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CLINICAL ARTICLE - SPINE

Results of treatment of unstable thoracolumbar burst fractures using pedicle instrumentation with and without fracture-level screws

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Abstract
Background Two different techniques of short-segment instrumentation, with and without a pedicle screw at the fracture level, were compared in thoracolumbar burst fractures in neurologically intact (ASIA-E) patients. The sagittal index, kyphosis angle (Cobb), canal compromise ratio, and compression ratio of the anterior vertebral height were analyzed.
Methods Seventy patients who underwent short-segment stabilization for thoracolumbar (T11-L2) burst fractures in our clinic between 2008 and 2012 were included in this retrospective study. In 35 patients (group 1), a pedicle screw was placed only one level down and one level up from the fracture level. In another 35 patients (group 2), a screw was placed at the fracture level in addition to the short segment. Only neurologically intact patients with burst fractures according to the Denis classification were included. The patients were evaluated according to their age/gender, trauma etiology, and fracture level. Their preoperative and most recent postoperative follow-up radiographs and CTs were evaluated in terms of the sagittal index, kyphosis angle (Cobb), ratio of canal compromise, and anterior vertebral height.
Results The two groups were similar in their ages, follow-up periods, and severity of the deformity and fracture. When the pedicle screw was placed at the fracture level in addition to short-segment stabilization, statistically significant improvements in the sagittal index ($p<0.001$), local kyphosis (Cobb) angle ($p=0.006$), and compression ratio of the anterior vertebral height ($p=0.002$) were observed. Concerning the ratio of canal compromise according to the CT findings ($p=0.189$), moderate differences were found.
Conclusions Short-segment stabilization in thoracolumbar burst fractures with additional screws at the level of the fracture results in an improved kyphosis correction, sagittal index, and compression ratio of the anterior vertebral height. However, long-term follow-up is needed to determine the clinical significance of these findings.

Keywords Thoracolumbar · Burst fractures · Fracture level · Short-segment pedicle instrumentation

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Introduction

The goals of thoracolumbar vertebral burst fracture treatment include restoring vertebral column stability and preventing deformity, neural canal decompression, and early mobilization [1, 7, 9, 18, 24, 28, 34]. Although anterior, posterior, and combined surgical approaches are all used for this purpose, the selection of the treatment approach is still controversial

[22]. The posterior approach is used more frequently among spinal surgeons because of its easy application, reduction of bleeding, and small incision area. In contrast, the application of short- or long-segment pedicle screws is controversial. Despite the advantages of long-segment instrumentation, such as tighter fixation and better canal recovery, it also results in a motionless spine due to fixing more segments [1, 18, 24, 28]. In recent years, short-segment instrumentation with the pedicle screws introduced one level down and one level up from the fractured vertebra has become the preferable surgical method because of its ease of application, use of less surgical fixation material, reduction of blood loss, and smaller incision field [1, 2, 13, 18, 20, 22, 24, 28, 31, 33]. However, disadvantages of this method, such as inadequate long-term reduction, instrumentation insufficiency, and increases in kyphosis and pain, have also been reported [1, 2, 5, 7, 14, 17–20, 32, 34]. Osteoporosis, inadequate support of the anterior column, insufficiency of fixation points, and the application of laminectomy have been affirmed as potential reasons for insufficiency. To prevent such insufficiency, alternative procedures [1, 6, 7, 26, 27, 29] supporting the anterior column have been suggested, such as vertebroplasty, kyphoplasty, or screw application for burst vertebrae. This method results in stronger biomechanical stability of the anterior column by forming a more segmental structure [4, 13, 15, 18].

The purpose of this study was to evaluate the efficacy of the placement of an additional screw at the fracture level regarding the correction of deformity, maintenance of the correction, and prevention of fixation failure in thoracolumbar burst fractures.

Methods

The study included 70 patients who underwent short-segment stabilization because of the diagnosis of thoracolumbar (T11-L2) burst fracture between 2008 and 2012. Only patients who were neurologically intact (ASIA-E) with burst fractures according to the Denis [9] classification were included. The patients were evaluated according to their age/gender, trauma etiology, and fracture level (Table 1). The follow-up periods for patients in both groups ranged from 9–31 (average: 26.5) months. The stability of at least one pedicle was confirmed; patients in whom both pedicles were fractured were excluded from the study. All patients with poor bone mineral density (T score ≥2.5) or instrumentation failure (screw breakage in two patients in group 1) were also excluded. Three different surgeons operated on the patients. In 35 patients (group 1), a pedicle screw was placed only one level down and one level up from the fracture level; in another 35 patients (group 2), a screw was placed at the fracture level in addition to the short segment. Papers that referred to screws at the fracture level improving construct stiffness influenced our surgical strategy.

Table 1 Demographic properties of the patients according to their age-gender, etiology, fracture level, and Denis burst fracture type

	Group 1	Group 2	P
Age, mean±SD	39.2±15.3 (R: 18–70)	40.4±15 (R: 18–61)	0.742
Sex, M/F	25 10	27/8	0.785
Fracture level, n (%)			
T11	3 (%9)	2 (%6)	0.946
T12	7 (%20)	8 (%23)	
L1	18 (%51)	19 (%54)	
L2	7 (%20)	6 (%17)	
Denis fracture type, n (%)			
A	5 (%14)	8 (%23)	0.694
B	20 (%57)	20 (%57)	
C	6 (%17)	5 (%14)	
D	4 (%11)	2 (%6)	
Etiology, n (%)			
Traffic accident	12 (%34)	9 (%26)	0.328
Fall from height	22 (%63)	22 (%63)	
Impact by hard object	1 (%3)	4 (%11)	

R: range

After 2010, we placed screws at the fracture level in all appropriate cases. In three patients, only one screw was inserted at the fracture level in group 2.

Radiographic review

The preoperative and most recent postoperative follow-up radiographs and CTs of the patients were evaluated in terms of the sagittal index, kyphosis angle (Cobb), ratio of canal compromise, and anterior vertebral height. The sagittal index was calculated by measuring the angle that crosses lines drawn from the upper and lower endplates of the traumatic vertebra, as defined by Farcy et al. [12]. The local kyphosis (Cobb) angle was calculated by measuring the angle between the upper endplate of the vertebra one level up and the lower endplate of the lower vertebra [15]. The amount of retropulsion (spinal canal compromise) was measured using computed tomographic (CT) scans, and the percentage of spinal canal compromise was expressed as follows [23]:

Percentage of spinal canal compromise:

$$a = (1 - x/y) \times 100$$

a Percentage of canal compromise
x Mid-sagittal diameter of the spinal canal at the level of injury
y Average mid-sagittal diameter of the spinal canal (one level above and one level below the level of injury)

The anterior body height of the traumatic vertebra was evaluated by taking the percentage of anterior body height compression as a reference by measuring the anterior heights of the one-level-up and one-level-down vertebrae using the method of Mumford et al. [25]. The preoperative and follow-up radiographs were evaluated.

Surgical technique

Surgery was indicated in the patients in whom the sagittal index was above 15°, the Cobb angle was above 10°, the ratio of canal compromise was greater than 25 %, and the anterior vertebral height was less than 50 % of the posterior vertebral height, according to the method of Mumford et al.

A majority of the patients underwent surgical intervention within 72 h. The patients were evaluated based on preoperative radiograms, thin-slice CT and MRI, and radiographs and CT in postoperative controls. Their pedicle levels were scanned using thin-slice CT. Before surgery and in the controls, radiographic angles were measured.

Two different (TIPMED-Izmir, Turkey, HIPOKRAT-Izmir, Turkey) instrumentation methods were employed. Fracture reduction and indirect decompression of the spinal cord were achieved by applying distraction and producing an appropriate contour in the rod. Transverse connections were used in each case. No laminectomies were performed. Kyphosis was corrected only through postural reduction and cantilever reduction of the rods in the screws. Autografts and allografts were used for posterolateral bone fusion. The patients were mobilized with a corset on the 2nd day after surgery, and it was recommended that they wear the corset for 1 month.

Statistical analysis

The SPSS (Statistical Package for the Social Sciences) 18.0 software package was used for the statistical analysis of the data. Categorical measurements were summarized as numbers and percentages, and numerical measurements were summarized as the average and standard deviation (minimum-maximum). Chi-squared statistics were employed in the comparison of categorical measurements between groups, and independent t-tests were employed for the comparison of numerical measurements between groups. The statistical significance level was taken as 0.05 in all tests.

Results

Age-gender

The age range of the patients in group 1 was 18–70 (average age: 39.2) years, and the female:male ratio was 10:25. The age range in group 2 was 18–61 (average age: 40.4) years, and the female:male ratio was 8:27 (Table 1).

Etiology

All patients experienced high-energy trauma. Falling from height was the most common reason for injury, presented by 63 % of the patients in both groups. The etiology of the injury was a traffic accident in 12 patients in group 1 and 9 patients in group 2, and the impact of a hard body was observed in 1 patient in group 1 and 4 patients in group 2 (Table 1).

Fracture level

Thoracolumbar fractures between T11 and L2 were included in this study. L1 fracture was sustained by 51 % of the patients in the first group and 54 % in the second group. When groups 1 and 2 were compared according to the fracture level, the results were as follows: T11:3/2, T12:7/8, and L2:7/6 (Table 1).

Denis classification

B-type fractures were observed in 20 patients (57 %) in each group. When groups 1 and2 were compared according to Denis type, the results were as follows: Denis A: 5/8, Denis C: 6/5, and Denis D: 4/2.

No statistically significant differences were found between the groups in terms of age, gender, etiology, fracture localization, or Denis classification (Table 1).

Sagittal index

The average sagittal index was 20.5° preoperatively and 11.4° in the controls in group 1, while it was 19.8° preoperatively and 7.4° in the controls in group 2. The results showed a statistically significant difference ($p<0.001$) between groups 1 and 2 in terms of the sagittal index in the controls (Fig. 1).

Local kyphosis (Cobb) angle

The average Cobb angle was 17.4° preoperatively and 10.5° in the controls in group 1, while it was 17.3° preoperatively and 5.4° in the controls in group 2. No statistically significant differences were observed between the groups in terms of the preoperative evaluation. The difference in the Cobb angle between groups 1 and 2 was statistically significant ($p=0.006$) in the controls (Fig. 2).

Ratio of canal compromise

While the ratio of canal compromise was 30.7 % in group 1, it was 14.7 % in the controls. The ratio was 32.1 % in group 2 and 12 % in the controls. The ratio of canal compromise was

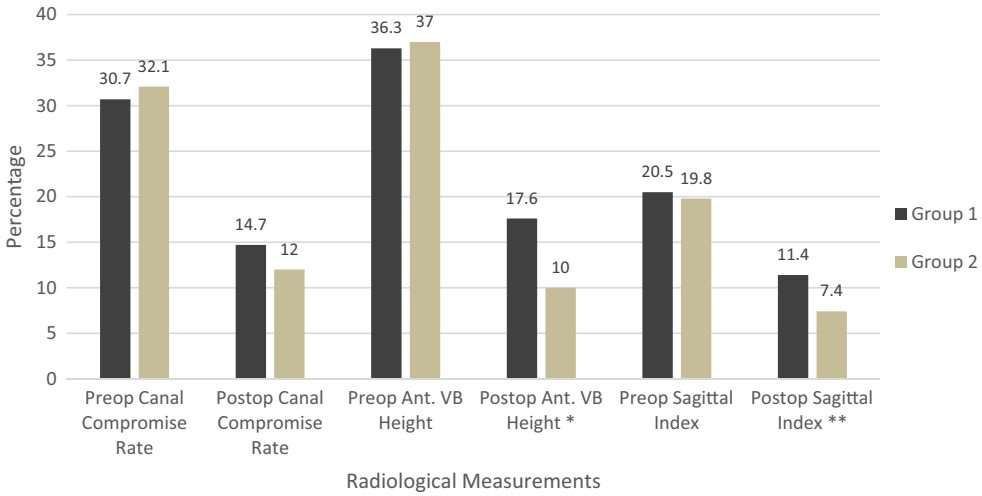

Fig. 1 The comparisons of radiological measurements of the canal comprise the ratio, vertebral height, and sagittal index between the two groups (**p value:* 0.002, ***p value:* 0.001)

of limited significance (p=0.189) in group 2 in the controls (Fig. 1).

Anterior vertebral height

While the anterior vertebral height was 36.3 % preoperatively and 17.6 % in the controls in group 1, it was 37 % preoperatively and 10 % in the controls in group 2. These results were statistically significant (p=0.002) in both groups (Fig. 1).

Discussion

The ideal treatment of thoracolumbar burst fractures remains a matter of discussion. Posterior transpedicle instrumentation is the most frequently applied surgical treatment for these fractures because of its low morbidity and comorbidity [3, 7, 8, 10, 19].

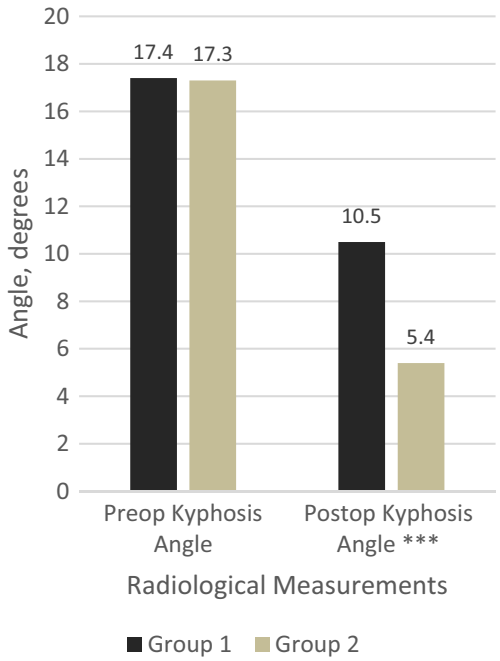

Fig. 2 Kyphosis angle in groups 1 and 2 (****p value:* 0.006)

In the current study, two patient groups who underwent short-segment posterior fixation were compared. The demographic, clinical, and radiologic properties of the two groups were matched as closely as possible. Homogeneity was confirmed, as no statistical significance was observed in terms of the sagittal index, kyphosis angle, ratio of canal compromise, or anterior vertebral height at preoperative evaluation. These parameters were found to be statistically significant in the long-term control period, indicating that short stabilization with the application of a pedicle screw at the fracture level results in a greater correction of kyphotic deformity, an increase in anterior vertebral height, and a decrease in the sagittal index. In the controls, the sagittal index was 11.4° in group 1, while it was 7.4° in group 2; the kyphosis angle was corrected by 6.9° in group 1 and by 11.9° in group 2. The anterior vertebral height was increased from 36.3 % to 17.6 % in group 1 and from 37 % to 12 in group 2.

In recent years, insufficiency of the implants and loss of correction have been reported as the most significant disadvantages of short-segment instrumentation by some authors [1, 17, 20, 27, 28, 32, 34]. Because residual kyphotic deformity generates high anterior vertebral stress on pedicle screws, failure, dislocation, and disconnection of screws due to overload on the instrument are insufficiencies that are frequently observed in short-segment fixation [7, 8, 19, 24, 28, 34]. Increasing the fixation level decreases the chance of this insufficiency by reducing the stress on each pedicle. However, it also decreases the protective advantage of mobile segments compared with short-segment instrumentation [1, 18, 20, 24, 28, 34]. Some authors have reported successful results when using short-segment instrumentation in long-term controls [21, 24, 30, 33]. In cadaver studies conducted by Mahar et al., adding pedicle screws at the fracture level in addition to short-segment pedicle fixation in burst fractures was shown

to significantly increase spinal stability [18]. According to the hypothesis of Guven et al., intraoperative fracture reduction and correction of sagittal deformity can be easily achieved via the placement of a screw at the fracture level [15]. Anekstein et al. reported that screws placed into fractured vertebrae can maintain the burst vertebra and separated pedicle [4]. Gelb et al. found that thoracolumbar fractures can be successfully treated with short-segment pedicle instrumentation [13]. The reported advantages of this method include the protection of more mobile segments and reduction of donor field complications, the operation duration, and blood loss. Some researchers have stated that short-segment pedicle instrumentation is the best choice in terms of flat back syndrome and loss of lumbar lordosis [3].

In cases of neurological deficit, the combined anterior and posterior approach is a treatment option that achieves complete kyphosis correction, immediate stability, and complete spinal canal decompression [28]. However, this technique has not been widely accepted in neurologically intact patients because it requires a more invasive surgical procedure and increases operative time, blood loss, and morbidity [16].

Another alternative that is increasingly being used in recent years is to place a screw within the fractured vertebra [4, 13, 15, 18]. According to Mahar et al., the application of limited posterior segmental instrumentation in thoracolumbar burst fractures is a method that achieves short-segment fixation. Segmental construction using a pedicle screw in the fractured vertebral body has been shown to be more reliable and more corrective in terms of biomechanical stability compared with non-segmental construction [18]. Axial torsion stability has been shown to be approximately 2 times greater in biomechanical tests in cadaver models. Incremental increases in flexion and extension stability and in lateral bending have been achieved, although they have not been statistically significant.

Screws placed within the fractured vertebra can hold a mechanically burst vertebra and separated pedicles together. In short-segment fixation performed without placing a screw into the fractured vertebra, cavities occurring inside the fractured vertebra after restoration will eventually lead to a loss of correction. Guven et al. observed increments of compression, anterior vertebral height, or the kyphosis angle in long-term controls for long- and short-segment fixation [15]. However, these increments are more substantial when a screw is not placed within the fractured vertebra, and this difference is statistically significant. In this study, screws placed at the fracture level were found to generate a mass effect and to prevent vertebral collapse. According to the results of Guven et al., better correction is achieved in short-segment applications combined with a screw placed at the fracture level compared with short-segment fixations in which no screw is used. The recovery of the kyphosis angle and anterior vertebral height is superior in long-segment fixations in which a screw is applied to the fracture level.

In many studies, the correction of the kyphosis angle observed in the early postoperative period is decreased in long-term controls [5, 7, 13, 18, 20, 21, 34]. Carl et al. [5] reported the first postoperative kyphosis correction to be 7°, while Cho et al. [7] achieved a correction of 6°. In both studies, the early kyphosis correction observed in the postoperative period was lower than in the controls. Similarly, McNamara et al. [21] reported an initial loss of the kyphosis correction of 9° when using the non-segmental fixation technique. McLain et al. [20] found that progressive deformity developed within 6 months postoperatively in a majority of patients with residual anterior column instability. Gelb et al. [13] used the fractured vertebra as an intermediate fixation point in 74 % of patients. The loss correction observed in Gelb's study was the same as in other studies. In the current study, we only evaluated the most recent postoperative radiological measurements.

According to Gelb et al., the success of short-segment pedicle instrumentation depends upon multiple factors [13]. Current instrumentation with improved metallurgy and screw-to-rod locking mechanisms has undoubtedly contributed to the decrease in instrumentation failure. Advances in surgical techniques have also been instrumental in the success of the construct. Early surgical intervention promotes easier postural reduction. We advise precontouring of the rod, providing a three-point bending force as the apex of the rod engages the intermediate fractured vertebra, similar to the concept of the spinal rod-sleeve method previously described by Edwards and Levine [11]. The intermediate vertebra could be engaged directly as the rod contacts the posterior lamina or through use of a screw into one or both of the pedicles of the fractured vertebra.

A limitation of this study was clinical data such as the VAS score and quality of life, which were absent in this study.

Conclusion

The purpose of surgical treatment of thoracolumbar junction burst fractures is to preserve the height and alignment of the vertebral body, decompress the spinal cord, enable early ambulation and rehabilitation with tight fixation, and prevent progressive deformity and neurologic deficits. While attempting to achieve these aims, the number of immobile segments should be limited by instrumenting as few vertebrae as possible.

Short-segment instrumentation using additional screws at the fracture level in thoracolumbar burst fractures is a proper surgical approach for obtaining clinically and radiologically successful results in terms of the sagittal index, kyphosis angle, ratio of canal occupation, and correction of collapse in the anterior body.

Ethical standards All patients gave their informed consent prior to their inclusion in the study.

Conflicts of interest None.

References

1. Alanay A, Acaroglu E, Yazici M, Oznur A, Surat A (2001) Short-segment pedicle instrumentation of thoracolumbar burst fractures: does transpedicular intracorporeal grafting prevent early failure? Spine 26(2):213–217
2. Altay M, Ozkurt B, Aktekin CN, Ozturk AM, Dogan O, Tabak AY (2007) Treatment of unstable thoracolumbar junction burst fractures with short- or long-segment posterior fixation in magerl type a fractures. Eur Spine J 16(8):1145–1155
3. An HS, Simpson JM, Ebraheim NA, Jackson WT, Moore J, O'Malley NP (1992) Low lumbar burst fractures: comparison between conservative and surgical treatments. Orthopedics 15(3):367–373
4. Anekstein Y, Brosh T, Mirovsky Y (2007) Intermediate screws in short segment pedicular fixation for thoracic and lumbar fractures: a biomechanical study. J Spinal Disord Tech 20(1):72–77
5. Carl AL, Tromanhauser SG, Roger DJ (1992) Pedicle screw instrumentation for thoracolumbar burst fractures and fracture-dislocations. Spine 17(8 Suppl):S317–S324
6. Chen JF, Lee ST (2004) Percutaneous vertebroplasty for treatment of thoracolumbar spine bursting fracture. Surg Neurol 62(6):494–500
7. Cho DY, Lee WY, Sheu PC (2003) Treatment of thoracolumbar burst fractures with polymethyl methacrylate vertebroplasty and short-segment pedicle screw fixation. Neurosurgery 53(6):1354–1361
8. Dai LY, Jiang SD, Wang XY, Jiang LS (2007) A review of the management of thoracolumbar burst fractures. Surg Neurol 67(3):221–231
9. Denis F (1983) The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. Spine 8(8):817–831
10. Dick W, Kluger P, Magerl F, Woersdörfer O, Zäch G (1985) A new device for internal fixation of thoracolumbar and lumbar spine fractures: the 'fixateur interne'. Paraplegia 23(4):225–232
11. Edwards CC, Levine AM (1986) Early rod-sleeve stabilization of the injured thoracic and lumbar spine. Orthop Clin N Am 17(1):121–145
12. Farcy JP, Weidenbaum M, Glassman SD (1990) Sagittal index in management of thoracolumbar burst fractures. Spine 15(9):958–965
13. Gelb D, Ludwig S, Karp JE, Chung EH, Werner C, Kim T, Poelstra K (2010) Successful treatment of thoracolumbar fractures with short-segment pedicle instrumentation. J Spinal Disord Tech 23(5):293–301
14. Gurwitz GS, Dawson JM, McNamara MJ, Federspiel CF, Spengler DM (1993) Biomechanical analysis of three surgical approaches for lumbar burst fractures using short-segment instrumentation. Spine 18(8):977–982
15. Guven O, Kocaoglu B, Bezer M, Aydin N, Nalbantoglu U (2009) The use of screw at the fracture level in the treatment of thoracolumbar burst fractures. J Spinal Disord Tech 22(6):417–421
16. Knop C, Fabian HF, Bastian L, Rosenthal H, Lange U, Zdichavsky M, Blauth M (2002) Fate of the transpedicular intervertebral bone graft after posterior stabilisation of thoracolumbar fractures. Eur Spine J 11(3):251–257
17. Kramer DL, Rodgers WB, Mansfield FL (1995) Transpedicular instrumentation and short-segment fusion of thoracolumbar fractures: a prospective study using a single instrumentation system. J Orthop Trauma 9(6):499–506
18. Mahar A, Kim C, Wedemeyer M, Mitsunaga L, Odell T, Johnson B, Garfin S (2007) Short-segment fixation of lumbar burst fractures using pedicle fixation at the level of the fracture. Spine 32(14): 1503–1507
19. McCormack T, Karaikovic E, Gaines RW (1994) The load sharing classification of spine fractures. Spine 19(15):1741–1744
20. McLain RF, Sparling E, Benson DR (1993) Early failure of short-segment pedicle instrumentation for thoracolumbar fractures. A preliminary report. J Bone Joint Surg Am 75(2):162–167
21. McNamara MJ, Stephens GC, Spengler DM (1992) Transpedicular short-segment fusions for treatment of lumbar burst fractures. J Spinal Disord 5(2):183–187
22. Modi HN, Chung KJ, Seo IW, Yoon HS, Hwang JH, Kim HK, Noh KC, Yoo JH (2009) Two levels above and one level below pedicle screw fixation for the treatment of unstable thoracolumbar fracture with partial or intact neurology. J Orthop Surg Res 4:28
23. Mohanty SP, Venkatram N (2002) Does neurological recovery in thoracolumbar and lumbar burst fractures depend on the extent of canal compromise? Spinal Cord 40:295–299
24. Müller U, Berlemann U, Sledge J, Schwarzenbach O (1999) Treatment of thoracolumbar burst fractures without neurologic deficit by indirect reduction and posterior instrumentation: bisegmental stabilization with monosegmental fusion. Eur Spine J 8(4):284–289
25. Mumford J, Weinstein JN, Spratt KF, Goel VK (1993) Thoracolumbar burst fractures. The clinical efficacy and outcome of nonoperative management. Spine 18(8):955–970
26. Oner FC, Verlaan JJ, Verbout AJ, Dhert WJ (2006) Cement augmentation techniques in traumatic thoracolumbar spine fractures. Spine 31(11 Suppl):S89–S95, discussion S104
27. Parker JW, Lane JR, Karaikovic EE, Gaines RW (2000) Successful short-segment instrumentation and fusion for thoracolumbar spine fractures: a consecutive 41/2-year series. Spine 25(9):1157–1170
28. Payer M (2005) Unstable burst fractures of the thoraco-lumbar junction: treatment by posterior bisegmental correction/fixation and staged anterior corpectomy and titanium cage implantation. Acta Neurochir (Wien) 148(3):299–306
29. Rommens PM, Weyns F, Van Calenbergh F, Goffin J, Broos PL (1995) Mechanical performance of the Dick internal fixator: a clinical study of 75 patients. Eur Spine J 4(2):104–109
30. Sanderson PL, Fraser RD, Hall DJ, Cain CM, Osti OL, Potter GR (1999) Short segment fixation of thoracolumbar burst fractures without fusion. Eur Spine J 8(6):495–500
31. Sasso RC, Cotler HB, Reuben JD (1991) Posterior fixation of thoracic and lumbar spine fractures using DC plates and pedicle screws. Spine 16(3 Suppl):S134–S139
32. Siebenga J, Leferink VJ, Segers MJ, Elzinga MJ, Bakker FC, Haarman HJ, Rommens PM, ten Duis HJ, Patka P (2006) Treatment of traumatic thoracolumbar spine fractures: a multicenter prospective randomized study of operative versus nonsurgical treatment. Spine 31(25):2881–2890
33. Tezeren G, Kuru I (2005) Posterior fixation of thoracolumbar burst fracture: short-segment pedicle fixation versus long-segment instrumentation. J Spinal Disord Tech 18(6):485–488
34. Zileli M, Baldwin NG, Benzel EC (1999) Iatrogenic spine destabilization. In: Benzel EC (ed) Spine surgery: techniques, complication avoidance, and management, vol 2. Churcill Livingstone, New York, pp 1121–1127