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Clinical Article

Unstable burst fractures of the thoraco-lumbar junction: treatment by posterior bisegmental correction/fixation and staged anterior corpectomy and titanium cage implantation

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Summary

Background. Controversy exists about the best treatment of unstable thoraco-lumbar (TL) burst fractures. Kyphosis correction and canal decompression in case of a neurological deficit are recognized treatment objectives, and various conservative and surgical strategies have been proposed. This prospective observational study evaluates the benefits and risks of a posterior bisegmental transpedicular correction/fixation and staged anterior corpectomy and titanium cage implantation in unstable TL junction burst fractures.

Method. 20 consecutive patients with a single-level traumatic unstable burst fracture at the TL junction were operated on by a bisegmental posterior correction/fixation, followed by anterior corpectomy and titanium cage implantation 7–10 days later. The radiological and clinical course is documented over a period of 24 months.

Findings. The mean posttraumatic loss of anterior vertebral body height was 58% (45–70%). The posttraumatic mean regional kyphosis was 16° and could be corrected by the posterior approach to a mean lordosis of 2°. Mean secondary loss of the kyphosis correction was 3° over 24 months. No hardware failure occurred, and construct stability was observed in all 20 patients. One surgical complication occurred during the posterior approach, and three transient surgical complications by the anterior approach. 12 of the 14 patients with an initial neurological deficit recovered an average of 1.5 grades on the ASIA scale. At 24 months postoperatively, the mean regional TL back pain on a VAS (0–10) was 1.6, and the mean pain at the anterior approach site was 1.2.

Conclusion. Posterior bisegmental transpedicular correction/fixation and staged anterior corpectomy and titanium cage implantation is a safe and reliable surgical treatment option in unstable TL junction burst fractures. The advantages of this technique are a complete kyphosis correction, immediate stability, maintenance of kyphosis correction, and complete spinal canal decompression in case of a neurological deficit. However, these advantages have to be carefully weighed against the double approach morbidity.

Keywords: Spine; thoracolumbar; burst fracture; combined approach.

Introduction

Most traumatic thoraco-lumbar (TL) fractures occur at the TL junction (T11-L2) [24]. Burst fractures are the most frequent type of TL fractures, resulting from a compression mechanism or as part of a hyperflexion-extension or rotation injury [24]. Due to the anterior column destruction with spinal canal encroachment, a regional kyphosis and a high incidence of neurological deficit are characteristic for TL junction burst fractures [7, 14, 15, 17, 19, 21, 30, 33, 34, 37, 41, 45]. Kyphosis correction and, in case of a neurological deficit, optimal decompression of the spinal canal are therefore primary treatment objectives. However, the literature is inconclusive about the ideal conservative or surgical treatment.

This prospective observational study evaluates the benefits and risks of a posterior bisegmental transpedicular correction/fixation and staged anterior corpectomy and titanium cage implantation in unstable TL junction burst fractures.

Material and methods

22 consecutive patients were admitted to the author's institution with an unstable traumatic single-level burst fracture at the TL junction. One patient was lost to follow-up after transfer abroad, and one patient refused follow-up controls. Altogether, 20 patients, 6 women and 14 men, with a mean age of 36 years (19–58 years), were prospectively followed during a 24-month period. Instability of the burst fracture was defined as presence of at least one of the following criteria: a

Table 1. *Standard neurological classification of spinal cord injury according to the American Spinal Injury Association, "ASIA impairment scale"*

A	Complete spinal cord injury: No motor or sensory function is preserved in the sacral segments S4–S5
B	Incomplete spinal cord injury: Sensory but not motor function is preserved below the neurological level and includes the sacral segments S4–S5
C	Incomplete spinal cord injury: Motor function is preserved below the neurological level, and more than half of key muscles below the neurological level have a muscle grade less than 3
D	Incomplete spinal cord injury: Motor function is preserved below the neurological level, and at least half of key muscles below the neurological level have a muscle grade of 3 or more
E	Normal: Motor and sensory function is normal

neurological deficit (14/20 patients), more than 20° of regional kyphosis (6/20 patients), at least 50% loss of anterior vertebral body height (18/20 patients), and/or a significant posterior element lesion (6/20 patients). None of the patients suffered from manifest spinal osteoporosis, tumor, infection, or inflammatory disease of the spine. The fracture was caused by a parachute accident in nine patients, a fall from height in eight patients, a skiing accident in two patients, and a car accident in one patient. Neurologically, the patients were classified according to the ASIA classification (Table 1) [25]. Six patients had complete paraplegia (ASIA A), eight patients an incomplete injury (ASIA C or D), and six patients were neurologically intact (ASIA E) (Table 3). All patients with a neurological deficit received intravenous steroids according to the NASCIS II protocol [5].

CT with coronal and sagittal reconstructions was performed upon admission, and the fractures were classified according to Margerl's comprehensive classification of TL spine injuries (Table 2) [24]. In all 20 patients, a single-level burst fracture was found. In 14 patients, there was no posterior element lesion according to preoperative CT scan and intraoperative findings (type A3 fracture), while in 6 patients there was an additional posterior element lesion from a hyperflexion-extension lesion (type B lesion, 3 patients) or from a rotation injury (type C lesion, 3 patients). The fracture level was T11 in one patient, T12 in two patients, L1 in ten patients, and L2 in seven patients. Preoperative regional kyphosis was measured on sagittal CT reconstructions as the Cobb angle between the superior endplate of the vertebra above the fracture and the inferior endplate of the vertebra below the fracture. Postoperative and follow-up regional kyphosis was indicated as the Cobb angle on supine lateral radiographs. The anterior vertebral body height loss was measured on sagittal CT reconstructions and indicated in percent of the normal vertebral body height of the subjacent intact vertebral body.

Surgical technique

The posterior approach was performed within 8 hours after the accident in neurologically compromised patients, and within 3 days in neurologically intact patients. The patients were positioned in the prone position with cushions under the iliac crests and the thorax. After midline incision and standard exposure, pedicle screws (USS fracture system, Synthes, Solothurn, Switzerland) were inserted into the vertebra above and below the fracture, and compression of the pedicle screw extension tips enabled complete kyphosis correction in all patients under lateral fluoroscopic control. Axial distraction of approximatively 3–5 millimeters (mm) was performed to restore the vertebral body height and to obtain indirect canal decompression by ligamentotaxis. Laminectomy with or without pediculectomy and removal or reposition of the posterior wall fragment was performed in patients with a severe neurological deficit (ASIA A, B, C). The local spinous processes, bone from the decompression, and additional allograft bone chips were used for posterolateral and/or posteromedial fusion.

7–10 days after the posterior fixation, the anterior approach was performed. After double-lumen intubation, the patient were positioned in the right lateral position. The left lung was excluded by the anesthesiologist, and a left-sided thoracotomy with resection of the 10th rib was performed. The diaphragm was opened from the upper surface at 1–2 centimeters from the thoracic wall, to expose most T12 and all L1 or L2 fractures. After medial retraction of the peritoneal sack, the lateral surface of the fractured vertebral body was exposed and the segmental vessels ligated. The disc above and below the fracture was removed, then a subtotal corpectomy of the fractured vertebral body was performed, leaving the right lateral and anterior vertebral body wall in place. In case of a neurological deficit, the posterior wall was also removed and thus the dura exposed. A hollow expandable titanium cage (VBR, Ulrich, Ulm, Germany), 20 or 24 mm in diameter, was filled with cancellous bone from the corpectomy and inserted into the corpectomy

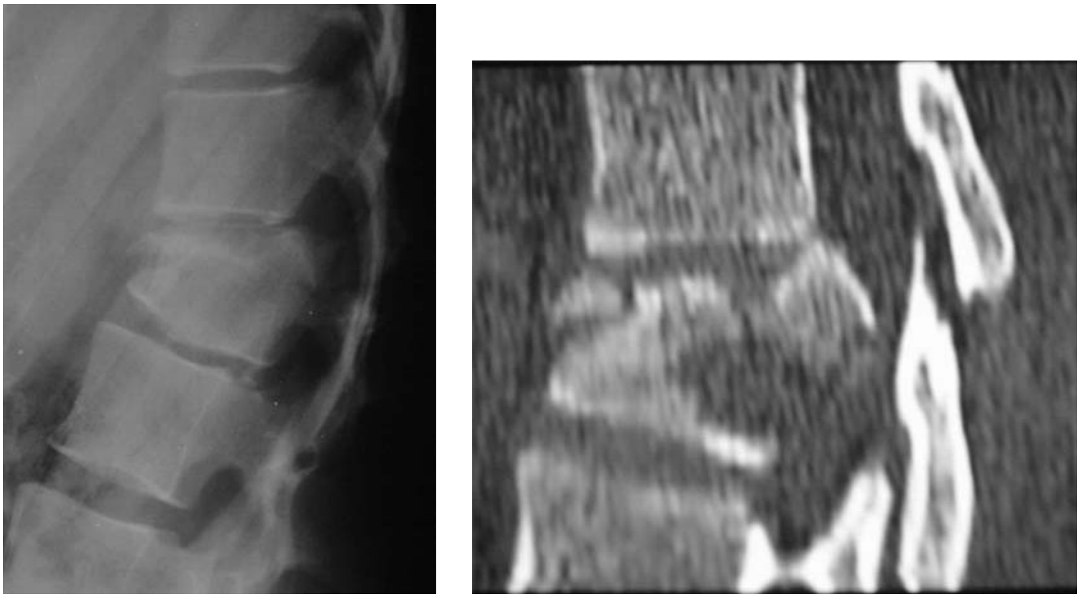
Table 2. *Magerl's comprehensive classification of thoracic and lumbar injuries*

Type A injuries:	Vertebral body compression
	A1 Impaction fractures
	A2 Split fractures
	A3 Burst fractures
Type B injuries:	Anterior and posterior element injury with distraction
	B1 Posterior disruption predominantly ligamentous (flexion-distraction injury)
	B2 Posterior disruption predominantly osseous (flexion-distraction injury)
	B3 Anterior disruption through the disc (hyperextension-shear injury)
Type C injuries:	Anterior and posterior element injury with rotation
	C1 Type A injuries with rotation
	C2 Type B injuries with rotation
	C3 Rotational-shear injuries


Fig. 1. Standard wounds of the described combined approach

defect under lateral and AP fluoroscopic control. The cage was progressively distracted to engage well into the vertebral endplates and then locked. Additional cancellous bone from the corpectomy was layed around the cage. The diaphragm and the thoracotomy wound were closed in a standard fashion over two thoracic drains.

The patients were mobilized on the second postoperative day after the posterior approach, and then again on the third postoperative day after the anterior surgery. No brace was given. The thoracic drains were removed between the first and fourth postoperative day. Later hardware removal was not performed in any of the patients.



a b

Fig. 2. (a) Supine plain lateral radiograph of a 31-year-old man with a L1 burst fracture type A3.1 with a regional kyphosis of 25°. (b) Sagittal CT reconstruction of the same patient

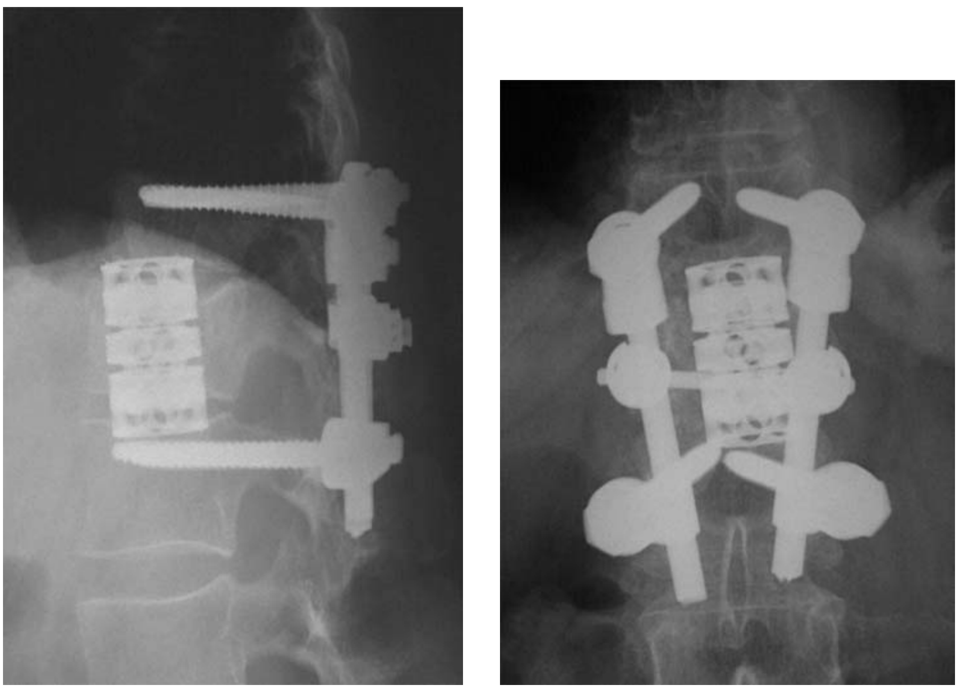


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Fig. 3. (a) Standing plain lateral radiograph of the same patient at the 24-month-follow-up showing a regional lordosis of 2°. (b) Antero-posterior radiograph of the same patient at the 24-month-follow-up

The patients were prospectively observed with plain lateral and antero-posterior (AP) radiographs after the first and second surgery, as well as 3, 6, 12, and 24 months postoperatively. Neurological grading according to the ASIA classification as well as pain evaluation on a visual analogue scale (VAS) from 0–10 for TL back pain and for pain in the anterior approach site were recorded at 3, 6, 12, and 24 months postoperatively.

Figures 1–3 show an illustrative example.

Results

Surgical results

The mean surgical duration for the posterior approach was 148 minutes (range: 109–208 minutes), and 183 minutes (range: 142–247 minutes) for the anterior approach. The average blood loss was 710 cc for the posterior approach (range: 400–1300 cc) and 640 cc for the anterior approach (range: 350–1200 cc).

Radiological results (Table 3)

The mean posttraumatic loss of anterior vertebral body height on sagittal CT reconstructions was 58% (45–70%); all patients had at least 45% of vertebral body height loss. The posttraumatic mean regional kyphosis was 16° (range: 25° kyphosis to 0°) and was corrected by the posterior approach to a mean regional lordosis of 2° (range: 6° kyphosis to 11° lordosis), which was unchanged after the anterior approach, then decreased to 0° at 3 and 6 months, and to 1° of kyphosis at 12 and 24 months. Altogether, the mean loss of regional kyphosis correction was 3° over 24 months.

Preoperative traumatic regional scoliosis was only found in one patient; it was corrected by the posterior approach from 12° to 6° and remained stable at the follow-ups.

Since bony fusion of a titanium corpectomy cage can not be reliably assessed on plain radiographs or CT [31], *construct stability* was defined in the current series as absence of progressive kyphosis, absence of hardware failure, and absence of radiolucencies at the screw–bone or cage–bone interface. Construct stability was found in all 20 patients.

Clinical results (Table 3)

Mean local TL back pain at the fracture site was 2.4 (range: 0–4) at 3 months postoperatively, 2.0 (range: 0–4) at 6 months, 1.5 (range: 0–3) at 12 months, and 1.6 (range: 0–3) at 24 months. Mean pain at the site of the anterior approach was 2.9 (range: 0–6) at 3 months, 1.9 (range: 0–5) at 6 months, 1.3 (range: 0–4) at 12 months, and 1.2 (range: 0–3) at 24 months.

Of the six patients with initial complete paraplegia (ASIA A), one patient remained completely paraplegic, one patient improved one grade, one patient improved two grades, and three patients improved three grades. All three patients with an initial incomplete lesion ASIA C improved one grade. Four of the five patients with initial incomplete lesion ASIA D recovered completely, while one patient remained unchanged. All six initially intact patients remained so during the observation period. Altogether, 12/14 patients with an initial neurological deficit recovered an average of 1.5 grades on the ASIA scale.

Complications

No perioperative complications were observed from the posterior approach apart from one screw malpositioning; a T12 pedicle screw was placed too laterally and replaced during the anesthesia for the anterior approach. There were three complications after the anterior approach. One patient suffered from a transient paralytic ileus for one week postoperatively; no organic lesion was found on abdominal CT, and the further clinical course was uneventful. One patient had persistent

Table 3. *Radiological and clinical results*

	Post trauma	Post 1st and 2nd op.	3 m	6 m	12 m	24 m
Mean regional kyphosis (Cobb angle)	16°	−2°	0°	0°	1°	1°
Mean TL back pain (VAS, 0–10)			2.4	2.0	1.5	1.6
Mean ant. approach pain (VAS, 0–10)			2.9	1.9	1.3	1.2
Nbr. of pts.						
ASIA A	6	6	3	1	1	1
ASIA B	0	0	2	2	2	1
ASIA C	3	2	1	3	1	2
ASIA D	5	4	4	4	6	6
ASIA E	6	8	10	10	10	10

ilioinguinal hypesthesia after the anterior surgery. Compression of the ilioinguinal nerve from retraction of the psoas muscle might be responsible for this complication. And finally, one patient developed a progressive anterior pneumothorax with dyspnea within 3 hours postoperatively despite the two thoracic drains, of which one was positioned too posteriorly and was malfunctioning. A third thoracic drain had to be inserted and the patient recovered well.

Discussion

Almost two thirds of all traumatic TL spine injuries occur at the TL junction, most frequently at L1, followed by T12 [24]. About half of all TL junction lesions are characterized by a burst of the vertebral body, which can result from a compression mechanism (type A3 lesion) or occur as part of a hyperflexion-extension (type B) or rotation lesion (type C) [24]. Due to the anterior column destruction, traumatic TL junction burst fractures typically show a marked initial regional kyphosis of 10–32° on supine lateral radiographs or sagittal CT reconstructions [1, 2, 6, 7, 14, 15, 17, 19, 21, 30, 31, 33, 34, 37, 41, 45]; they are associated with a high rate of neurological deficit of 32–55%, as shown in Magerl's large series of 1445 cases [24]. The "stability" or "instability" of a burst fracture has not been uniformly defined. According to the legendary definition by Whitesides, "a stable spine is one that can withstand stress without progressive deformity or further neurologic damage" [44]; in this sense, all TL junction burst fractures therefore are "unstable", in that they commonly progress in regional kyphosis, if untreated [11, 36, 41], and only exceptionally, secondary neurological worsening has been observed [11, 30]. However, most authors speak about "unstable burst fracture" in the presence of a neurological deficit, more than 50% canal stenosis, more than 20° of regional kyphosis, at least 50% loss of anterior vertebral body height, and/or a significant posterior element lesion [8, 15, 26, 28, 30, 33, 36, 41, 45].

From an anatomical standpoint, the ideal treatment of unstable TL junction fractures should consist of complete kyphosis correction with long-term correction maintenance, and optimal spinal canal decompression in case of a neurological deficit. Yet, the treatment of TL junction burst fractures remains very controversial for a number of reasons: No correlation between radiological kyphosis correction and clinical outcome has been established yet [18, 36, 45], and the Scoliosis Research Society Multicenter spine fracture study showed that significant back pain and disability was only associated with kyphosis exceeding 30° at a 2 year follow-up [13]. Furthermore, spontaneous remodelling of the spinal canal with near-complete intracanalicular fragment resorption within 1–5 years after a TL burst fracture has been consistently observed [10, 12, 16, 38], and a recent debatable meta-analysis failed to show a benefit from surgical decompression in cases TL fractures with a neurological deficit [4]. Finally, several studies have even shown that the single most important predictive factor of return to work after TL fractures was the educational background and the presence or absence of compensation claims [7, 37, 42].

Conservative treatment has frequently been used in TL burst fractures without neurological deficit, less than 50% canal stenosis, and less than 40% loss of anterior vertebral body height, and consisted of bed rest between two days and six weeks, with or without closed reduction, and mobilisation with or without a hyperextension cast for at least three months [15, 30, 36, 41, 45]. In a large series, radiological and clinical results did not show any difference between functional treatment and closed reposition with subsequent immobilization in a cast [36]. With the above indications, clinical results of different conservative treatments were satisfying, but progressive regional kyphosis beyond the post-accident angle was regularly observed [2, 15, 30, 36, 45]. Interestingly, kyphosis progression under conservative treatment has been equally observed in TL junction burst fractures, regardless of whether the posterior elements were injured or not [2].

Kyphosis correction, spinal canal decompression, and immediate stability can be achieved by surgery, after which the patient can be immediately mobilized. The most commonly performed technique has been a short posterior transpedicular fixation from the vertebra above to the vertebra below the fracture [1, 19–22, 29, 37]. Spinal canal decompression through a posterior approach can be achieved indirectly by ligamentotaxis, especially between T12 and L3, where there is a strong double layer structure of the posterior longitudinal ligament [22]. However, ligamentotaxis has been shown to be inefficient in greater than 50% canal compromise [39]. Direct canal decompression through a posterior approach can be obtained by laminectomy, pediculectomy, fragment reposition or fragment removal [23]. Posterior correction usually achieves complete kyphosis correction [1, 21, 29, 37]; however, secondary loss of correction of between 7–16° down to the initial posttraumatic angle is observed predominantly within the first postoperative year, and is mainly due to a collapse of the upper disc and upper half of the burst vertebral body [1, 20, 21, 23, 29, 32, 37, 45]. Postero-medial or postero-lateral fusion or transpedicular bone grafting have not been able to prevent this secondary loss of kyphosis correction [1, 19, 21, 29, 37].

The anterior approach with corpectomy, structural autograft or allograft and a lateral plate or rod fixation, has been used to directly reconstruct the weight-bearing anterior column, but has only been able to correct at best two thirds of the kyphotic deformity [6, 14, 17, 27, 33]. Long-term loss of correction of 1–4° after the anterior approach is reportedly less than after the posterior approach [6, 14, 17, 33], and seems to be in contrast to recent studies, which found the biomechanical stability of a single anterior cage and plate stabilization at the TL junction questionable and recommended to consider additional posterior fixation [35, 40].

Complete canal decompression in TL burst fractures is certainly best obtained by the anterior approach, due to direct access to the posterior wall fragment(s) [3, 17, 27, 33, 39]. However, corpectomy performed within the first 24 hours or even the first few days after the accident usually causes an important blood loss with the necessity to transfuse the patient [6, 27]. In McDonough's series, the average blood loss from the anterior approach was 1750 cc [27]; less than half of the patients in his study underwent surgery within the first 24 hours, and it can be assumed that this subgroup may have had an even higher blood loss. In Carl's series about corpectomy and anterolateral reconstruction after TL burst fractures, an estimated average blood loss of 2300 cc is reported with his patients being operated at an average of four days after the accident [6]. Blood loss from the posterior approach on the other hand has been found reported in one article, in which the delay between accident and surgery was a few days, and was very moderate with an average of 396 cc [23]; it was equally moderate with an average of 710 cc per patient in the current series, in which 14/20 posterior approaches were performed within the first 8 hours. From a hemodynamic standpoint therefore, the posterior approach seems much better suited for emergency decompression than the anterior approach.

Finally, in an attempt to reunite the advantages of both the posterior approach (complete initial kyphosis correction, smaller blood loss in case of emergency decompression) and the anterior approach (reconstruction of the weight-bearing anterior column, complete anterior spinal canal decompression in case of neurological deficit), TL junction burst fractures have been treated by the combined approach [3, 9]. Yet, Verlaan in his recent meticulous and systematic review found that no surgical method, even the combined approach, could maintain physiological kyphosis correction; final regional kyphosis converged to 10° with all short and long posterior, anterior, or combined approaches [43]. However, his review could not yet integrate newer techniques such as the use of titanium cages for anterior column reconstruction.

In the current study, the average loss of kyphosis correction after the combined approach in unstable TL junction fractures was only 3° over 24 months, and occurred mainly within the first six postoperative months. It can be hypothesised, that this maintenance of the initial kyphosis correction is due to the use of recently developed titanium corpectomy cages in conjunction with a posterior transpedicular fixation. Titanium cages have a much stronger biomechanical resistence to axial compression than the traditional autograft or allograft bone, making them an ideal load-bearing device after a TL junction corpectomy [35]. Even though 24 months is a relatively short follow-up, further substantial correction loss after these 24 months is unlikely, since no relevant correction loss occurred in any of the patients of the current study between the 12- and 24-month-follow-up.

Though very satisfying radiological results and complete spinal canal decompression in case of a neurological deficit could be achieved by the technique described in this study, there is a double approach morbidity. While there was only one complication from the posterior approach and three transient complications in the 20 anterior approaches in the current series, there was some persisting pain from the anterior approach even at 24 months postoperatively in most patients, averaging 1.2 on the VAS, in addition to residual posterior TL back pain. Whether or not this residual anterior approach pain is below a potential increase of TL back pain after a single posterior approach with significant re-kyphosis, remains unproven.

Altogether, the presented combined approach might be a good therapeutic choice in case of unstable TL junction burst fractures, especially in younger and otherwise healthy patients, who wish to resume heavier physical acitivities in their remaining decades of life, as well as in patients with a neurological deficit, where complete spinal canal decompression should favor a recovery potential. However, this study is by no means suggesting that the combined approach should be the preferred treatment of unstable burst fractures at the TL junction; it is merely one of the surgical options.

Drawbacks of this study are the lack of a comparative study group, the relatively short follow-up, and the limited patient number. On the other hand, a uniform surgical strategy and technique has been applied by a single surgeon at a single institution.

Conclusion

Posterior bisegmental transpedicular correction/fixation and staged anterior corpectomy and titanium cage implantation is a safe and reliable surgical treatment option in unstable TL junction burst fractures. The advantages of this combined technique are a complete kyphosis correction, immediate stability, maintenance of kyphosis correction, and complete spinal canal decompression in case of a neurological deficit. These advantages have to be carefully weighed against the double approach morbidity.

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Comment

As the name implies this is very much a spine orientated paper describing a staged posterior and anterior reduction, fixation and fusion of a specific type of single segment thoraco-lumbar fracture. Essentially the message is that by carrying out an anterior approach a week to ten days after the initial posterior primary correction, the secondary loss of correction can be prevented. When a fracture of this type is corrected using a posterior pedicle screw technique there is what is referred to as a secondary loss of correction of up to 16 degrees. This is due to the vertebral body and disc "settling" to some extent as the fracture site heals. The author has described how to prevent this by carrying out a second procedure to replace the fractured vertebral body using an expandable Titanium cage filled with bone graft. In this way the "pit prop" effect limits the secondary loss of correction to 2 or 3 degrees. This is effectively the message of this paper.

The author presents his results arguments in a clear and readable fashion. It is a prospective observational study matched against historical controls from the literature. It is, therefore, of limited value other than to indicate the technique can be employed, but has not been really tested.

I enjoyed reading his discussion element, particularly because he does include statements and comments from the literature which go against his philosophy of urgent surgical decompression and fusion.

Perhaps the main point he makes in this respect is that a recent study showed that significant spinal pain and disability following injury was only associated with a kyphosis exceeding 30 degrees at two year follow-up, suggesting that the anterior component is not particularly necessary other than to improve the post-operative x-rays.

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