Goulet et al.,[17] similarly found that the presence of a retropulsed comminuted fragment was an independent predictor of poor neurological recovery. These findings confirm that canal compromise carries not only anatomical but prognostic significance, particularly when considered in terms of the probability of neurological deficit resolution.[14,17]

At the same time, the literature suggests that severe canal compromise does not invariably require direct surgical decompression, especially in neurologically intact patients. Shen et al.,[69] in a prospective study, demonstrated that substantial spontaneous remodelling of the spinal canal is possible with conservative treatment, through gradual resorption of retropulsed fragments. They also showed that surgical treatment can achieve indirect canal decompression via ligamentotaxis, though this effect was less pronounced. Notably, despite differences in the dynamics of anatomical restoration, functional outcomes at two-year follow-up were comparable between groups.[69] These data imply that radiologically apparent stenosis is not always equivalent to a poor clinical outcome. Additional comparative data indicate that, in certain patients, the absence of direct fragment removal does not impair neurological or radiological recovery when adequate stabilisation and indirect decompression are achieved.[70]

Canal compromise should be regarded as an important radiological factor closely related primarily to initial neurological status and the prognosis for neurological recovery.[14,17,69] Its relevance to long-term quality of life, however, is not strictly linear and likely depends on the interaction of several circumstances: the presence or absence of neurological deficit, the degree of instability, the nature of the retropulsion, and the potential for spontaneous or induced canal remodelling. In practice, this makes canal assessment particularly valuable in guiding initial treatment decisions, but demands caution when extrapolating its isolated influence on long-term functional outcomes.

Loss of vertebral body height

Loss of vertebral body height is primarily a structural marker of anterior column injury severity and a component of local deformity. Unlike global sagittal balance, this parameter has a relatively narrow clinical scope and is more commonly used to assess the stability of achieved correction. Its main relevance relates to the wedge deformity of the injured segment, the disruption of anterior column load-bearing function, and a potential contribution to segmental instability.[9,37,71]

In the literature, this parameter is usually analysed not in isolation but together with the local kyphotic angle and other structural correction measures. Zhao et al.,[37] showed that one year postoperatively, loss of vertebral body height was significantly smaller in the short-segment fixation group with supplementary screws at the fractured level-an advantage accompanied by better preservation of Cobb angle correction. Ledlie et al.,[71] evaluating kyphoplasty outcomes, demonstrated that this technique can restore and maintain vertebral body height for at least one year of follow-up. Chen et al.,[9] further showed that a reduction in anterior vertebral body height to less than 50% of the presumed normal is associated with an elevated risk of kyphotic deformity recurrence after implant removal, underscoring the prognostic relevance of this parameter.[9,37,71]

Restoring and maintaining vertebral body height are thus regarded as important treatment objectives, primarily in the context of preventing progressive local deformity and correction loss.[9,37,71] Its influence on quality of life, however, appears to be primarily indirect, operating through its relationship with kyphotic deformity, segmental stability, and the durability of achieved correction. Vertebral body height loss is therefore better understood as a clinically relevant structural and prognostic marker than as a standalone direct determinant of patient-reported outcomes.

Intervertebral disc injury

Traumatic injury to the thoracolumbar segment frequently involves not only the bony structures but the adjacent intervertebral discs, which can have significant implications for long-term stability and clinical outcome. Structural disc disruption promotes accelerated degeneration, height loss, abnormal load distribution, and segmental instability. As a result, the disc component of the injury may become one of the factors driving progressive post-traumatic deformity, loss of achieved correction, and the perpetuation of chronic pain.[42,44,72–74]

The available data confirm that the condition of the intervertebral disc can materially influence the radiological result of treatment. Dong et al.,[72] examining predictors of unfavourable outcomes after percutaneous fixation, identified disc injury as an independent predictor of poor radiological results. Aono et al.,[73] found that correction loss after implant removal was related not primarily to further vertebral body collapse but to a reduction in the height of the injured disc—and that worsening back pain after hardware removal correlated with progressive kyphosis attributable to this disc component.[73] Similar conclusions were reached by Andress et al.,[42] and Steib et al.,[44] both of whom showed that after posterior fixation, the principal source of correction loss is often the adjacent disc rather than the fractured vertebral body itself.[42,44]

The available data are not entirely uniform, however. Moller et al.,[74] in a very long-term follow-up of conservatively managed patients, found no evidence that initial disc injury predetermines accelerated height loss in subsequent follow-up. This discrepancy with surgical series may reflect differences in biomechanical conditions: after instrumented fixation, loading of the injured disc and adjacent segments is redistributed differently than in conservative management, potentially amplifying subsequent disc degeneration and collapse.[42,44,73,74] The clinical significance of disc injury therefore likely depends not only on its presence per se but on the chosen treatment approach, the fixation configuration, and the duration of follow-up.

Intervertebral disc injury should be regarded as a clinically and radiologically significant factor capable of influencing correction durability, chronic pain development, and long-term functional outcomes.[42,44,72–74] In practical terms, this adds weight to assessing the condition of adjacent discs when planning the extent of fixation, choosing between temporary stabilisation and fusion, and anticipating the risk of late correction loss.

Adjacent segment disease (ASD)

Adjacent segment disease is considered a potential late consequence of surgical stabilisation and fusion, in which movement at the instrumented levels is restricted or eliminated. Load and motion are thereby redistributed to neighbouring non-fused levels, which may theoretically accelerate degenerative changes in adjacent

intervertebral discs, facet joints, and ligamentous structures. The clinical relevance of these changes lies in the possibility of new pain, worsening functional limitations, or secondary neurological symptoms—which, in the long term, could impair quality of life and occasionally necessitate additional surgery.[65]

In the post-traumatic context, however, the evidence base for this problem remains limited. Hoffmann et al.,[65] in one of the few long-term studies specifically addressing this issue, assessed outcomes after minimally invasive anterior fusion at a mean of 13 years postoperatively and found that radiological signs of adjacent segment disease were relatively uncommon and did not correlate with clinical outcomes. These data suggest that in trauma patients-particularly younger individuals without pre-existing degenerative pathology at neighbouring levels-radiological ASD signs may not always carry direct clinical significance.[65]

Interpreting these results requires caution, however. The low rate of clinically relevant ASD in the Hoffmann et al. study[65] may reflect characteristics of that particular population as much as the technique itself. The anterior fusion approach used in that series is also less disruptive to posterior stabilising structures than typical posterior instrumentation. Moreover, unlike patients with degenerative spinal disease, trauma patients' adjacent segments are more often structurally intact at baseline—potentially reducing the risk of rapid symptomatic degeneration. The absence of a pronounced clinical problem in any given trauma series does not preclude ASD from becoming a meaningful concern over longer time horizons, particularly after multilevel fixation or in patients with additional risk factors.

Adjacent segment disease should be regarded as a potentially significant long-term factor whose clinical impact in post-traumatic settings remains incompletely characterised.[65] Current data do not support treating ASD as a universal or inevitable source of QoL deterioration after thoracolumbar injury, but this risk warrants consideration when selecting construct length and evaluating the late consequences of surgical treatment.

Treatment factors

The choice of treatment is among the most consequential-and most debated-aspects of managing patients with thoracolumbar spine injuries. The treatment strategy largely determines the degree of deformity correction, the stability of the injured segment, the risk of complications, the pace of rehabilitation, and, ultimately, long-term quality of life. This section examines the principal conservative and surgical treatment options and their influence on clinical, functional, and patient-reported outcomes.

Surgical vs. conservative treatment

Choosing between surgical and conservative management is the most fundamental-and the most contested-decision in the care of patients with thoracolumbar spine injuries. The potential advantages of a surgical approach include immediate stabilisation of the injured segment, deformity correction, restoration of spinal load-bearing capacity, and-when indicated-neural decompression. This can facilitate earlier mobilisation, more rapid pain reduction, and faster functional recovery. At the same time, surgery carries perioperative risks and the potential for implant-related problems including infection, pseudarthrosis, and hardware-associated complications.[75] Conservative management avoids these operative hazards, but may be accompanied by more prolonged immobilisation, less complete deformity correction, and limited effectiveness for unstable injuries-particularly those involving PLC disruption.

Available data indicate that surgical treatment often provides faster clinical improvement in the short term. Shen et al.,[69] in a prospective study, showed that in the first months after injury, patients in the surgical group experienced less pain and demonstrated better functional outcomes. Medici et al.,[22] analysing patients with type A1/A2 fractures, found advantages of percutaneous stabilisation over bracing at 6 months for both VAS and ODI. Similar conclusions were reached by Landi et al.,[76] who reported more rapid functional recovery and earlier return to work after surgical stabilisation. Wang et al.,[77] comparing conservative management, percutaneous fixation, and kyphoplasty for type A1 fractures, found that by one month, the surgical groups had more favourable pain and function scores. D'Oria et al.,[52] similarly demonstrated that vertebroplasty provided faster pain reduction and ODI improvement than conservative care.

In the medium to long term, however, this early advantage does not consistently persist. At two-year follow-up, Shen et al.,[69] found no longer statistically significant differences in functional results between surgical and conservative groups-despite the substantially higher cost of operative treatment. Wang et al.,[77] similarly showed that intergroup differences narrowed progressively by the two-year mark. Pehlivanoglu et al.,[78] at three years, noted better radiological results after surgery, yet clinical outcomes were comparable between groups. Most striking are the data from Wood et al.,[79] who-in a study with an exceptionally long 16-22-year follow-up-found that patients with stable burst fractures managed conservatively actually fared slightly better on pain and function measures than those who underwent surgery.

This divergence between short- and long-term results is the central tension in this field. In the early period, surgical treatment does typically offer faster symptom relief, better deformity correction, and earlier mobilisation.[22,52,69,76,77] Over time, several factors may attenuate these advantages. First, randomised and comparative studies frequently enrol patients with stable burst fractures without neurological deficit-precisely the group in whom conservative treatment has the highest baseline potential. Second, the long-term consequences of instrumented stabilization-including restricted mobility, residual pain, and other implant-related issues-may erode the early gains. Third, with conservative management, gradual canal remodelling and partial adaptation to residual deformity can contribute to improved late outcomes.[69,79]

Systematic reviews and meta-analyses broadly confirm the enduring uncertainty. Thomas et al.,[55] Abudou et al.,[75] and Gnanenthiran et al.,[80] all reached similar conclusions: the available evidence-based predominantly on a limited number of comparative studies-does not convincingly establish the superiority of either surgical or conservative approaches in terms of pain and function over the medium to long term. Surgical treatment is associated with greater cost and a higher risk of complications.[55,75,80] A summary of comparative results from key studies is presented in Table 1.

The influence of treatment choice on quality of life should be regarded as clinically important but strongly dependent on the time horizon of assessment and the characteristics of the patient population. The most defensible conclusion is that surgery more reliably provides faster short-term recovery, whereas for stable fractures without neurological deficit, its long-term superiority over conservative management has not been convincingly demonstrated.[55,75,80] Interpreting outcomes therefore requires attention not only to radiological correction but to fracture type, initial stability, neurological status, the need for early mobilisation, and the priority placed on patient-reported outcomes.

Table 1 Comparative outcomes of surgical versus conservative treatment in key studies

Study	Number of patients	Follow-up	Pain	Functional outcomes	Radiological results	Return to work	Main conclusion
Shen WJ et al.,[69]	80	2 years	Less pronounced in the early period after surgical treatment	Outcomes were better after surgical treatment during the first 6 months; no differences were observed at 2 years	Surgery achieved better kyphosis correction, whereas conservative treatment was associated with remodelling of the spinal canal	No significant differences were identified	At 2 years, the clinical outcomes were comparable, while surgical treatment was associated with substantially higher costs
Wood KB et al.,[79]	37	16–22 years	Less pronounced with conservative treatment	More favourable ODI and RMDQ scores with conservative treatment	No significant differences in kyphotic deformity were observed	Not reported	At very long-term follow-up, conservative treatment was associated with better functional outcomes
Medici A et al.,[22]	39	6 months	Less pronounced after percutaneous stabilisation (VAS 21 vs 43)	Better ODI scores after percutaneous stabilisation (165 vs 271)	Surgical treatment achieved better correction of kyphotic deformity	More frequent after surgical treatment (80% vs 8%)	Percutaneous stabilisation provided better short-term clinical and functional outcomes
Wang J et al.,[77]	63	2 years	Better in the surgical groups at 1 month; differences disappeared thereafter	Better in the surgical groups at 1 month; no differences were observed by 2 years	No significant final differences were identified	Not reported	All methods were effective; the short-term advantages of surgical treatment were not maintained in the long term

Surgical approach

The choice of surgical approach in thoracolumbar spine injuries is determined by injury morphology, the degree of instability, the nature of neural compression, the need to reconstruct the anterior load-bearing column, and the patient's overall condition. The posterior approach remains the most widely used, as it permits reduction, pedicle screw fixation, and-when needed-indirect or direct decompression with comparatively lower operative morbidity. The anterior approach provides direct visualisation of ventrally compressing structures and allows more complete anterior column reconstruction using a cage or bone graft. Combined procedures offer the most rigid stabilisation and the broadest reconstructive possibilities, but carry greater invasiveness and a potentially higher perioperative burden.[19,41,53,65]

The available data suggest that the superiority of any given approach depends primarily on the clinical context rather than on a formal advantage of one technique over another. Hoffmann et al.,[65] in a long-term study, found no significant differences in clinical or radiological outcomes between isolated anterior and combined stabilisation. Briem et al.,[53] comparing posterior and combined approaches, demonstrated superior radiological results with combined fixation, yet this advantage was not accompanied by higher SF-36 QoL scores. Been et al.,[41] showed that correction loss and implant failure were more common after isolated posterior fixation than after combined treatment, while indirect decompression via the posterior route was adequate in the majority of cases. These findings suggest that more aggressive approaches may offer better mechanical stability in selected complex cases, but this does not always translate into an equivalent clinical benefit.[41,53,65]

Less traumatic modifications of traditional approaches also merit attention. Jacobs et al.,[81] and Smits et al.,[82] described thoracoscopic anterior procedures that demonstrated good results and were proposed as alternatives to open surgery with potentially lower operative morbidity.[81,82] Pang et al.,[83] and Wu et al.,[84] presented posterior paraspinal approaches that reduced blood loss and accelerated postoperative recovery.[83,84] In the most severe injuries requiring extensive decompression and reconstruction, Sandquist et al.,[16] and Zahra et al.,[20] described anterior and posterior vertebrectomy techniques, emphasising the necessity of individualising the approach based on injury anatomy and neurological status.[16,20]

On current evidence, no single surgical approach holds universal superiority in terms of quality of life.[19,41,53,65] Oner et al.,[19] similarly emphasised that in incomplete neurological deficit, no approach can be identified as having a definitive advantage in neurological recovery. The most defensible position is that combined and anterior approaches may offer superior radiological and reconstructive outcomes in more severe and unstable injuries, whereas for a substantial proportion of burst fractures the posterior route remains adequate and less morbid. The practical significance of approach choice is best understood in terms of its effects on operative scope, complication risk, the extent of reconstruction, and the balance between mechanical efficacy and surgical invasiveness.

Posterior fixation technique

Short-segment fixation (SSF) vs. long-segment fixation (LSF)

The choice of posterior fixation length is one of the key technical decisions in the surgical management of thoracolumbar spine

injuries. Short-segment fixation preserves a greater number of motion segments and involves lower operative morbidity, but the construct is subjected to higher mechanical loading and may be less reliable in the context of significant instability. Long-segment fixation provides a more rigid load distribution and greater construct durability, but sacrifices more motion levels-which can potentially affect spinal mobility and functional outcome.[35,36,85–87] Additional clinical series using adjustable anterior vertebral body replacement implants and anterior reconstruction also demonstrated improved pain, functional status, and relatively high activity return rates, though full QoL restoration was not achieved in all patients.[88–94]

The available data suggest that the relative merits of each strategy depend primarily on the severity of the injury and the degree of mechanical instability. Waqar et al.,[35] observed a trend towards better clinical and radiological results with long-segment fixation, with the SSF group showing significant kyphotic deformity progression at 6-month follow-up. Altay et al.,[36] demonstrated that the choice between SSF and LSF is best linked to the injury's load-sharing characteristics as assessed by the Load-Sharing Classification (LSC). At low LSC scores, short-segment fixation may be sufficient, while at higher scores its reliability diminished and resulted in correction loss, making long-segment fixation preferable.[35,36] Biomechanical data also support the use of more rigid pedicular constructs in severe instability, as these provide greater stiffness and better correction maintenance compared with older distraction-based systems.[95]

Advances in posterior stabilisation technique have, however, expanded the viable indications for shorter constructs. Wei et al.,85 Perera et al.,[86] and La Maida et al.,[87] demonstrated that in specific clinical situations, even more limited fixation configurations—including monosegmental constructs-can succeed with careful patient selection.[85–87] The contemporary trend is therefore not towards universal preference for long constructs, but towards individualising construct length based on fracture morphology, PLC status, and the expected ability of the construct to sustain load without significant correction loss. Similar findings were obtained when comparing limited-long versus short-segment instrumentation, where the longer but still economical construct showed better correction maintenance without a clear ODI superiority.[96]

The choice between short- and long-segment fixation should not be made in isolation from fracture morphology and the mechanical demands placed on the construct.[35,36,85–87] On balance, the available evidence supports long-segment fixation for more severe and unstable injuries, while for less unstable fractures, short-segment strategies-particularly when technically modified-can be appropriate.

SSF with intermediate screws at the fracture level

One of the most significant advances in posterior fixation technique has been the inclusion of intermediate screws at the fractured vertebra within a short-segment construct. This modification converts a bridging construct into a more stable system by providing an additional anchor point, improving fragment reduction control, optimising load distribution, and reducing the risk of correction loss. By these means, SSF with screws at the fracture level is regarded as a way to improve construct reliability without the need to extend to a longer configuration.[38,97]

The literature fairly consistently supports the advantages of this technique. Saglam et al.,[1] showed that short-segment fixation with supplementary screws at the fractured vertebra can provide mechanical stability comparable to long-segment fixation, with similar clinical outcomes. Zhao et al.,[37] Li et al.,[39] and Zhang et al.,[98] demonstrated that the inclusion of screws at the fracture level is associated with better deformity reduction, less loss of Cobb angle correction and vertebral body height, and more favourable pain outcomes. Kapoen et al.,[38] in a systematic review and meta-analysis, confirmed that intermediate screws improve radiological results and reduce the rate of implant failure.

These conclusions are supported by additional clinical and biomechanical studies. Tanasansomboon et al.,[24] consider this technique preferable for a substantial proportion of burst fractures. Guven et al.,[99] and Özbek et al.,[100] showed that including a screw at the fracture level improves both initial correction and its maintenance postoperatively, and may facilitate faster union. Hu et al.,[101] and Korovessis[102] proposed specific modifications and combinations of this strategy aimed at further improving construct reliability. The biomechanical study by Liao et al.,[97] additionally showed that combining short-segment fixation with two intermediate screws and vertebroplasty provides particularly high construct rigidity.

Short-segment fixation with intermediate screws at the fractured vertebra can now be considered one of the most successful refinements of posterior stabilisation for thoracolumbar spine injuries.[24,38] While the choice of technique should still depend on the specific fracture morphology and degree of instability, this approach frequently allows the advantages of a limited fixation length to be combined with adequate mechanical reliability and favourable radiological outcomes.

The role of fusion

Whether or not to perform spinal fusion at the time of surgical stabilisation for thoracolumbar spine injuries remains one of the most debated aspects of posterior fixation. Fusion is theoretically aimed at achieving a bony block that provides long-term stability once the metalwork has transferred its load. From this perspective, omitting bone grafting may be seen as a risk factor for late mechanical failure, particularly if the implant is retained for a prolonged period. Conversely, avoiding fusion-when planned implant removal is anticipated-allows for preservation or partial restoration of motion in the stabilised segment, which may offer functional advantages.[24,103–106]

The available data suggest that for certain burst fractures, routine posterior fusion is not obligatory. Sanderson et al.,[105] and Tanasansomboon et al.,[24] concluded that short-segment fixation without fusion can yield satisfactory results and that mandatory bone grafting in all cases lacks sufficient justification. Dai et al.,[103] in a randomised study, found no difference in kyphotic deformity correction loss between fused and non-fused groups treated with short-segment fixation in patients with intermediate load-sharing characteristics. These findings support the view that construct reliability in some cases is determined not only by the presence of a bony block but by the fracture morphology, the quality of the fixation, and appropriate patient selection.[24,103,105] Additional comparative data on transpedicular bone substitution indicate that calcium sulphate cement can achieve clinical and occupational outcomes comparable to autograft while reducing operative morbidity and eliminating donor-site pain.[107–109]

A further argument for a less aggressive strategy was provided by Lee et al.,[104] who-comparing percutaneous fixation without fusion to open fixation with bone grafting—found more favourable short-term pain and function outcomes in the non-fusion group. Ko et al.,[106] similarly suggested that posterior fixation without fusion followed by planned implant removal may benefit selected patients by allowing restoration of segmental motion after consolidation. Avoiding routine fusion in appropriate cases can thus be viewed not as a compromise

but as a deliberate strategy aimed at preserving function during an adequate period of temporary stabilisation.[104,106]

That said, this approach is not universal. The clinical rationale and available data point to a context-dependent role for fusion: in severe distraction and rotational injuries, or where anterior column reconstruction is required, achieving a solid bony arthrodesis retains greater importance. The most defensible position is therefore not a uniform strategy but a differentiated approach, in which the need for fusion is determined by fracture morphology, construct stability, the likelihood of subsequent implant removal, and the priority placed on preserving segmental mobility.[24,103–106]

Minimally invasive surgery (MIS)

Minimally invasive technologies have established an important role in the management of thoracolumbar spine injuries, driven by the goal of reducing surgical morbidity without substantially compromising stabilisation effectiveness. The principal techniques in this category include percutaneous pedicle screw fixation and various forms of vertebroplasty, kyphoplasty, and combined augmentation procedures. The theoretical advantages of MIS relate to reduced trauma to the paraspinal musculature and ligamentous structures, lower intraoperative blood loss, less postoperative pain, shorter hospitalisation, and faster functional recovery.[110]

Percutaneous pedicle screw fixation

The available data fairly consistently indicate that percutaneous fixation achieves clinical and radiological results at least comparable to open surgery, with lower operative morbidity. Medici et al.,[22] and Landi et al.,[76] demonstrated advantages of percutaneous stabilisation over conservative management in terms of faster pain reduction and better functional recovery.[22,76] In comparative studies by Lyu et al.,[111] Lee et al.,[104] Dong et al.,[112] and Vanek et al.,[113] percutaneous fixation showed less blood loss and generally lower operative trauma, with comparable radiological and clinical outcomes to open stabilisation.[104,111–113] Additional morphological confirmation of reduced surgical trauma came from Grass et al.,[114] who used MRI to demonstrate that open fixation is associated with marked and irreversible multifidus damage, whereas percutaneous technique can avoid this injury.[114]

The scope of percutaneous fixation is not unlimited, however. A key limitation is the difficulty of performing reliable direct posterior fusion in the standard percutaneous configuration, which may reduce its applicability in highly unstable injuries that require not only temporary stabilisation but durable long-term reconstruction. Additionally, percutaneous procedures can entail higher radiation exposure, particularly in anatomically complex cases and multilevel instrumentation.[112] Despite the obvious appeal of this approach, its use must therefore be weighed against fracture type, the need for anterior column reconstruction, and the overall treatment plan. Of additional interest are data in patients with ankylosing spinal diseases, where less rigid percutaneous constructs allowed a reduction in surgical complications with comparable clinical outcomes.[115,116]

Vertebroplasty, kyphoplasty, and augmentation techniques

Cement augmentation techniques are used both as standalone treatment for selected stable compression fractures and in combination with posterior fixation to reinforce anterior support and improve construct stability. D'Oria et al.,[52] and Wang et al.,[77] showed that vertebroplasty and kyphoplasty for type A1 fractures produce faster pain reduction and functional improvement compared to conservative management.[52,77] Ledlie et al.,[71] and De Gendt et al.,[117] demonstrated good and reasonably durable long-term kyphoplasty outcomes.[71,117] Fuentes et al.,[118] Zairi et al.,[119] and He et al.,[120] further showed that kyphoplasty can be successfully combined with percutaneous fixation, highlighting the role of augmentation as a component of combined stabilisation.[118–120]

Augmentation techniques take on particular importance in patients with osteoporotic fractures, where compromised bone quality demands additional support. Various cement formulations[121–125] and technical modifications[126–131] have been described in this setting. Interpreting these results requires care, however. The effectiveness of vertebroplasty for acute osteoporotic fractures remains contested-several placebo-controlled trials questioning its benefit were outside the scope of this review. Among the included sources, Rousing et al.,[132] found that while vertebroplasty produced faster short-term pain relief, differences compared to conservative management disappeared at later follow-up timepoints.[132] This reflects a pattern common to minimally invasive technologies more broadly: advantages tend to be most pronounced in the early postoperative period, while long-term superiority over alternative approaches warrants more cautious interpretation. Selected series examining open kyphoplasty and calcium phosphate augmentation also demonstrated significant pain reduction and functional improvement, though the durability of radiological correction could be limited.[123,133]

Minimally invasive surgery represents one of the most important directions in the evolution of thoracolumbar spine injury treatment.[110] Its primary clinical value lies in reducing surgical morbidity and accelerating early recovery, particularly in elderly and medically frail patients. At the same time, the selection of a minimally invasive strategy must remain selective and guided by fracture morphology, the degree of instability, the need for fusion, and the reconstructive objectives for both anterior and posterior support. In certain patients with atypical pain syndromes or multilevel osteoporotic fractures, surgical augmentation has provided substantial improvements in pain, ODI, and overall QoL measures compared to conservative management.[134,135]

Perioperative parameters

Perioperative parameters-operative duration, blood loss, and length of hospital stay-matter principally as composite markers of surgical morbidity. They do not directly determine long-term quality of life, but they help quantify the physiological cost of the intervention, its tolerability, and the likelihood of a smoother early postoperative course.[83,85,86,111–113,136]

Available data consistently show that less invasive surgical techniques improve perioperative parameters. Lyu et al.,[111] Pang et al.,[83] Dong et al.,[112] and Vanek et al.,[113] all demonstrated that percutaneous and paraspinal approaches are associated with less blood loss and generally lower operative morbidity than open procedures.[83,111–113] Similarly, Wei et al.,[85] and Perera et al.,[86] showed that more limited fixation configurations-including monosegmental constructs-can reduce operative duration and intraoperative blood loss compared to longer constructs.[85,86] Additional perioperative gains were demonstrated by Wang et al.,[136] who showed that the use of tranexamic acid substantially reduces both overt intraoperative and occult postoperative blood loss.[136] Further support for less traumatic strategies came from data on three-stage reduction with minimally invasive stabilisation, which was associated with less blood loss and more favourable early ODI scores compared to conventional open surgery.[137]

Perioperative parameters should be understood primarily as clinically relevant markers of surgical invasiveness, with an indirect influence on recovery tempo and treatment tolerability.[83,85,86,111–113,136] Improving them does not guarantee better long-term patient-reported outcomes, but reducing blood loss, shortening operative time, and decreasing the duration of hospitalisation remain important goals of modern spinal surgery-particularly in elderly, comorbid, and physiologically vulnerable patients.

Complications

Treatment complications rank among the most adverse factors capable of directly worsening both clinical outcomes and quality of life after thoracolumbar spine injuries. Their significance lies in the fact that they do not merely reflect incomplete treatment success-they themselves become a source of additional pain, deformity progression, instability, neurological deterioration, and renewed loss of functional independence. Beyond this, complications frequently necessitate technically demanding revision procedures, prolong recovery, and substantially increase the overall physical and psychological burden of treatment.[15,35,36,38,41,138]

Implant-related complications, particularly mechanical construct failure, are the most frequently discussed in the literature. Altay et al.,[36] Waqar et al.,[35] Been et al.,[41] and Kapoen et al.,[38] showed that the risk of implant failure is higher with short-segment fixation, particularly under high mechanical loading-including unfavourable LSC scores-while longer or combined constructs provide greater reliability. The same data indicate that using intermediate screws at the fracture level reduces the likelihood of correction loss and mechanical failure. A portion of complications is therefore closely related not only to the severity of the injury but to the appropriateness of the chosen stabilisation technique.

Infectious complications are less common, but their clinical impact is equally serious. Verlaan et al.,[15] in a systematic review, reported that deep infection rates varied by procedure type and ranged from approximately 1.4% to 3.1%. Despite their relative rarity, such complications can necessitate debridement, implant removal, extended hospitalisation, and significant deterioration in functional outcome.[15]

Pseudarthrosis occupies a specific position among complications because it represents a failure to achieve lasting stability. Grobost et al.,[138] demonstrated that early anterior column reconstruction yields better clinical results than delayed reconstruction performed for established pseudarthrosis-reinforcing that timely achievement of reliable stabilisation and bony union is essential not only for radiological success but for preventing late clinical deterioration.[138] In high-risk subgroups-including patients with severe osteoporosis and impaired sagittal biomechanics-the development of adjacent or proximal junctional fractures around the fixation zone can substantially worsen outcomes, underscoring the importance of preventing junctional failure and timely revision.[139]

Treatment complications should be regarded as one of the most clinically significant factors impairing long-term quality of life after thoracolumbar spine injuries.[15,35,36,38,41,138] Their impact is self-evident and relatively uncontested: regardless of the specific complication type, its development typically means worsening pain, reduced functional outcome, and higher rates of repeat intervention. In practical terms, this places complication prevention, early detection, and timely management among the central objectives of surgical care.

Orthosis (brace) after treatment

External immobilisation with a brace after thoracolumbar spine injuries was long regarded as a self-evident component of both conservative and postoperative management. The assumption was that a corset provides additional stabilisation, reduces pain, restricts unwanted movements, and lowers the risk of progressive deformity. At the same time, bracing carries potential drawbacks-restricted mobility, muscular deconditioning, daily discomfort, and a prolonged subjective sense of being unwell-which can in themselves impair the patient's perception of recovery.[140–144]

Contemporary data increasingly question the need for routine bracing, at least for a proportion of patients with stable injuries. Giele et al.,[140] in a systematic review, found no convincing evidence supporting the use of bracing in patients with traumatic thoracolumbar fractures. The most compelling evidence comes from the randomised studies by Bailey et al.,[141,143] and Shamji et al.,[142] which demonstrated that in patients with stable type A3 burst fractures, treatment without a TLSO was not inferior to braced management on functional outcomes at 3 and 6 months.[141–143] These findings are significant because they challenge the assumption that external immobilisation is a necessary condition for favourable recovery in stable injuries.

Similar conclusions were reached in the postoperative context. Zhang et al.,[144] studying bracing after vertebroplasty, found no improvement in clinical results with brace use-and short-term orthosis use for three weeks was actually associated with a reduction in quality of life.[144] The available literature thus shows a clear trend towards abandoning routine bracing where its benefit has not been objectively demonstrated.

The value of bracing after thoracolumbar spine injury treatment should be assessed on a case-by-case basis rather than treated as a universal component of standard management.[140–144] Current evidence most strongly supports the position that for stable fractures and in several postoperative scenarios, routine bracing does not improve functional outcomes and may actually compromise patient comfort. Practically, this makes the selective use-and selective omission-of bracing an important step towards earlier mobilisation and more patient-centred rehabilitation.

Implant removal

Planned hardware removal after fracture consolidation remains a contentious step in postoperative management, particularly in patients stabilised without fusion. The potential arguments for removal include pain relief from implant-related symptoms, elimination of the sensation of a foreign body, and restoration of motion in previously fixed segments. Against this, the second procedure carries its own operative risk, and deformity progression with partial correction loss after removal is possible-making this decision clinically ambiguous.[48,73,106,145,146]

The available data confirm that implant removal can restore segmental motion in selected patients. Axelsson et al.,[145] using the high-precision RSA technique, demonstrated that late implant removal in non-fused patients can lead to the return of movement in a previously stabilised segment.[145] Ko et al.,[106] similarly support the concept of removal in carefully selected patients where the goal is not only symptom relief but restoration of functional mobility.[106]

The clinical consequences of hardware removal are not uniformly favourable, however. Smits et al.,[146] found that while most patients-both symptomatic and asymptomatic-subjectively rated removal as

beneficial, symptoms worsened in a subgroup after the procedure.[146] Aono et al.,[73] and Kitzen et al.,[48] noted that a degree of kyphosis correction loss-averaging approximately 4°-can occur after removal, largely attributable to disc height collapse, and that this may be accompanied by worsening back pain.[48,73] The potential functional gain from restored mobility must therefore be weighed against the risk of late deformity and clinical deterioration.

Routine removal of asymptomatic hardware is not currently well-justified, and the decision to perform revision surgery should be made on an individual basis.[48,73,106,145,146] A selective approach is most appropriate, accounting for the presence of symptoms, whether or not fusion was performed, patient expectations, the risk of correction loss, and the realistic probability of meaningful functional gain. From the perspective of quality of life, the value of implant removal remains moderate and variable: for some patients it may be genuinely beneficial, while for others it offers no meaningful advantage or is associated with clinical deterioration.

Psychosocial and rehabilitation factors

Pain syndrome (chronic pain, neuropathic pain)

Pain is one of the most frequent and clinically significant consequences of thoracolumbar spine injuries, and it does much to determine long-term quality of life. Its impact operates through multiple channels. Chronic nociceptive pain may relate to residual instability, post-traumatic degenerative changes in facet joints and discs, muscular imbalance, adjacent segment overloading, or implant-related factors. The neuropathic component arises from nerve root or other neural structure injury and is generally less responsive to standard analgesic therapy. Regardless of mechanism, persistent pain limits physical activity, disrupts sleep, degrades daily functioning, and fosters anxiety, depression, and social withdrawal.[30,53,73]

The literature consistently confirms that pain remains a central component of unfavourable outcomes. Schouten et al.,[147] in a review article, noted that one year after conservative treatment of burst fractures, complete freedom from pain is achieved in only a proportion of patients-underscoring how often chronic pain persists.[147] Sanderson et al.,[105] found that the presence of a compensation claim was the only factor significantly affecting treatment outcome-an indirect indicator of the close link between persistent pain, subjective dissatisfaction, and the psychosocial context of recovery.[105] Aono et al.,[73] observed that worsening back pain after implant removal correlated with progressive kyphosis driven by disc degeneration-confirming the existence of a mechanical contributor to chronic pain.[73] Bing et al.,[30] specifically examined neuropathic pain and showed that it is largely related to nerve root injury, highlighting the independent role of neurogenic mechanisms in QoL impairment.[30]

The importance of pain control is further underlined by the fact that virtually all comparative treatment studies use pain scores as one of their primary outcome measures. In the work of Medici et al.,[22] Lee et al.,[104] and Kapoen et al.,[38] improvement in VAS pain scores was considered one of the most clinically meaningful markers of treatment success, with faster and more sustained pain reduction associated with better functional outcomes.[22,38,104] The literature also shows that the sources of chronic pain are heterogeneous and that pain intensity does not always correlate straightforwardly with individual radiological parameters. Several studies failed to establish a clear relationship between residual kyphotic deformity and pain severity[8,53] -a finding that points to the multifactorial nature of pain and the limitations of purely morphological explanations.

Pain should be regarded as one of the most clinically decisive determinants of quality of life after thoracolumbar injury. Its influence is least in doubt; the principal scientific and clinical challenge lies in the heterogeneity of pain mechanisms and the need to understand them in a differentiated way. Effective control of both nociceptive and neuropathic pain components is a central task of treatment, rehabilitation, and long-term management in this patient population.

Functional limitations (ODI, RMDQ)

Functional limitations, as captured by the ODI, RMDQ, and similar instruments, represent the practical expression of day-to-day disability following thoracolumbar injury. These measures do not simply replicate the pain assessment-they integrate pain with impaired mobility, reduced endurance, muscular weakness, and the consequences of neurological deficit. They thereby provide a more direct evaluation of how much the injury actually restricts self-care, household activity, and physical independence.[31,148]

Virtually all clinical studies examining long-term outcomes after thoracolumbar injury use functional scales as one of their primary outcome criteria. Post et al.,[148] in a five-year follow-up of conservatively treated patients, demonstrated that a significant proportion of patients retain limitations in physical functioning, detectable both by questionnaire and by performance testing.[148] Schulz et al.,[31] showed that ODI scores were significantly worse in patients with more pronounced residual kyphotic deformity, pointing to a relationship between the structural consequences of injury and long-term disability.[31] In the long-term surgical series of Hoffmann et al.,[65] and Lang et al.,[40] relatively satisfactory ODI values were reported many years after reconstructive procedures, suggesting that acceptable functional recovery remains achievable even after severe injuries.[40,65]

Functional scales are also widely used to compare the effectiveness of different treatment approaches. In the work of Medici et al.,[22] D'Oria et al.,[52] Lee et al.,[104] and Kapoen et al.,[38] ODI improvement was considered one of the most clinically relevant treatment outcomes, with more effective surgical approaches associated with less short-term disability.[22,38,52,104] This underscores that a reduction in ODI or RMDQ values is not merely a statistical artefact but reflects a real improvement in the patient's capacity to return to daily activities.

Functional limitations measured by ODI, RMDQ, and comparable instruments should be regarded as among the most informative and clinically meaningful outcome indicators after thoracolumbar injury. In essence, they not only characterise the consequences of injury but serve as an integrated expression of how pain, deformity, neurological status, and treatment decisions combine to affect the physical dimension of the patient's quality of life.

Return to work and daily activities

Return to work and habitual daily activity should be understood as a social measure of recovery, not simply as another proxy for pain or disability. It reflects the extent to which achieved clinical improvement proved sufficient for genuine professional, domestic, and social reintegration-influenced not only by residual symptoms and functional limitations, but also by occupational demands, patient motivation, the character of rehabilitation, and the broader social context.[2,15,22,41,148,149]

The available data show that return-to-work rates after thoracolumbar injuries can be reasonably high, though they vary considerably depending on the population and treatment strategy. Verlaan et al.,[15] in a systematic review, reported that functional

outcomes after surgical treatment-including return to work-were generally better than commonly assumed, with 83–84% of patients resuming employment.[15] Medici et al.,[22] documented a particularly striking early advantage of surgical treatment: at 6 months, 80% of patients in the percutaneous fixation group had returned to their previous employment, compared to only 8% in the conservative management group.[22] These figures align well with the idea that faster stabilisation and early mobilisation can accelerate social and vocational recovery. In the acute phase, even in neurologically intact fractures managed conservatively, the timing of initial mobilisation and the extent of physical therapy required are influenced by associated injuries-particularly lower extremity fractures.[150]

Even with relatively satisfactory overall functional results, return to work does not always signify full restoration of prior activity levels. Post et al.,[148] found that despite the absence of significant SF-36 differences compared to a healthy reference population, some patients had to stop working or modify their workload after conservative treatment. Leferink et al.,[149] similarly reported a high overall return-to-work rate after posterior fixation, but in roughly half of patients the nature or intensity of occupational activity had changed.[149] Andress et al.,[42] noted reduced work capacity in some patients even when clinical and radiological outcomes were otherwise acceptable.[41] These findings underscore that resuming employment is not always synonymous with full recovery of prior functional status. A comparable pattern was observed after surgical treatment of certain unstable injuries-including flexion-distraction fractures-where high rates of return to previous employment did not preclude the need for subsequent occupational load modification.[151]

Baseline population characteristics are also relevant. Belmont et al.,[2] in a military aviator cohort, reported high occupational return rates with no decisive influence of treatment type-likely reflecting the characteristics of an initially fit, highly motivated, and professionally selected group with greater adaptive and rehabilitative potential than the general spinal injury population.

Return to work and daily activities should be considered one of the most meaningful composite outcomes after thoracolumbar spine injuries.[2,15,22,41,148,149] In the short term, surgical treatment-particularly minimally invasive approaches-may accelerate vocational recovery; in the long term, what matters is not only whether the patient returns to work but whether they maintain their previous level of activity, occupational demands, and social role. This outcome is particularly valuable precisely because it integrates the consequences of pain, disability, psychological adaptation, and rehabilitation effectiveness into a single practical measure.

Psychological status

The patient's psychological state is an important factor capable of substantially influencing long-term quality of life after thoracolumbar spine injuries. Its significance lies in the fact that subjective pain perception, willingness to engage in rehabilitation, the level of daily activity, and overall satisfaction with treatment results depend not only on the morphology of the injury and the extent of functional restoration, but on how the patient emotionally and cognitively processes the consequences of trauma. An unfavourable psychological background can amplify pain perception, reduce motivation to recover, and impede adaptation to persistent limitations. Conversely, greater psychological resilience tends to support better rehabilitative engagement and social reintegration.[53]

Despite the comparatively limited attention paid to psychological status in the reviewed sources, the available data point to its considerable clinical importance. Briem et al.,[53] found that the mental health component of the SF-36 was a strong predictor of postoperative vitality, whereas other parameters-including radiological measures-showed no comparable predictive value. This observation is particularly striking because it shifts the focus from purely structural and technical characteristics of treatment towards a broader, patient-centred understanding of recovery.[53]

Psychological status should be regarded as an independent and clinically relevant factor that can substantially modify how the outcome of treatment is experienced and the ultimate quality of life following thoracolumbar injury.[53] Although the evidence base within the reviewed studies is limited, the available data point clearly to the need for systematic psychological assessment and support-not as an optional add-on but as an important component of comprehensive care alongside surgical, pharmacological, and rehabilitative management.

Compensation status

Compensation status is a psychosocial factor capable of substantially modifying the subjective experience of symptoms, the pace of recovery, and the ultimate quality of life following thoracolumbar injury. Its influence should not be simplistically interpreted as malingering or deliberate symptom amplification. More often, it reflects a complex interaction between pain, functional limitations, psychological adaptation, and the social-legal context-in which financial claims, litigation, and disability proceedings may indirectly reinforce the patient's focus on symptoms and impede full recovery.[13,105]

The available data point to the high prognostic significance of this factor. Sanderson et al.,[105] analysing the results of short-segment fixation without fusion, found that the presence of a compensation claim was the only factor significantly affecting the Low Back Outcome Score.[105] Similarly, Vorlat et al.,[13] examining predictors of outcome after conservative fracture management, identified insurance status—alongside smoking-as one of the most adverse predictors of recovery.[13] These observations suggest that the socio-legal context can influence outcomes as profoundly as certain morphological or technical treatment characteristics.

Compensation status should be regarded as a clinically relevant psychosocial modifier of outcome after thoracolumbar spine injuries.[13,105] Its importance does not lie in questioning the authenticity of the patient's complaints, but in the need to account for the broader context of recovery when interpreting symptoms, forecasting rehabilitation, and evaluating patient-reported outcomes. From a practical standpoint, this factor calls for a particularly careful and interdisciplinary approach-one that combines clinical assessment, rehabilitative support, and an awareness of the psychosocial dimensions of prolonged recovery.

Social adaptation and leisure

Social adaptation and the ability to maintain habitual leisure activities are important components of long-term quality of life after thoracolumbar spine injuries. Their significance extends beyond purely physical recovery, because participation in social life, maintenance of interpersonal relationships, engagement in hobbies, and a return to activities that are meaningful to the patient are closely linked to psychological well-being, self-esteem, and overall life satisfaction. Conversely, chronic pain, restricted mobility, and reduced functional independence can lead to social isolation, loss of familiar roles, and a gradual deterioration of emotional health.[10,152]

The available data, while limited, support the relevance of this domain. Hallberg et al.,[10] in a long-term study of women with vertebral fractures, demonstrated that QoL decline affected not only physical but

also social SF-36 domains-indicating that the consequences of fracture persistently impair everyday social engagement.[10] Cankaya et al.,[152] in a more specialised study, assessed sexual function and its relationship to QoL in patients after different posterior fixation strategies. They found that patients after short-segment fixation had better sexual function and QoL scores than those after long-segment stabilization-underscoring that social adaptation encompasses not only return to work but more personal dimensions of family and intimate life that standard clinical studies rarely examine.[152] Comparable findings were obtained in broader osteoporotic cohorts, where the presence, number, and severity of vertebral fractures were associated with impaired social as well as physical functioning.[153,154]

Social adaptation and maintenance of leisure activity should be regarded as clinically relevant dimensions of long-term outcome after thoracolumbar spine injuries.[10,152] Although the evidence base in this area remains limited, the available data indicate clearly that successful rehabilitation must be judged not only by pain, ODI, or radiological parameters, but by the patient's ability to re-engage in a full social, personal, and daily life.

Spinal mobility and back muscle strength

Spinal mobility and the functional state of the back musculature are important determinants of daily capacity following thoracolumbar injury. Their clinical relevance stems from the fact that restricted range of motion-caused by pain, muscular spasm, deformity, or previous fusion-directly impairs bending, rotation, prolonged sitting, walking, and other everyday movements. Simultaneously, weakness of the spinal extensor muscles reduces the active muscular corset's ability to support the spine, potentially increasing load on passive stabilising structures, contributing to chronic fatigue, and perpetuating pain.[27,28]

The available data suggest that functional spinal parameters may be more closely related to QoL than the mere fact of having sustained a fracture. Miyakoshi et al.,[27] demonstrated that spinal mobility is a stronger predictor of quality of life than the presence of vertebral fractures alone, and that functional deterioration is associated primarily with postural deformities-particularly pronounced kyphosis.[27] In a subsequent study, Miyakoshi et al.,[28] found that the strength of the spinal extensor muscles is one of the most important determinants of spinal mobility-confirming the close relationship between muscle function, posture, and daily functional capacity.[28]

Spinal mobility and back muscle strength should be regarded as clinically relevant functional determinants of quality of life following thoracolumbar injury.[27,28] Even where much of this evidence comes primarily from osteoporotic cohorts, its implications are important for post-traumatic rehabilitation: successful recovery depends not only on anatomical fracture stabilisation but on preserving or restoring the spine's dynamic function. In practice, strengthening the back musculature and restoring range of motion are therefore among the key targets of physical rehabilitation.

Patient expectations and treatment satisfaction

The patient's expectations of treatment represent an important psychosocial factor that can substantially influence the subjective assessment of outcomes and ultimate quality of life. Even when objective clinical and radiological results are acceptable, a patient may remain dissatisfied if their initial assumptions about recovery timelines, the degree of pain relief, or the extent of return to prior activity were unrealistically high. Conversely, realistic expectations-formed on the basis of clear and consistent information-help the patient better tolerate the inevitable difficulties of the recovery period, improve treatment adherence, and facilitate adaptation to any lasting consequences of the injury.[147]

Among the reviewed sources, this issue is most explicitly addressed by Schouten et al.,[147] who demonstrated that providing patients with accurate and consistent information about the likely course of recovery helps them form more realistic expectations. The authors emphasised the practical value of concrete prognostic markers that can be used in discussions with patients, including likely timelines for return to work and the probability of persistent pain at defined follow-up intervals.[147] While such data do not always measure quality of life directly, their clinical relevance is clear: treatment satisfaction is substantially determined not only by the outcome itself but by how well that outcome matches what the patient was led to expect.

Patient expectations and treatment satisfaction should be regarded as clinically relevant dimensions of long-term outcome after thoracolumbar injuries.[147] Despite the limited direct evidence base in the reviewed studies, the importance of adequate information provision and expectation management is practically self-evident. From a clinical standpoint, this makes high-quality physician-patient communication not a secondary supplement to care, but an important element of treatment and rehabilitation with the potential to influence adherence, the subjective evaluation of outcomes, and ultimate quality of life.

Limitations

One limitation of this review is the potential incompleteness of the literature coverage. In research on thoracolumbar spine injuries, quality of life is relatively rarely used as a primary endpoint. Most studies focus on narrower and clinically intuitive outcomes-pain severity, functional limitations, neurological status, residual deformity, radiological results, and return to work. Since such parameters are frequently used as surrogate or partial reflections of QoL, some relevant studies may not have been identified in the initial search, particularly where quality-of-life terminology did not appear in titles, abstracts, or indexing terms.

In addition, the included studies were clinically and methodologically heterogeneous with respect to patient populations, injury types, treatment approaches, follow-up duration, and outcome measurement instruments, which limits direct comparability of results.

Conclusion

The literature reviewed here makes clear that quality of life following thoracolumbar spine injuries is multifactorially determined and cannot be explained by any single clinical, radiological, or technical parameter. The ultimate outcome emerges from the intersection of initial injury severity, treatment effectiveness, the extent of residual symptoms, and the patient's capacity for functional, psychological, and social adaptation.

The strongest predictors of unfavourable long-term outcomes appear to be the initial neurological deficit, the degree of subsequent neurological recovery, persistent pain, and the functional limitations associated with it. Age, comorbidity, injury severity, global sagittal balance, and the characteristics of social and vocational reintegration also play important roles. Radiological parameters-traditionally regarded as the benchmark of treatment success-vary considerably in their clinical significance. The prognostic value of global sagittal profile appears reasonably well established, whereas the influence of local kyphotic deformity on quality of life remains less clear-

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cut, depending on the magnitude of the deformity, the patient's compensatory capacity, and the broader functional context.

Treatment selection remains one of the most debated aspects of managing these patients. Surgical treatment more often provides better short-term results through faster stabilisation, pain reduction, and early mobilization-but its long-term superiority over conservative management, particularly for stable burst fractures without neurological deficit, cannot be considered definitively proven. Similarly, debates continue over the optimal surgical approach, fixation extent, the need for fusion, and the role of motion-preserving techniques. Contemporary evidence supports a more differentiated and personalised approach, in which treatment selection is guided not only by fracture type but by bone quality, PLC integrity, neurological status, age, functional demands, and complication risk.

An important conclusion of this review is that patient-reported outcomes after thoracolumbar spine injuries cannot be adequately assessed using radiological and technical criteria alone. Pain, ODI/RMDQ, return to work, social adaptation, psychological status, and patient expectations matter as much as-and in many cases more than-technical endpoints in evaluating the final result. This underscores the need for a comprehensive, multidisciplinary approach in which surgical stabilisation is understood as one stage of a broader treatment process, not its only purpose.

Despite the considerable body of evidence accumulated to date, important unresolved questions remain. These include the long-term comparison of surgical and conservative treatment for stable burst fractures, the clinical significance of residual local deformity, the optimal extent of reconstruction, and strategies for preventing chronic pain. Promising directions for future research include long-term prospective comparative studies emphasising patient-reported outcomes, investigation of individual compensatory mechanisms, broader integration of psychosocial variables into study design, and the search for predictors of unfavourable functional recovery. Ultimately, improving the quality of life of patients after thoracolumbar spine injuries will require not only advances in surgical technology, but more precise risk stratification, individualised rehabilitation, and sustained attention to the psychological and social dimensions of recovery.

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