Anterior-Only Stabilization of Three-Column Thoracolumbar Injuries

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Objective: The optimal treatment of "unstable" thoracolumbar injuries remains controversial. Studies have shown the advantages of direct anterior decompression of thoracolumbar injuries along with supplemental posterior instrumentation as a combined or staged procedure. Others have also shown success in decompression as a single-stage anterior procedure, largely limited to two-column (anterior and middle) injuries. A retrospective review of all available clinical and radiographic data was used to classify unstable three-column thoracolumbar fractures according to the Association for the Study of Internal Fixation (AO) classification system. This was conducted to evaluate the efficacy of stand-alone anterior decompression and reconstruction of unstable three-column thoracolumbar injuries, utilizing current-generation anterior spinal instrumentation.

Methods: Between 1992 and 1998, 40 patients underwent anterior decompression and two-segment anteriorly instrumented reconstruction for three-column thoracolumbar fractures. Retrospective review of all available clinical and radiographic data was used to classify these unstable injuries according to the AO classification system, evaluating for neurologic changes, spinal canal compromise, preoperative and postoperative segmental angulation, and arthrodesis rate.

Results: According to the AO classification system, there were 24 (60%) type B1.2, 10 (25%) type B2.3, 5 (12.5%) type C1.3, and 1 (2.5%) type C2.1 three-column injuries. Preoperative canal compromise averaged 68.5% and vertebral height loss averaged 44.5%. There were no cases of neurologic deterioration, and 30 (91%) patients with incomplete neurologic deficits improved by at least one modified Frankel grade. Mean preoperative segmental kyphosis of 22.7° was improved to an early mean of 7.4° ($P < 0.0001$). At latest follow-up, angulation had increased by an average 2.1° but maintained significant improvement from preoperative measurements ($P < 0.0001$). There was one early construct failure due to technical error. Thirty-seven of the remaining patients (95%) went on to apparently stable arthrodesis.

Conclusions: Current types of anterior spinal instrumentation and reconstruction techniques can allow some types of unstable three-column thoracolumbar injuries to be treated in an anterior stand-alone fashion. This allows direct anterior decompression of neural elements, improvement in segmental angulation, and acceptable rates of arthrodesis without the need for supplemental posterior instrumentation.

Key Words: thoracolumbar fracture, instability, spinal instrumentation, anterior plates

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Although "unstable" thoracolumbar injuries are a common type of spinal trauma,[1–4] their optimal treatment remains controversial, as evidenced by the variety of surgical management options available. These include posterior reduction and decompression by indirect (ligamentotaxis)[5–8] and direct[9] posterolateral methods (costotransversectomy or transpedicular approaches), with short- or long-segment instrumentation, direct anterior decompression (with or without instrumentation),[10–13] and combined anteroposterior approaches.[2,4,12,14–16] Whereas direct anterior decompression of thoracolumbar injuries and its advantages have been well described by many others, it has often been along with supplemental posterior instrumentation as a combined or staged procedure.[12,14,17]

Somewhat more recently, subsequent to improvements in the design and biomechanical performance of currently available anterior thoracolumbar instrumentation, others have reported on the successful management of thoracolumbar burst fractures (with or without neurologic deficit) as a single-stage anterior procedure.[1,2,15,18,19] However, this treatment has largely been limited to two-column (anterior and middle) injuries, corresponding to the "burst fracture" of the Denis classification,[20] the "stable burst fracture" of the McAfee et al classification,[21] and the type A injury of the Magerl et al Association for the Study of Internal Fixation (AO) classification.[3] Most authors have advocated posterior stabilization for the significantly more unstable three-column injuries similar to the Denis fracture-dislocation (flexion-distraction type), McAfee unstable burst fracture and flexion-distraction injuries, and AO type B and type C injuries.[4,6,16,22,23]

Conceptually, the ability to treat such thoracolumbar injuries as a single-stage anterior procedure could offer theoretical benefits such as improved canal decompression (which may or may not result in improved neurologic recovery),[1,11,12,22,24] restoration of anterior load sharing, fewer levels requiring arthrodesis,[15,25] restoration of sagittal alignment, and decreased surgical morbidity (as compared with a two-stage anterior and posterior approach).[10,11,15,17]

The purpose of this study was to review the authors' experience in the surgical management of some types of unstable three-column thoracolumbar injuries (based on the AO

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classification system) as a single-stage, stand-alone anterior procedure with recent-generation anterior instrumentation.

MATERIALS AND METHODS

A multicenter review of all patients with thoracolumbar injuries from 1992 to 1998 was conducted at the University of Mississippi Medical Center and the Indiana Spine Group. Of the 203 consecutive trauma patients managed by operative stabilization from 1992 to 1998, 40 patients with unstable injuries based on the AO classification were managed with single-stage anterior decompression and reconstruction. This system allows the classification of essentially any injury into a triad of descriptors, reflecting a progressive scale of injury and instability. In brief, there are three fundamental injury patterns determined by radiographic criteria: Type A represents compression injuries, with damage to the anterior/middle columns; type B is characterized by anterior and posterior element injuries (three column) with distraction; the more severe type C lesions involve anterior and posterior element injuries, with a superimposed rotational deformity resulting from axial torque. Each of these major types may be further subdivided into three groups and subgroups. Type A includes two-column "burst fractures" (type A3), which present with retropulsed bony fragments, vertebral height loss, but with an intact posterior ligamentous complex and without sagittal plane translation. Type B (anterior and posterior element) patterns often involve a type A vertebral body fracture along with posterior disruption of ligamentous (B1: with facet subluxation, fracture, or very rare dislocation) (Fig. 1) or bony (B2: failure of posterior column through pars interarticularis or pedicle) structures. These may be marked by clinical findings of posterior hematoma, palpable interspinous gap and tenderness, and with radiographic evidence of some sagittal translation, interspinous widening, or evidence of posterior ligamentous complex failure on appropriate magnetic resonance imaging (MRI) sagittal views. Computed tomography (CT) sagittal reconstruction, with or without MRI, can differentiate type B from type A injuries.[3] Type C represents another three-column injury pattern, involving anterior and posterior elements, having type A or type B characteristics, along with superimposed rotation. They present with translation in any plane. (Fig. 2) Therefore, the 40 patients identified in this study all had type B or type C three-column thoracolumbar injuries. The AO classification for thoracic and lumbar spine fractures describing the major types and the first-level subtypes is as follows:

Type A compression vertebral body (anterior and middle columns)
- A1: impaction fracture
- A2: split fracture
- A3: burst fracture

Type B distraction (all three columns)
- B1: Posterior injury—ligamentous
- B2: Posterior injury—osseous
- B3: Anterior injury—through disc

Type C rotational (all three columns)
- C1: type A with rotation
- C2: type B with rotation
- C3: rotational shear

Patient Demographics

There were 29 male and 11 female patients with mean age of 37.4 years (range 19–70 years) and 40.2 years (range

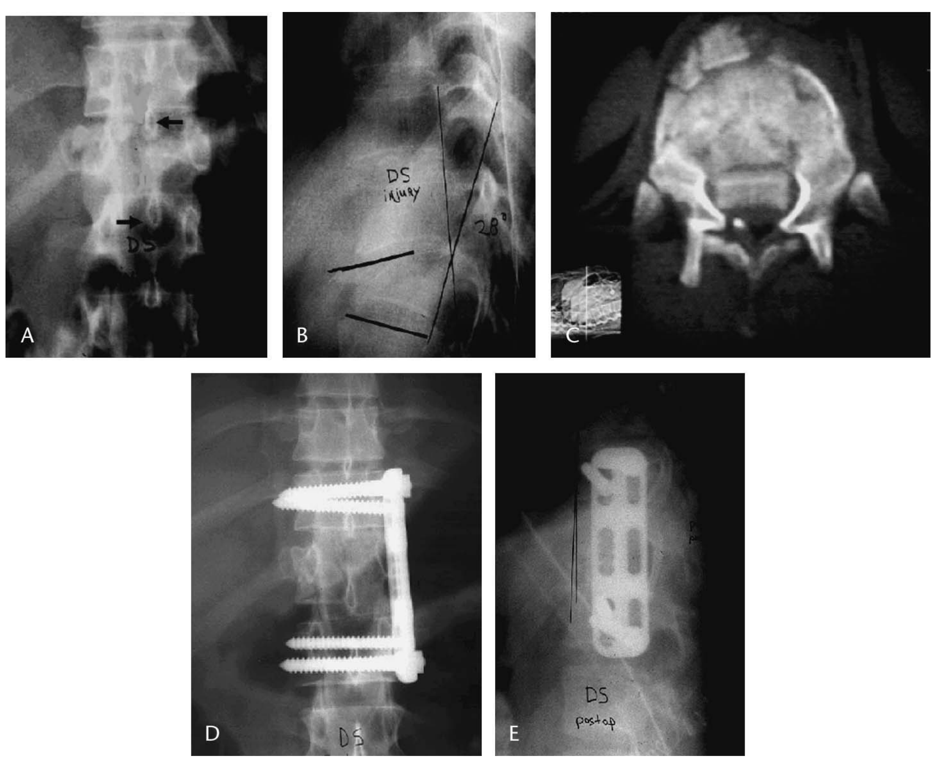

FIGURE 1. A 56-year-old woman with AO type B1.2.1 injury and grade C neurologic deficit. A, Radiographs show significant interspinous process widening between T11 and T12 (arrows). B, With sagittal angulation, consistent with posterior ligamentous injury. C, CT axial image shows severe spinal stenosis secondary to the anterior vertebral body component of this three-column injury (AO type A3.1 pattern). D, Late follow-up postoperative radiographs after T12 corpectomy and reconstruction with structural allograft and University plate. E, Sagittal angulation improvement was maintained and neurologic deficit improved to grade D.

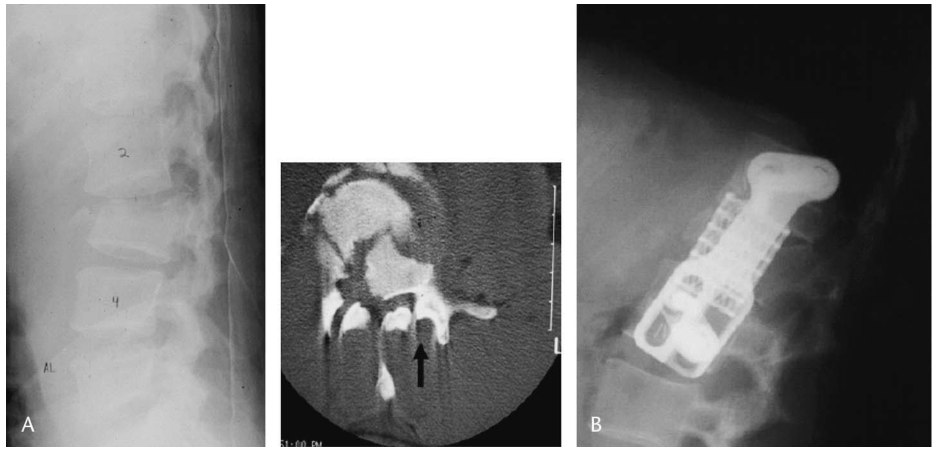

FIGURE 2. A 41-year-old woman with AO type C1.3.1 injury and grade B neurologic deficit. A, Radiograph shows anterior translation and segmental kyphosis. CT axial image shows canal stenosis and unilateral empty facet (arrow) due to the rotational component of this three-column injury. B, Latest postoperative radiograph after reconstruction with titanium-mesh cage and Z-plate. Neurologic status improved to grade D.

15–67 years), respectively. Mechanisms of injury included motor vehicle accident in 2 (62.5%), falls from height in 13 (32.5%), and direct impact trauma in 2 patients (5%). All injuries occurred between T12 through L3 (Table 1). All patients underwent evaluation with preoperative and serial postoperative anteroposterior and lateral radiographs from which segmental angulation was measured using the Cobb method. Canal compromise was estimated from preoperative CT scans according to the method of Hashimoto et al.[26] Preoperative radiographs and CT scans (with or without MRI) were used to categorize these three-column injuries according to the AO classification system. Twenty-four (60%) were type B1.2, 10 (25%) type B2.3, 5 (12.5%) type C1.3, and 1 (2.5%) type C2.1 (Table 2). Factors determining timing of operative intervention included timing of transfer from outside hospitals to our tertiary care centers, associated injuries, and neurologic condition. The mean interval from injury to surgery was 2.5 days (range 8 hours-11 days).

Operative Technique

All patients underwent a single-stage anterolateral approach (either transthoracic, thoracoabdominal, or retroperitoneal) with single-level corpectomy decompression and reduction. Reconstruction was performed with titanium-mesh cage packed with local autograft (19 patients), structural iliac autograft (13 patients), or structural tibial allograft (8 patients). Intraoperative radiographic assessment is essential during reconstruction of these unstable three-column injuries to evaluate reduction and avoid overdistraction. Two-level anterior instrumentation was performed with Z-plate (Medtronic, Memphis, TN) in 21 patients (Fig. 3), University plate (Depuy Acromed, Cleveland, OH) in 16 patients, or Kaneda device (Depuy Acromed) in 3 patients (Table 3). Bicortical fixation was performed in all constructs, which were appropriately compressed to improve load sharing. Postoperatively, all patients were managed in a total-contact thoracolumbar sacral orthosis for 3–6 months.

Preoperative and postoperative neurologic status was assessed according to the American Spinal Cord Injury Association modified Frankel Impairment Scale.[27] As radiographic determination of fusion can be difficult with anterior thoracolumbar instrumentation, a construct was deemed stable in the absence of motion in flexion-extension films, lack of significant radiolucency at the interbody graft-vertebral body junction, and no evidence of interval change in angulation in a >1-year period.[16,28] Average patient radiographic and clinical follow-up was 31.1 months (range 9–50 months).

Statistical Methods

Analysis of variance and Tukey post-hoc tests tested differences across patient demographics, mechanism of injury, AO classification injury types, reconstruction methods, and type of anterior spinal instrumentation. Matched preoperative and postoperative measurements were analyzed with paired *t* tests. Differences in arthrodesis probability among injury types and instrumentation/reconstruction methods were analyzed with a likelihood ratio test. Statistical analysis was performed with SAS (for Windows, version 8.00; SAS Institute, Cary, NC).

RESULTS

Neurologic Recovery

No patients deteriorated neurologically as a result of operative treatment. Thirty of 33 patients (91%) with incomplete injuries improved at least one modified Frankel grade (range one to three grades). Three of four patients categorized as modified Frankel A demonstrated some improvement, whereas all three modified Frankel E neurologically intact patients (7.5%) remained unchanged (see Table 1).

Radiographic Results

Preoperative canal compromise, based on preoperative CT scan, averaged 68.5% (range 32–100%). Average vertebral body height loss at the injured level was 44.5% (range 30–60%). Mean preoperative segmental kyphosis measured 22.7° (range 10–42°, SD 8.3°) with significant ($P < 0.0001$) early postoperative correction to 7.4° (range 0–28°, SD 7.4°). At latest radiographic follow-up, angulation was significantly changed but only by an average 2.1° (range −6–7°) to 9.3° (range 0–28°, SD 8.2°) ($P < 0.001$) (Figure 4). However, latest postoperative sagittal angulation remained significantly

TABLE 1. Patient Demographics

Male/female				29/11
Av. age (y)				37.4/40.2
Mechanism of injury				
MVA				25 (62.5)
Fall				13 (32.5)
Other				2 (5.0)
Level of primary vertebral fracture				
T12				7 (17.5)
L1				23 (57.5)
L2				6 (15.0)
L3				4 (10.0)
Preoperative neurologic status				
A	B	C	D	E
4	9	11	13	3
Postoperative neurologic status				
A	B	C	D	E
1	0	4	15	20

Values in parentheses are percentages.
MVA, motor vehicle accident.

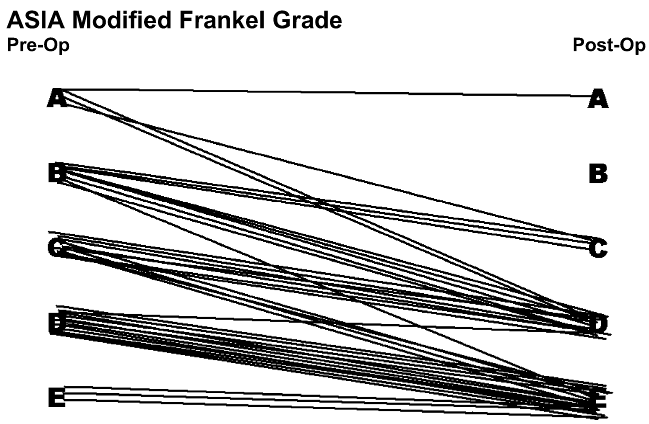

TABLE 2. Three-Column Thoracolumbar Injury According to AO Classification

Injury Type	No. pts.	Injury Subgroup	
B1.2	24 (60%)		
		B1.2.1	18
		A3.1	12
		A3.2	2
		A3.3	4
		B1.2.3	6
		A2.2	1
		A3.3	5
B2.3	10 (25%)		
		B2.3.1	2
		A3.1	2
		B2.3.2	8
		A3.1	8
C1.3	5 (12.5%)		
		C1.3.1	1
		C1.3.2	1
		C1.3.3	3
C2.1	1 (2.5%)		
		C2.1.1	1

different from preoperative angulation ($P < 0.0001$). One patient with a type C2.1 injury (type B1 flexion–distraction injury with posterior ligamentous disruption and associated rotational component) experienced early failure due to a technical error with a malpositioned derotational screw, allowing recurrence of translational and rotational deformity. This required an early posterior thoracolumbar instrumentation for salvage, which went on to uneventful healing. Aside from this patient, 37 of 39 (95%) patients demonstrated apparently stable constructs by radiographic evaluation at latest follow-up. Two patients had evidence of pseudarthrosis and subsequently underwent successful posterior thoracolumbar arthrodesis with instrumentation; both had type B2.3 injuries (flexion–distraction injury with type A vertebral body burst fracture and posterior element fractures through pars interarticularis) reconstructed with structural iliac graft and University plate instrumentation. There was no statistically significant difference in the apparent arthrodesis rates at 95% confidence interval likelihood testing among the different AO injury classes ($P = 0.21$) or anterior thoracolumbar implant types and reconstruction methods ($P = 0.18$).

Complications

Three of 40 patients (8%) required either early or delayed supplemental posterior thoracolumbar arthrodesis with instrumentation. There was no progression of initial neurologic deficit in these or any of the other 37 patients. There were no intraoperative or late vascular injuries. Three patients demonstrated radiographic evidence of minor screw loosening that did not progress; no cases required removal of anterior thoracolumbar implants. Two patients who underwent thoracolumbar approaches (5%) developed low thoracic dermatomal pain from intercostal neuralgia that was improved after a series of intercostal nerve blocks. Perioperative complications included two cases of pneumonia/atelectasis, one urinary tract infection, and one superficial wound infection that was successfully treated with antibiotics.

DISCUSSION

The anterolateral approach allows direct decompression of ventral osseous and soft tissue pathology, offering superior canal clearance as compared with posterior indirect (ligamentotaxis) and posterolateral decompression techniques.[10,11,22,24,25,29–31] Although some have reported that this improved anterior decompression results in better neurologic recovery as compared with the posterior management of thoracolumbar fractures,[1,11,12,22] others found no significant difference.[31,32] Initial uninstrumented reconstruction methods with simple anterior strut grafting resulted in unacceptably high rates of pseudarthrosis, ranging from 10% to 100%.[1,9,10,33]

FIGURE 3. A 33-year-old man with AO type B1.2.3 injury and grade C neurologic deficit. A, Radiograph shows anterior translation of T12 on L1. B, CT scan shows similar findings as well as facet fracture/dislocation. C, T2-weighted sagittal MRI shows disruption of posterior ligamentous complex (arrow). D, Three-dimensional postoperative radiograph at 20 months after anterior reconstruction and instrumentation, demonstrating maintenance of segmental sagittal alignment.

Therefore, two-stage anterior decompression and posterior instrumentation were recommended.[1,10,14,17,20,22,34]

Early anterior thoracolumbar instrumentation, developed by Dwyer, Hall, and Zielke,[1,33] was used in the correction and stabilization of scoliosis. However, these devices were biomechanically insufficient in the setting of unstable thoracolumbar injuries.[10,11,35,36] More recently, anterior thoracolumbar instrumentation has significantly evolved, greatly increasing its utility in treating thoracolumbar trauma.[17,36–38] Current devices allow both distraction and compression, with greater deformity correction and improved load-sharing ability.[1,17,36,38,39]

Numerous biomechanical studies have demonstrated the stability provided by these newer, more rigid designs.[36,40,41] An et al[17] evaluated the biomechanical characteristics of four different types of anterior thoracolumbar instrumentation (three of which were the Kaneda device, University plate, and Z-plate, used in the authors' current study) in a calf spine model with anterior and middle column defects. All showed significant stabilizing effects, and all restored axial rotation stability. In another calf spine model, Gurr et al[40] compared the mechanical stiffness of an anterior construct (Kaneda device) with posterior pedicle screws, concluding that posterior

TABLE 3. Reconstruction Methods and Instrumentation

Anterior Instrumentation	Reconstruction Method	
Z-plate	Structural allograft	2
	Titanium cage/autograft	19
		21
University plate	Structural autograft	10
	Structural allograft	6
		16
Kaneda device	Structural autograft	3
Total		40

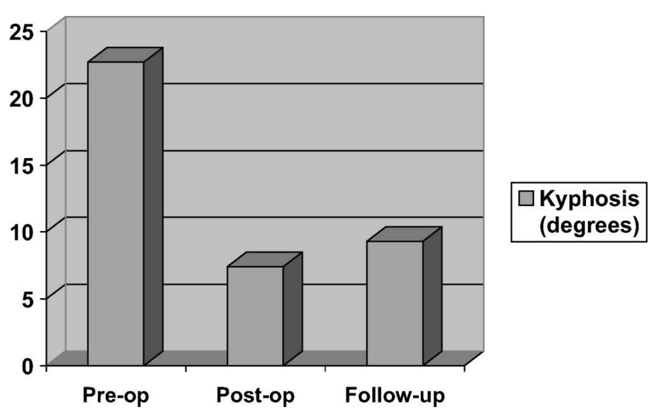

FIGURE 4. Sagittal alignment.

systems spanning five levels produced results similar to the Kaneda device spanning three levels.

As a result of these biomechanical improvements in anterior thoracolumbar instrumentation,[17] several investigators began using these constructs in the single-stage management of acute or late thoracolumbar injuries.[1,2,11,12,15,28,42] Kostuick[11] reported on a series of 49 patients with "burst injuries," 25 of whom underwent early or delayed anterior decompression and stand-alone instrumentation. Clinical results were very good, with an average 1.6 Frankel grade neurologic improvement and, among this subgroup, no pseudarthroses. Kaneda et al[15] initially reported on their early results in the anterior decompression and Kaneda device stabilization of 110 patients with thoracolumbar burst fractures with neurologic deficits. Thirteen years later, they included longer-term follow-up (mean 8 years) on 150 such patients, the largest published series to date.[2] Reportedly, these were all burst fractures according to the Denis classification, with a preoperative mean canal stenosis of 47% (improved to 2% postoperative mean) and mean kyphotic deformity of 19° (corrected to 7° postoperatively, without significant loss at latest follow-up). Ninety-five percent improved neurologically by at least one Frankel grade. Schnee and Ansell[16] reported on 25 patients with thoracolumbar burst fractures, 15 of which they considered three-column injuries. Although not specifically delineated, at least four of these three-column injury patients underwent successful stand-alone anterior decompression and reconstruction. In their series, preoperative mean stenosis was 48.3% and mean kyphosis 16.8°, corrected to 2.9° postoperatively. Sixteen of 17 patients with neurologic deficit improved.

With few exceptions,[13] the majority of studies describing stand-alone anterior treatment of thoracolumbar injuries have been in reference to the burst fracture groups of the Denis and McAfee classifications. These represent two-column (anterior and middle) injuries, corresponding to the type A3 injury of the AO classification. Although some authors label some of these injuries "three column" due to a posterior element injury in the form of an associated longitudinal laminar split fracture, this does not result in inherent insufficiency of the posterior ligamentous complex.[3,16,19] Thus, these fractures would not be considered type B or C injuries in the AO classification system. However, it is certainly possible that some of the series reporting stand-alone anterior thoracolumbar treatment of two-column Denis burst fractures did include subtle type B1.2 or C1.3 AO classification injuries (true three-column injuries).

The authors' current study, reviewing the results of single-stage, stand-alone anterior surgical management of some types of three-column (type B and C) thoracolumbar injuries, demonstrates findings not unlike those previously reported for such treatment of theoretically more stable two-column injuries. Ninety-one percent of the patients with an incomplete neurologic injury developed neurologic improvement of at least one modified Frankel grade; none experienced neurologic deterioration. Aside from one early failure due to a technical error, 37 of 39 (94%) patients appeared to have stable constructs at latest follow-up, similar to results from Kaneda et al.[2,15] Two patients who developed known pseudarthrosis underwent successful augmentation with instrumented posterior arthrodesis. Although both occurred in type B2.3.2 injuries (posterior osseous flexion–distraction injury through pars interarticularis with type A anterior vertebral body fracture), this injury subgroup was not significantly different from other type B or C groups ($P = 0.21$). Significant angulation improvement was achieved postoperatively with a mean preoperative 22.7° kyphosis correcting to a mean postoperative 7.4°. Although some kyphosis returned at latest follow-up, this represented only an average 2.1° loss of correction, with overall sagittal angulation still remaining significantly improved from preoperative angulation ($P < 0.0001$).

Several investigators have reported that anterior management of acute thoracolumbar injuries allows improved kyphosis correction (and maintenance of that correction), as compared with posterior instrumentation.[1,4,8,26,43] This is a result of the restoration of anterior column load bearing, which can be achieved with anterior reconstruction methods, placing the interbody graft material in a biomechanically optimal environment of compression. Alanay et al[5] described a technique that replicates this anterior column restoration through posterior intracorporeal transpedicular grafting to prevent angulation and failure of short-segment pedicle instrumentation. Twenty consecutive patients were prospectively randomized into short-segment posterior instrumentation with or without intracorporeal transpedicular grafting. There was no significant difference between the two groups, each with a 40–50% failure rate of >10° correction loss and 10% hardware breakage.[5] The importance of maintenance of correction is controversial.[19] Malcom et al,[44] as well as others,[11] have concluded that compensatory hyperlordosis below a kyphotic segment resulted in increased posttraumatic back and buttock pain. Others have found no correlation between clinical outcome and residual kyphosis.[19]

Additionally, stand-alone anterior thoracolumbar treatment of unstable injuries allows short-segment constructs to be used, saving motion segments (particularly in comparison with long-segment posterior constructs, the traditional treatment method for these types of injuries).[17,24,39,41] In this study of unstable three-column injuries, a single-level corpectomy reconstruction with two-segment instrumented arthrodesis resulted in relatively high stability. Short-segment posterior constructs can accomplish the same goal; however, they have been associated with reportedly high failure rates, ranging from 10% to 50%.[4,5,8,16,43,45] Subsequently, McCormack and co-workers[43] have described a "load-sharing" classification to identify which unstable thoracolumbar fractures are likely to have poor anterior load-bearing capabilities (such as some AO type B1.2, B2.3, and C injuries), resulting in loss of kyphosis correction and posterior instrumentation failure. In those instances, they recommend either a long-segment posterior instrumented arthrodesis or two-stage anterior and posterior procedures.[4,43]

The authors' current study is limited by its retrospective nature and relatively small population, which restricts the conclusions drawn from reconstruction subgroup comparisons (structural allograft versus structural autograft versus titanium-mesh cage packed with local autograft). Similarly, although all three cases requiring supplemental posterior instrumentation occurred with University plate instrumentation, this was not statistically significant (P = 0.15). Whereas most current anterior thoracolumbar implants perform acceptably well in biomechanical testing, some instrumentation (such as Kaneda-like linked dual-rod constructs) provides significantly greater rigidity than some screw and plate designs (such as the University and Z-plates),[19,36] particularly in torsion. Despite this experimental biomechanical advantage, all implants yielded equally acceptable clinical results, pointing toward the important role of meticulous attention to surgical technique in reconstruction of an appropriate load-sharing environment (helping to decrease instrumentation failure rates).[36,38]

Finally, the authors certainly do not advocate single-stage stand-alone anterior management of all three-column thoracolumbar injuries. No attempt was made to treat any type C3 (rotational shear) or most type C2 injuries with this approach, owing to the significant instability associated with such injury patterns. In these circumstances, this stand-alone construct would not provide an adequate degree of stability.

CONCLUSIONS

The efficacy of stand-alone single-stage anterior decompression and reconstruction of unstable three-column thoracolumbar injuries, utilizing current-generation anterior spinal instrumentation, was studied. Modern anterior spinal instrumentation and reconstruction techniques can allow some types of unstable three-column thoracolumbar injuries to be treated in an anterior stand-alone fashion similar to those previously reported for stable burst fractures without posterior column disruption. Sagittal alignment was restored and maintained, 91% of patients developed neurologic improvement of at least one modified Frankel grade, and 94% of patients appeared to have stable constructs. The advantages of this anterior stand-alone technique in unstable AO B-type fractures are allowing direct anterior decompression of neural elements, improvement in segmental angulation, and acceptable rates of arthrodesis without the need for supplemental posterior instrumentation. Caution should be used with extremely unstable C-type fractures with rotational, translational, and shearing instabilities. These fractures and fracture–dislocations should first undergo posterior stabilization.

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