Toyohiko Oda
Manohar M. Panjabi
Yoshihiko Kato

The effects of pedicle screw adjustments on the anatomical reduction of thoracolumbar burst fractures

Received: 14 January 2000
11 December 2000
Accepted: 3 April 2001
Published online: 27 July 2001
© Springer-Verlag 2001

The research was partially funded by National Institutes of Health grant AR39209.

T. Oda · M.M. Panjabi (✉) · Y. Kato
Biomechanics Laboratory,
Department of Orthopaedics
and Rehabilitation, Yale University,
School of Medicine,
PO Box 208071,
New Haven, CT 06520–8071, USA
e-mail: Manohar.Panjabi@yale.edu,
Tel.: +1-203-7852812,
Fax: +1-203-7857069

Abstract The short segmental pedicle screw device is widely used for the decompression of neural elements and reduction of normal anatomy. Many biomechanical studies concerning proper decompression are available. However, no study has determined the optimal device adjustment for reduction of the burst fracture to the normal anatomy. In this study, cadaveric thoracolumbar spine specimens (T11–L3) with L1 burst fractures were studied. A pedicle screw device was attached to the pedicles of the T12 and L2 vertebrae. Spinal postural changes were determined due to a set of eight clinically relevant adjustments of the device. The adjustments were combinations of axial translation (distraction/compression) and extension. The adjustments caused varying changes in spinal posture. The se-

quence of applying the translation and extension had no effect on the spinal posture changes. The adjustment combining 5 mm distraction with 6° extension brought the burst fracture closest to the intact state, compared to all other adjustments. With this adjustment, on average the spine became 0.9 mm compressed and 2.0° lordotic, compared to the intact. The results of the study show that the device adjustments of axial translation and sagittal angulation can be applied in any sequence, with the same results. The combination of 5 mm distraction with 6° extension was the device adjustment that produced the closest anatomical reduction.

Keywords Biomechanics · Burst fracture · Pedicle screw · Anatomical reduction

Introduction

Burst fractures are serious injuries with frequent neurological deficits. Incidences of burst fractures are more common among the young, between the ages of 16 and 30 [7, 15, 26]. Burst fractures result not only in personal suffering, but also significant social loss. There have been many reports suggesting appropriate therapies for these injuries. Surgical treatment of these patients is still controversial, but is gradually gaining more acceptance. The ideal goal of surgical treatment of burst fractures is decompression of the neural elements and reduction of the normal anatomy, leading to mobilization of the patient as early as possible [1, 5, 6, 18, 20].

There are many new and innovative surgical devices for operative treatment of burst fractures. However, a selection needs to be made carefully. Generally, there are two different types of surgical approach: anterior and posterior. The benefits of the anterior approach are well recognized: although it may be technically more difficult, the surgeon has direct access to the broken vertebral body. On the other hand, the posterior approach has some advantages, such as being technically less challenging and offering the possibility of removing the device at a later date. Of the many devices available for the posterior approach, use of the pedicle screw has become increasingly popular. Two benefits of the pedicle screw device are strong anchoring of the device to the vertebrae and the need to fuse fewer segments [14]. Furthermore, variable

adjustments of translation and angulation are possible using the new pedicle screw devices. These adjustments may be advantageous for the reduction of the deformity and decompression of the neural elements.

There have been several previous investigations concerning spinal reduction using pedicle screw distraction with or without angulation. Most studies have focused on the decompression of the neural canal and/or foraminal spaces [1, 4, 5, 6, 8, 16, 17, 25]. The present study focused on the anatomical reduction of thoracolumbar burst fractures. This included reduction of the spinal lordosis and segmental height. It is beneficial, prior to surgery, to know the effects of pedicle screw adjustments on the anatomical reduction. It has been suggested that the intracanal fragment is best reduced when the anatomic lordosis is restored in addition to a correction of the posterior vertebral height [30]. However, it is still uncertain whether the ideal reduction for the decompression of neural elements is associated with the anatomical reduction.

The objectives of our study were to determine the effects of applying several combinations of translation and angulation of the pedicle screw device on the anatomical reduction of a thoracolumbar burst fracture, and to choose the optimal adjustment set.

Materials and methods

Specimen preparation

Nine thoracolumbar specimens, T11–L3, were harvested from fresh human cadavers. There was no trauma history associated with any of these cadavers. In one specimen the age and gender was unknown. Of the remaining specimens, two were female and six were male, with an average age of 51.0 years (range: 20–74 years). They were wrapped in saline-soaked gauze, kept in double plastic bags, and stored frozen at -20°C until testing. For each specimen, soft tissues were cleaned off while preserving ligamentous structures. The top and bottom vertebrae were mounted in polyester resin casts, with the middle vertebra (L1) aligned horizontally. The adjacent vertebrae (T12 and L1) were provided with temporary tight-fitting casts, which protected these vertebrae during the impacts [13].

Radiographs

A headpiece fixed to the top of the upper mount was used to apply a functional load, which was a posteriorly directed force resulting in an extension moment of approximately 4 Nm at the center of the burst fracture vertebra. The load was applied for 30 s, and the radiograph was taken. This time period allowed for the creeping deformation of the specimen to occur. Before the burst fracture, a lateral radiograph was taken of the intact specimen, along with a scale, as a baseline ("intact").

Experimental burst fracture production

The experimental burst fractures were produced using an incremental impact protocol designed to produce burst fractures of predetermined severity, as defined by canal encroachment. The burst fracture producing apparatus and the procedure have been pre-

sented in earlier publications [11, 12, 22, 23, 24, 25]. A brief description follows. The impact trauma apparatus consisted of a steel frame rigidly attached to the concrete floor and the ceiling of the laboratory. An impact mass, guided by a vertical tube, was dropped onto an impounder resting on top of the specimen. The average drop height was 1.4 m, resulting in an impact speed of 5.2 m/s. A wedge was placed between the impounder and the specimen to force the latter into a slightly flexed posture, so that the mechanism of loading was flexion-compression. Each specimen was impacted with an initial mass of 3.3 kg. After the impact, a lateral radiograph was taken. If no burst fracture occurred, the mass was increased by 2 kg for the next impact. This incremental trauma was continued until a burst fracture of desired severity (defined by canal encroachment) occurred.

Applied adjustments

After the burst fracture, two pairs of Schanz screws were inserted into the T12 and L2 pedicles using the standard clinical technique [1, 3]. In T12, screws were inserted to a depth of approximately 40–45 mm, and in L2, the depth was 50 mm. To avoid loosening of the specimen-screw interface, polyester resin was poured into the screw hole before inserting the screw. This allowed us to precisely control the applied adjustment to the vertebra via the Schanz screws. With the headpiece applying zero force to the specimen, a lateral radiograph was taken. This posture constituted the "burst fracture in neutral posture (Burst-NP)". An AO internal fixator rod system (Synthes, Paoli, Pa.) was attached to the Schanz screws in this neutral posture. This pedicle screw system allowed us to apply varying amounts of axial translation and sagittal angulation independently.

It is recognized that there are innumerable combinations of translation and angulation, but only a limited number of combinations that can be studied in an experiment. Our choice depended upon such factors as: no injury to the specimen because of an adjustment, limiting experiment time and specimen degradation, and clinical relevance. Therefore, four axial translations, -5 , 0 , 5 , and 10 mm, and two sagittal angulations, 0° and -6° , were combined into a select set of eight adjustments: A–H. A positive translation meant distraction, and a negative one meant compression. A negative angulation meant extension. Those adjustments applied to the device in the present study are described in Table 1. The eight adjustments were: pure compression (-5 mm) in A, pure distractions (5 mm and 10 mm) in B and C, pure extension (-6°) in D, and combinations: compression (-5 mm) with extension (-6°) in E, and distraction (5 mm) with extension (-6°) in F. In the combined adjustments, E and F, compression/distraction was applied first, followed by extension. There were two additional adjustments, G and H, which were identical to adjustments E and F, except the extension was applied first.

Postural changes

Two postural parameters were studied: segmental height and segmental angle (Fig. 1). The height was measured between the line XX, tangent to the lower endplate of L2, and the line YY, parallel to

Table 1 Eight device adjustments (A–H) were studied. In these adjustments, translation was followed by extension, except in two adjustments, G and H (see Fig. 1 for sign convention)

Device adjustment	A	B	C	D	E	F	G	H
Translation (mm)	-5	5	10	0	-5	5	-5	5
Angulation (deg)	0	0	0	-6	-6	-6	-6	-6

Fig. 1 Definition of the spinal segmental height and angle, and the changes due to pedicle screw device adjustments. Line XX is tangent to the lower endplate of L2. Line YY is parallel to XX and passes through the posterior-inferior corner of the T12 vertebral body. Line ZZ is tangent to the inferior endplate of T12

XX and passing through the inferior-posterior corner of the T12 vertebral body. The segmental angle was measured between the line YY and the line ZZ, tangent to the lower endplate of T12. The increase/decrease in the segmental angle represented greater kyphosis/lordosis. To measure the postural changes of the spine specimen (between T12 and L2) due to the various device adjustments, the OPTOTRAK motion measurement system and specially written software were used.

Statistical analysis

Means and standard deviations were computed of the segmental heights and angles. Statistical analyses were performed to evaluate

the eight adjustments. To determine whether the sequence of applying translation and extension affected the postural changes, the effects due to E were compared with those due to G using a paired *t*-test. Similarly, F was compared to H. To determine the effects of the eight adjustments on the anatomical reduction, the differences between the intact spinal posture and the resulting spinal posture due to each adjustment were analyzed by performing single-factor repeated measure ANOVA and Fisher's PLSD post-hoc tests.

Results

The average intact segmental height and angle were 63.9 mm (SD: 4.2 mm) and -7.3° (SD: 7.7°) respectively. The Burst-NP segmental height and angle were 57.6 mm (SD: 3.5 mm) and -1.6° (SD: 10.3°) respectively. Thus, the burst fracture decreased the segmental height on average by 6.3 mm (SD: 3.6 mm), and the segmental angle changed to kyphosis by 5.7° (SD: 6.9°) (Fig. 2, Table 2).

The adjustments, with respect to the Burst-NP, caused varying changes in the spinal posture (Table 3 and Fig. 3). The postural changes due to adjustment E versus G, and also F versus H, were not significantly different, in either translation or angulation. Between adjustments E and G, and also F and H, only the sequence of translation and extension was different. Thus, the sequence of applying distraction/compression and extension did not affect the spinal postural changes. Another interesting result was that the changes in spinal posture were quite different from the applied device adjustment. For example, pure distractions of 5 and 10 mm were accompanied by some kyphosis, and pure extension also produced some distraction. Thus, pure device adjustments resulted in coupled spinal postural changes.

Fig. 2 Average changes in the segmental height and segmental angle due to burst fracture in neutral posture (Burst-NP)

Table 2 Individual changes in segmental height and segmental angle due to the burst fracture in nine specimens (see Fig. 1 for sign convention)

Specimen ($n=9$)	Segmental height (mm)	Segmental angle (deg)
1	-2.2	-0.8
2	-6.4	5.1
3	-7.1	11.3
4	-0.6	21.3
5	-5.8	1.1
6	-8.3	6.5
7	-4.5	1.2
8	-12.4	2.2
9	-9.6	3.0
Average	-6.3 (loss)	5.7 (kyphosis)
Standard deviation	3.6	6.9

Just as the postural changes due to the eight adjustments varied, so did the reduction of the burst fracture to the intact state (Table 4 and Fig. 4). The adjustment B (5 mm pure distraction) and C (10 mm pure distraction) produced results that deviated from the intact mostly in the segmental angle, while the adjustments A (5 mm compression) and E and G (5 mm compression, 6° extension)

deviated from the intact mostly in segmental height. The adjustments D (6° extension), and F and H (5 mm distraction, 6° extension), brought the burst fracture closer to the intact state than other adjustments.

Discussion

It is important to understand the effects of pedicle screw adjustments on the anatomical reduction of thoracolumbar burst fractures. The anatomical reduction has been correlated to the reduction of the intracanal fragments [30]. Additionally, loss of correction of deformity generally means higher risk of complications in the future. However, the reduction with the pedicle screw device is performed clinically, using the standard reduction techniques of Aebi et al. [1] and Dick et al. [3, 19, 30]. As the procedure is not based upon quantitative data, the results obtained are not optimal. Therefore, we conducted the study to first investigate the effects of pedicle screw adjustments on the spinal specimen with a burst fracture, and then to determine the adjustments that produced a spinal posture closest to the intact.

For the anatomical reduction of the burst fracture, the best adjustment is the one that restores the posture closest

Table 3 Average (SD) changes in segmental height and segmental angle, from the burst fracture in neutral posture to the resulting postures due to the respective device adjustments (see Fig. 1 for sign convention). Results shown by *arrows* in Fig. 3

Device adjustment	A	B	C	D	E	F	G	H
Segmental height (mm)	-3.7(1.4)	4.1(1.0)	7.9(1.0)	3.6(1.2)	-0.6(0.9)	7.2(1.2)	-0.4(0.8)	7.3(1.2)
Segmental angle (deg)	-2.9(1.0)	0.6(0.9)	1.5(1.9)	-4.8(2.0)	-6.1(0.8)	-3.6(1.9)	-6.7(1.1)	-3.4(1.7)

Fig. 3 Average changes in the posture from the Burst-NP due to the eight adjustments

Table 4 The average (SD) differences in segmental height and segmental angle between the resulting posture due to a device adjustment and the intact posture. Significant differences at $P < 0.05$ are indicated by an *asterisk*, showing that the corresponding ad-

justment did not restore the burst fracture to the intact state (see Fig. 1 for sign convention). Results are shown by *dashed lines* in Fig. 4

Device adjustment	A	B	C	D	E	F	G	H
Segmental height (mm)	-10.0*(4.1)	-2.2*(3.7)	1.6*(3.5)	-2.7*(3.7)	-6.9*(3.7)	0.9(3.6)	-6.7*(3.7)	0.9(3.4)
Segmental angle (deg)	2.8*(6.8)	6.2*(6.9)	7.1*(7.3)	0.8(6.7)	-0.5(7.1)	2.0(7.2)	-1.1(7.3)	2.2(7.8)

Fig. 4 Average differences between the intact posture and the eight resulting postures due to the adjustments

to the intact. From this point of view, adjustments F and H (5 mm distraction with 6° extension) seem to be the most advantageous, as this adjustment set resulted in postures not significantly different from the intact, with respect to both the segmental height and segmental angle. On the other hand, adjustments B and C (5 and 10 mm pure distraction) did not bring the segmental angle close to the intact, although they did restore the segmental height. The differences between the intact posture and the resulting postures due to the adjustments B and C were significant both in the segmental height and segmental angle. Adjustment A (5 mm pure compression) and adjustments E and G (5 mm compression with 6° extension) seem unsuitable, as they did not restore the segmental height.

One of the limitations of the present study was the ambiguity associated with the definition of the neutral posture. It is quite difficult to simulate the “clinical neutral spinal posture” in the laboratory. This is so because the in vivo loads in the patient’s spine are presently unknown. Our burst fracture neutral posture was measured under zero moment. However, our intact neutral posture was measured under 4 Nm extension moment. To define the intact neutral posture in vivo, different methods have been

used [2, 10, 29]. Jackson and McManus [10] reported the mean segmental sagittal angle in standing volunteers measured between the L1 and L3 upper endplates to be -8.7° (L1-L2: -1.7° and L2-L3: -7.0°). In our pilot study of intact specimens, the mean kyphotic angle was -7.3° under 4 Nm extension moment, and -3.3° under zero moment. Therefore, a 4 Nm extension moment was chosen for the intact specimen in neutral posture. Another limitation was that the specimens came from an older age group, with varying degrees of bone loss, which is a common problem in most biomechanical studies. In order that the results would not be affected by the differing quality of the bone, the screw-bone interface was standardized by injecting polyester resin. Thus, the postural changes documented in the present study mostly came from deformations of ligaments, discs and the fractured L1 vertebra, and no part was due to bone-screw interface loosening.

Among the eight adjustments, the adjustment that reduced the burst fracture closest to the intact state was the 5 mm distraction combined with 6° extension (adjustments F and H). This was true, taken on average. However, there was considerable variability in the severity of the burst fractures, and the results obtained. Thus, the op-

timal adjustment for an individual fracture may be somewhat different than the average optimal combination found in the present study. Another point to keep in mind is that the adjustment that is optimal for anatomical reduction may not be optimal for spinal stability or neural decompression. Future studies are planned to address this aspect of the burst fracture.

For the decompression of the neural canal, the sequence of compression/distraction and extension has been deemed important. Harrington et al. [8] suggested applying the distraction first, followed by the angular positioning of the vertebra. This was suggested based upon the concept that positioning the vertebra in lordosis without applying distraction significantly slackens the posterior longitudinal ligament. However, this concept was not based upon any quantitative data. The sequence did not affect postural changes in the present study of the anatomical reduction. Postural changes were the same for translation applied after extension and for extension applied after translation (between adjustments E and G, and also F and H). These results are similar to those for the decompression of the neural spaces by pedicle screw device adjustments [25]. Thus, a surgeon can select the sequence for the benefit of neural decompression.

Distraction is the basic reduction force in burst fracture surgery. Schlegel et al. [27] observed that pure distraction enhanced the space available for both the sclerotic spinal canal and intervertebral foramina. Shono and co-workers applied the AO fixator to an experimental burst fracture [28]. They observed an average correction of 150° (from 140° kyphosis to 10° lordosis) after the application of the fixator. However, they did not report the device adjustment used. Inufusa et al. [9] found the application of distraction in lumbar spine from the posterior to cause a loss of lumbar lordosis. They reported that the segmental lordosis at L4-5 decreased significantly with 4 mm distraction using a pedicle screw device. The results of the pre-

sent study support their findings. Adjustments of 5 mm and 10 mm pure distraction caused loss of lordosis on average by 0.6° and 1.5° respectively. Thus, for an anatomical reduction, the benefits of pure distraction are limited. Indications for pure distraction may be restricted to burst fractures with small kyphotic changes. Relationships between device adjustments and neural spaces have been recently studied [25]. In another related study, the effects of device adjustments on the spinal stability have also been investigated [21].

Extension is the primary reduction force in postural reduction using a pillow under the back. Many authors have reported negative effects of extension. Fredrickson et al. [5] demonstrated that an internal fixator that applied extension alone did not reduce fragments within the canal to any degree. Lin et al. [18] observed that the extension moment was not particularly effective in reducing the fractured vertebral body to its intact condition. Extension posture was successful in reducing the anterior vertebral and disc heights, but not the angular parameters and the posterior height. In the present study, pure applied extension rotation (adjustment D) reduced kyphosis. Thus, while Lin et al. found the extension moment not to be effective in reducing the angular deformity, we found the extension rotation applied by the pedicle screw device to be effective in reducing the angular parameters.

Conclusion

The sequence of applying translation (distraction/compression) and angulation (extension) by the pedicle screw device did not affect the postural reduction achieved.

The combination of 5 mm distraction and 6° extension was the device adjustment that produced the closest anatomical reduction among the eight device adjustments studied.

References

1. Aebi M, Etter C, Kehl T, Thalgott J (1987) Stabilization of the lower thoracic and lumbar spine with the internal spinal skeletal fixation system. Indications, techniques, and first results of treatment. *Spine* 12:544-551
2. Bernhardt M, Bridwell KH (1989) Segmental analysis of the sagittal plane alignment of the normal thoracic and lumbar spines and thoracolumbar junction. *Spine* 14:717-721
3. Dick W, Kluger P, Magerl F, Woerdorfer O, Zach G (1985) A new device for internal fixation of thoracolumbar and lumbar spine fracture. The "Fixateur Interne". *Paraplegia* 23:225-232
4. Esses SI, Botsford DJ, Wright T, Bednar D, Bailey S (1991) Operative treatment of spinal fractures with the AO internal fixator. *Spine* 16:S146-S150
5. Fredrickson BE, Mann KA, Yuan HA, Lubicky JB (1988) Reduction of the intracanal fragment in experimental burst fractures. *Spine* 13:267-271
6. Fredrickson BE, Edwards WT, Rauschnig W, Bayley JC, Yuan HA (1992) Vertebral burst fractures: an experimental, morphologic, and radiographic study. *Spine* 17:1012-1021
7. Gertzbein SD (1992) Scoliosis research society. Multicenter spine fracture study. *Spine* 17:528-539
8. Harrington RM, Budorick T, Hoyt J, Anderson PA, Tencer AF (1993) Biomechanics of indirect reduction of bone retropulsed into the spinal canal in vertebral fracture. *Spine* 18:692-699
9. Inufusa A, An HS, Glover JM, McGrady L, Lim T-H, Riley III LH (1996) The ideal amount for lumbar foraminal distraction for pedicle screw instrumentation. *Spine* 21:2218-2223
10. Jackson RP, McManus AC (1994) Radiographic analysis of sagittal plane alignment and balance in standing volunteers and patients with low back pain matched for age, sex, and size. A prospective controlled clinical study. *Spine* 19:1611-1618

11. Kifune M, Panjabi MM, Arand M, Liu W (1995) Fracture pattern and instability of thoracolumbar injuries. *Eur Spine J* 20:98–103
12. Kifune M, Panjabi MM, Liu W, Arand M, Vasavada A, Oxland T (1997) Functional morphology of the spinal canal after endplate, wedge, and burst fracture. *J Spinal Disord* 10:457–466
13. Kothe R, Panjabi MM, Liu W (1997) Multidirectional instability of the thoracic spine due to iatrogenic pedicle injuries during transpedicular fixation. A biomechanical investigation. *Spine* 22:1836–1842
14. Krag MH, Beynon BD, Pope MH, Frymoyer JW, Haugh LD, Weaver DL (1986) An internal fixator for posterior application to short segments of thoracic, lumbar, or lumbosacral spine. Design and testing. *Clin Orthop* 203:75–98
15. Kraus JF, Franti CE, Riggis RS, et al (1975) Incidence of traumatic spinal cord lesions. *J Chron Dis* 28:471–492
16. Kuner EH, Kuner A, Shlickewei W, Mullaji AB (1994) Ligamentotaxis with an internal spinal fixator for thoracolumbar fractures. *J Bone Joint Surg Br* 76:107–112
17. Kuner EH, Shlickewei W, Kuner A, Hauser U (1997) Restoration of the spinal canal by the Internal fixator and remodeling. *Eur Spine J* 5:417–422
18. Lin RM, Panjabi MM, Oxland TR (1993) Functional radiographs of acute thoracolumbar burst fractures. A biomechanical study. *Spine* 18:2431–2437
19. Lindsey RW, Dick W (1991) The fixator interne in the reduction and stabilization of thoracolumbar spine fractures in patients with neuralgic deficit. *Spine* 16:S140–S145
20. Mermelstein LE, McLain RF, Yerby SA (1998) Reinforcement of thoracolumbar burst fractures with calcium phosphate cement. A biomechanical study. *Spine* 23: 664–671
21. Oda T, Panjabi MM. Pedicle screw adjustments affect stability in thoracolumbar burst fracture. *Spine* (in press)
22. Oxland TR, Panjabi MM (1992) The onset and progression of spinal injury: a demonstration of neutral zone sensitivity. *J Biomech* 25:1165–1172
23. Panjabi MM, Oxland TR, Lin RM, McGowen TW (1994) Thoracolumbar burst fracture. Biomechanical investigation of its multidirectional flexibility. *Spine* 19:578–585
24. Panjabi MM, Kifune M, Liu W, Arand M, Oxland TR, Lin RM, Yoon WSS, Vasavada A (1995) Dynamic canal encroachment during thoracolumbar burst fractures. *J Spinal Disord* 8:39–48
25. Panjabi MM, Oda T, Wang JL (2000) Pedicle screw adjustments affect neural spaces in burst fracture surgery. *Spine* 25:1637–1643
26. Price C, Makintubee S, Herndon W, et al (1994) Epidemiology of traumatic spinal cord injury and acute hospitalization and rehabilitation charges for spinal cord injuries in Oklahoma, 1988–1990. *Am J Epidemiol* 139:37–47
27. Schlegel JD, Champine J, Taylor MS, Watson JT, Champine M, Schleusener RL, Savory KM (1994) The role of distraction in improving the space available in the lumbar stenotic canal and foramen. *Spine* 19:2041–2047
28. Shono Y, McAfee PC, Cunningham BW (1994) Experimental study of thoracolumbar burst fractures. A radiographic and biomechanical analysis of anterior and posterior instrumentation systems. *Spine* 19:1711–1722
29. Stagnara P, De Mauroy JC, Dran G, Gonon GP, Costanzo G, Dimnet J, Pasquet A (1982) Reciprocal angulation of vertebral bodies in a sagittal plane: approach to references for the evaluation of kyphosis and lordosis. *Spine* 7:335–342
30. Zou D, Yoo JU, Edwards WT, Donovan DM, Chang K-W, Bayley JC, Fredrickson E, Yuan HA (1993) Mechanics of anatomic reduction of thoracolumbar burst fractures: comparison of distraction versus distraction plus lordosis, in the anatomic reduction of the thoracolumbar burst fracture. *Spine* 18:195–203