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# Evaluation of Postoperative Clinical and Radiological Outcomes of Thoracolumbar Vertebral Fractures

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## Abstract

**Aim:** This study aimed to measure various clinical and radiological outcomes in a group of patients with thoracolumbar vertebral fractures who underwent surgery at a single center.

**Materials and Methods:** We retrospectively analyzed 50 consecutive patients who underwent surgery for thoracolumbar vertebral fractures between September 2000 and December 2011. We assessed clinical outcomes with the visual analog scale (VAS) for pain, the Oswestry Disability Index (ODI), and the Frankel scale. We measured radiological outcomes using the sagittal index (SI), local kyphosis angle (LKA), and anterior corpus height loss (ACHL).

**Results:** The preoperative, postoperative, and final visit follow-up mean VAS scores were 82 mm, 60 mm, and 13.5 mm, and the corresponding mean ODIs were 65%, 40%, and 15%. These clinical outcome improvements were statistically significant ($p<0.05$). The preoperative, postoperative, and final visit mean SIs were 20°, 14°, and 15° respectively; the corresponding mean LKAs were 17°, 9°, and 13° and mean ACHL values were 45%, 25%, and 28%. The preoperative to postoperative radiological outcome improvements were statistically significant ($p<0.05$), whereas the postoperative to final visit outcome measures demonstrated loss of correction, although these changes were not statistically significant.

**Conclusion:** Although major progress has been made in the treatment of thoracolumbar vertebral fractures, the lack of standardized, verified clinical and radiological outcome measures continue to pose a challenge to the accurate assessment of the results of management.

**Keywords:** Anterior corpus height loss, local kyphosis angle, sagittal index, thoracolumbar vertebral fracture, visual analog scale

## Introduction

The most common vertebral fractures occur in the thoracolumbar area, which is the transitional area of the spine (1-3). Thoracolumbar vertebral fractures most commonly occur in young adults (15 to 30 years of age) and may be associated with neurological deficits in 15% to 20% of patients (4, 5).The rate of these fractures is increasing, primarily because of the rising incidence of occupational and traffic accidents (1, 2, 4, 5).

This upturn in the rate of thoracolumbar vertebral fractures has led to additional developments in surgical techniques and field of instrumentation. As a result, even patients with short life expectancies and poor quality of life related to a broad range of comorbidities and who undergo surgery seem to subsequently experience improved life expectancy and the ability to resume regular activities. Despite updated techniques, posterior, anterior, and combined surgical approaches have remained in use for the treatment of thoracolumbar vertebral fractures in the past five decades with several studies reporting excellent results (6-9).

The main surgical indications for thoracolumbar vertebral fractures are the associated presence of neurological deficits and vertebral instability (6, 10-14).Nevertheless, numerous issues continue to hamper the process of determining the optimal management of thoracolumbar

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vertebral fractures. These include; the lack of a widely recognized and validated thoracolumbar vertebral fracture classification, similar results obtained for some patient groups with either surgical or conservative treatment, and ambiguity about how the best way to understand and define the concept of spinal instability (3, 15). Furthermore, the ideal parameters to use for measuring outcomes remain unclear.

In the present study, we aimed to measure various clinical and radiological outcomes in a group of patients with thoracolumbar vertebral fractures who underwent surgery at a single center.

## Materials and Methods

This retrospective study included 50 consecutive patients who underwent surgery for thoracolumbar vertebral fractures between September 2000 and December 2011 at Ankara University School of Medicine, Department of Orthopedics. We obtained approval from our Institutional Ethics Committee, and we conducted it in accordance with the principles of the Declaration of Helsinki. Written informed surgical consent was obtained from each patient.

We obtained clinical outcome responses from patients via the visual analog scale (VAS) and the Oswestry Disability Index (ODI), which were both assessed preoperatively, postoperatively, and at the final visit.The 100-mm VAS was used to measure the intensity of pain associated with the fracture, and the ODI was used to measure the degree of disability associated with the fracture (16). If all 10 sections of the ODI are completed, the score can range from 0 to 50. Scores are calculated as a percentage (out of 50), and the patients are described as minimally disabled (0% to 20%), moderately disabled (21% to 40%), severely disabled (41% to 60%), crippled (61% to 80%), or bed-bound/with exaggerating symptoms (81% to 100%).

The Frankel scale, a 5-point severity scale, was used to determine the severity of spinal cord injury associated with the fracture (17). On this scale, spinal injuries are classified as complete (grade A), sensory only (grade B), motor useless (grade C), motor useful (grade D), or no neurological deficit (grade E). This was measured preoperatively, postoperatively, and at the final visit.

The sagittal index (SI), local kyphosis angle (LKA), and anterior corpus height loss (ACHL) were measured using plain radiography preoperatively, postoperatively, and at the final follow-up visit. The SI is the measurement of a kyphotic vertebral segmental deformity corrected for the normal sagittal contour at the level of the deformed vertebral segment, and it is calculated as the angle between the posterior walls of the fractured vertebra and the intact vertebra immediately below it. The LKA, which is used to classify the sagittal plane deformityin the setting of traumatic thoracolumbar vertebral fractures, was measured using the Cobb method and was defined as the angle formed between a line drawn parallel to the superior endplate of the intact vertebra one level above the fracture and a line drawn parallel to the inferior endplate of the intact vertebra one level below the fracture (18). The ACHL was calculated as the height of the fractured vertebra divided by the mean height of the intact vertebrae just above and below the fractured vertebra, and it was reported as a percentage.
Following the initial physical examination, patients underwent localized computed tomography (CT) and bilateral radiography of any suspicious regions based on pain or tenderness. If an examination revealed any neurological deficit, magnetic resonance imaging (MRI) was performed immediately. Vertebral fractures were classified based on the Thoracolumbar Injury Severity Scale and Score (TLISS) as well as the Denis classification (5, 10,19-21). The TLISS is based on three major injury characteristics: fracture morphology, the integrity of the posterior ligamentous complex (PLC),and the neurologic status of the patient. The Denis classification divides the spine into the following three columns (with the disruption of two or more columns resulting in instability): the anterior column (anterior longitudinal ligament plus anterior half of vertebral body), the middle column (posterior half of the vertebral body plus the posterior longitudinal ligament), and the posterior column (pedicles, facet joints, and supraspinous ligaments). The Denis system classifies fractures into four types: compression,burst, flexion-distraction, and fracture-dislocation;it differentiates each of these into five subtypes: A to E.

The patients in this study most commonly remained hospitalized for 3 days after the surgery, and they typically underwent postoperative imaging 1 day after the surgery. Postoperative VAS and ODI responses and Frankel scale measurements were generally obtained 1 week after surgery. Follow-up visits were routinely done at 1 week,1 month,3 months, 6 months, and 1 year after surgery. The final visit VAS, ODI, and Frankel scale as well as imaging for the calculation of SI, LKA, and ACHL were done 1 year after surgery in most patients.

**Statistical analysis**

Statistical analysis was performed using the Statistical Package for the Social Sciences Statistics for Windows, Version 17.0 (SPSS Inc.; Chicago, IL, USA). Descriptive data are primarily presented asmeans. Friedman's test andunivariate logistic regression were implemented to assess and compare results. Statistical significance was defined at the 5% ($p<0.05$) level.

## Results

A total of 45 patients with vertebral fractures were admitted directly through our emergency department, whereas the remaining 5 patients were referred to our clinic from an external center. Of these 50 patients, 31 were females and 19 were males. Their mean age was 46.5 (range:16 to 76) years, and the mean follow-up duration was 96.5 (range:6 to 183) months. All patients were evaluated and managed according to their trauma etiology and fracture level.Vertebral fractures were classified using the TLISS (Table 1) and the Denis classification (Table 2).

Of the 50 patients, 7 (14%) underwent anterior instrumentation and fusion, 41 (82%) underwent posterior instrumentation and fusion, and 2 (4%) underwent combined anterior and posterior instrumentation and fusion in the same session. Representative examples of preoperative and postoperative imaging of a patient receiving posterior instrumentation (Figure 1), postoperative imaging of a patient with a burst fracture (Figure 2), and postoperative imaging of a patient receiving anterior instrumentation (Figure 3) are provided.

The mean VAS scores were 82 mm preoperatively, 60 mm postoperatively, and 13.5 mm at the final visit, and the mean ODIs were 65% preoperatively, 40% postoperatively, and 15% at the final visit.All

**Table 1.** Distribution of 50 patients with thoracolumbar vertebral fractures according to the three major injury characteristics of the Thoracolumbar Injury Severity Scale and Score[1] at the Ankara University School of Medicine, Department of Orthopedics, between September 2000 and December 2011

| | Fracture, n (%) |
|---|---|
| **Fracture morphology** | |
| Compression | 8 (16) |
| Burst | 39 (78) |
| Translation-rotation | 3 (6) |
| Distraction | 0 (0) |
| **Posterior ligamentous complex integrity** | |
| Intact | 3 (6) |
| Suspected/Indeterminate | 24 (48) |
| Injured | 23 (46) |
| **Neurologic status (level of involvement)** | |
| Intact | 42 (84) |
| Nerve Root | 3 (6) |
| Conus medullaris-complete | 4 (8) |
| Conus medullaris-incomplete | 1 (2) |
| Cauda equina | 0 (0) |

[1]The Thoracolumbar Injury Severity Scale and Score (TLISS) is based on three major vertebral injury characteristics: fracture morphology, integrity of the posterior ligamentous complex, and neurologic status (level of neurologic involvement) (10, 19-21)

**Table 2.** Distribution of 50 patients with thoracolumbar vertebral fractures according to the Denis classification[1] at the Ankara University School of Medicine, Department of Orthopedics, between September 2000 and December 2011

| | Fracture, n (%) |
|---|---|
| **Compression (n=8)** | |
| Type A | 0 (0) |
| Type B | 3 (6) |
| Type C | 0 (0) |
| Type D | 5 (10) |
| **Burst (n=39)** | |
| Type A | 8 (16) |
| Type B | 27 (54) |
| Type C | 0 (0) |
| Type D | 1 (2) |
| Type E | 3 (6) |
| **Flexion-Distraction (n=0)** | |
| **Fracture-Dislocation (n=3)** | |
| Type A | 0 (0) |
| Type B | 0 (0) |
| Type C | 3 (6) |

[1]The Denis classification classifies fractures into four types-compression, burst, flexion-distraction, and fracture-dislocation-and differentiates each of these into five subtypes of fractures: type A (fracture of both endplates without kyphosis), type B (fracture of the superior endplate), type C (fracture of the inferior endplate), type D (burst rotation fracture), and type E (burst lateral flexion fracture) (5)

**Table 3.** Distribution of 50 patients with thoracolumbar vertebral fractures by preoperative, postoperative, and final visit Frankel scale grades for the severity of associated spinal cord injury at the Ankara University School of Medicine, Department of Orthopedics, between September 2000 and December 2011

| | Preoperative visit, n (%) | Postoperative visit, n (%) | Final visit, n (%) |
|---|---|---|---|
| Grade A (complete) | 4 (8) | 3 (6) | 3 (6) |
| Grade B (sensory only) | 1 (2) | 1 (2) | 1 (2) |
| Grade C (motor useless) | 0 (0) | 0 (0) | 0 (0) |
| Grade D (motor useful) | 3 (6) | 1 (2) | 0 (0) |
| Grade E (no deficit) | 42 (84) | 45(90) | 46 (92) |


**Figure 1. a-d.** A 69-year-old female was admitted to the emergency department after falling from a height. On performing a physical examination, there was no neurological deficit detected, but there was sensitivity on palpation of the upper lumbar region. Preoperative (a) anterior-posterior and (b) lateral X-rays as well as (c) axial computed tomography (CT) demonstrated an L1 burst fracture. Posterior instrumentation and fusion were performed between T12 and L2 using pedicle screws, and (d) postoperative lateral and AP X-rays demonstrated improvement. The sagittal index, local kyphosis angle, and anterior corpus height loss were 20.5°, 70°, and 42% preoperatively and 15°, 50°, and 26% postoperatively, respectively

these improvements for both clinical outcome measures (including preoperative to postoperative, preoperative to final visit, and postoperative to final visit) were statistically significant ($p<0.05$). According to the Frankel scale, 42 (84%) patients had no neurological deficit preoperatively, 45 (90%) had no deficit postoperatively, and 46 (92%) had no deficit at the final follow-up visit (Table 3).

Changes in mean SIs, LKAs, and ACHL percentages showed consistent trends from the preoperative visit to the postoperative or final visit and from the postoperative visit to the final visit. All three radiological outcome measures demonstrated statistically significant improvements when preoperative values were compared to both post-

**Figure 2.** Postoperative AP X-ray after long-segment fixation for a T12 burst fracture

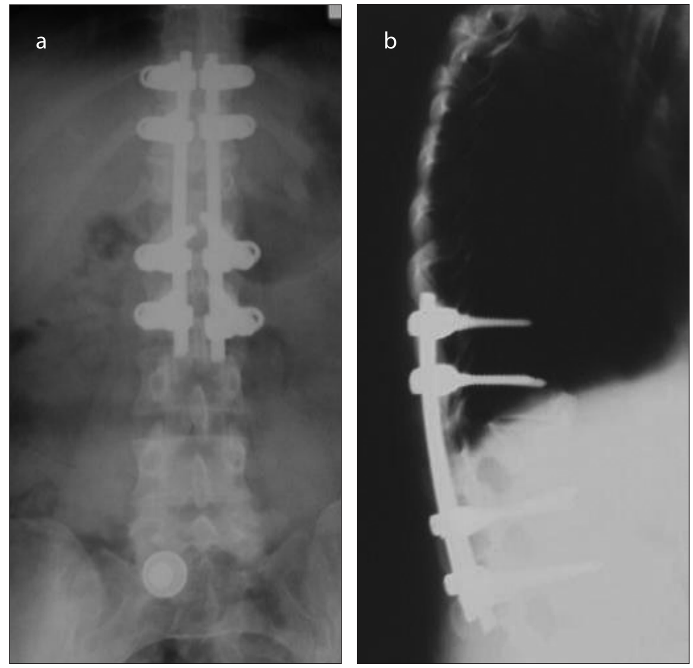


**Figure 3. a, b.** Postoperative (a) AP and (b) lateral X-ray showing the anterior interbody cage after anterior lumbar decompression and interbody fusion

**Table 4.** Preoperative, postoperative, and final visit sagittal indices[1], local kyphosis angles[2], and anterior corpus height loss percentages[3] in 50 patients with thoracolumbar vertebral fractures at the Ankara University School of Medicine, Department of Orthopedics, between September 2000 and December 2011

| | Preoperative visit | Postoperative visit | Final visit | Preoperative to postoperative visit (improvement) | Postoperative to final visit (Loss of correction) |
|---|---|---|---|---|---|
| Sagittal Index, degrees, mean | 20 | 14 | 15 | −4.8 | +1.9 |
| Local Kyphosis Angle, degrees, mean | 17 | 9 | 13 | −9.0 | +3.4 |
| Anterior Corpus Height Loss, %, mean | 45 | 25 | 28 | −18.0 | +4.2 |

[1]The sagittal index (SI) is the angle between the posterior walls of the fractured vertebra and the intact vertebra immediately below it.
[2]The local kyphosis angle (LKA) is the angle formed between a line drawn parallel to the superior endplate of the intact vertebra above the fracture and a line drawn parallel to the inferior endplate of the intact vertebra one level below the fracture.
[3]The anterior corpus height loss (ACHL) is the height of the fractured vertebra divided by the mean height of the intact vertebrae just above and below the fractured vertebra.

operative and final visit values (all $p<0.05$) (Table 4). However, unlike clinical outcome measures (which progressively improved with time), all three radiological outcome measures demonstrated a loss of correction between the postoperative and final visits. Specifically, the mean SI improved from 20° preoperatively to 14° postoperatively, before settling at 15° at the final visit. The mean LKA improved from 17° preoperatively to 9° postoperatively, before stabilizing at 13° at the final visit. Finally, the mean ACHL improved from 45% preoperatively to 25% postoperatively, before settling at 28% at the final visit. However, the postoperative to final visit losses of correction for the SI, LKA, and ACHL were not statistically significant.

## Discussion

We retrospectively assessed the outcomes of thoracolumbar vertebral fracture surgery in 50 patients using various clinical and radiological measures, including VAS, ODI, Frankel scale, SI, LKA, and ACHL. Others have supported this approach by recommending that investigations seeking to quantify outcomes following spine trauma should employ a combination of existing surveys in a complementary fashion, and that these should include determinants of both bodily pain and work-related disability (22). Further more, whereas there are numerous radiological variables that can be evaluated following the surgical treatment of thoracolumbar vertebral fractures, SI, LKA, and ACHL appear to be the most common, and several studies using these parameters have shown varying short-term and long-term results (23-28).

For clinical outcome measures, we found that both the mean VAS and the ODI for all patients improved progressively and significantly from the preoperative visit to the postoperative visit and to the final visit. Our results suggest that the severity of back pain was reported by patients to be minimal at the final visit. In addition, using the ODI definitions, patients reported that they had progressed from severely disabled prior to surgery to minimally disabled by their final visit.

For radiological outcome measures, we found that the mean SIs, LKAs, and ACHL percentages all showed consistent trends from before surgery to after surgery and to the final visit. All three of these radiological outcome measures demonstrated statistically significant improvements when preoperative values were compared to both postoperative and final visit values. However, in contrast to clinical outcomes that continued to improve over time, all three radiological outcomes demonstrated declines, or losses of correction, between postoperative visits and final visits, although none of these changes were statistically significant. Thus, while trends in clinical and radiological outcome measures were similar between preoperative and postoperative visits, the trends in these outcome measures were dissimilar after that.

Others have also described a lack of correlation between radiological and clinical outcome measures. For example, Andress et al. (11) used the Hannover Spine Score for the clinical evaluation of long-term results after surgery, and they did not find a significant correlation between improvements inLKA and clinical scores. They did report that clinical complaints were more frequent among patients with anLKA over 30°; however, postoperative improvement of such a severe kyphosis angle is uncommon, which might explain the lack of correlation between improvements in LKA and clinical scores in their study. Similarly, Knop et al. (23) did not find a correlation between improvements in the Hannover Spine Scores and any of the radiological outcome variables that they used. As a result, these authors suggested that radiological variables might not be useful for the long-term follow-up of patients with vertebral fractures.

Despite the findings that radiological outcome measures might not always correlate with clinical outcomes, these measures have still been utilized to assess the results in many studies. In 27 patients with short-segment thoracolumbar vertebral fractures, Wang et al.(29) found no significant correlation between the baseline or final severity of kyphosis and their pain scale, although 8 patients with an SI >15° showed a higher incidence of moderate to severe pain compared with the other 19 patients with an SI <15°. In another study, Liu et al. (30) undertook surgical treatment and follow-up of 18 patients using monosegmental transpedicular fixation plus posterior fusion. They used mean preoperative, postoperative, and latest follow-up SI values to demonstrate that their technique might provide the same or better fixation with the preservation of more motion segments among patients with thoracolumbar vertebral burst fractures with intact pedicles and facet joints accompanied by a PLC injury.

In their study of 50 patients undergoing short-segment vertebral posterior instrumentation, Andress et al. (11) reported a distinct improvement in SI values by restoring vertebral alignment but also a subsequent loss of correction of LKA during follow-up, reflecting alterations in the intervertebral disc space and the possibility of future degenerative disease. In their long-term study, Knop et al. (23) evaluated 62 patients who had surgery for thoracolumbar vertebral burst fractures. They reported a significant improvement in postoperative SI values, with no further alteration in these values during longer follow-up. They also found a mean loss of correction of LKA of 10°, despite also noting a significant improvement in the level of lordosis. Based on their study results,they concluded that LKAs tended to vary most in patients with a high preoperative ACHL percentage. In a related study, Toyone et al.(31) reported that the loss correction of LKA in the longterm was due to an unsupported anterior column. The authors recommended transpedicular intracorporeal hydroxyapatite grafting to address this, and they demonstrated that the loss of correction of LKA in patients in whom this technique was performed was significantly lower. The literature remains full of studies that have used radiological outcome measures to assess their results, suggesting the need to more definitively determine the value of these measures and to standardize how thoracolumbar vertebral fracture treatment results are assessed.

In this study, we were also able to assess the results of two different thoracolumbar vertebral fracture classification systems: the Denis classification and the TLISS. According to the Denis classification, the most common thoracolumbar vertebral fractures are burst fractures (5). Consistent with this, 78% of our patients had burst fractures, followed by compression fractures in 16% and fracture-dislocations in 6%. Surgical indications for burst fractures include progressive neurological deficit, conservative treatment failure (new-onset neurological signs, increasing pain, unacceptable deformity), and fracture-dislocations (7). Of import, in patients with mechanically and neurologically unstable burst fractures, pulmonary and venous complications can be prevented, mobility can be maintained, pain can be relieved, spinal deformity can be minimized, decompression of neural components can be achieved, and disease progression can be halted through the use of surgery (7, 32, 33).

Similarly, based on TLISS fracture morphology characteristics, 78% of our patients had burst fractures, 16% had compression fractures, and 8% had fracture-dislocations. Moreover, based on the TLISS, the vast majority of our patients (84%) had an intact neurologic status. However, looking at the third component of the TLISS, we noted that a PLC injury was suspected or confirmed in 94% of our patients. This was important because several studies have shown that most significant thoracolumbar vertebral fractures present with PLC injuries, that MRI is most helpful to confirm the injury, and that surgical fixation is the optimal treatment in such cases (34).

Nevertheless, the optimal treatment for thoracolumbar vertebral fractures is still being debated. In a meta-analysis that included 275 articles pertaining to thoracolumbar vertebral burst fractures, Boerger et al.(35) reported only variable neurological improvement, irrespective of the technique used, and they found no correlation between postoperative canal clearance and neurological improvement, suggesting that no surgical technique was superior in such a scenario. However, most would agree that surgery is indicated in patients with neurological deficits and/or fracture instability (6, 10-14).

Many authors have referred to the three-column concept described by Denis in assessing the stability of a spinal fracture (11, 36, 37). According to this concept, fractures that demonstrate damaged osteoligamentous (PLC) structures in the middle column on performing CT or MRI are unstable. Compared to stable fractures, unstable fractures are more often accompanied by a neurological deficit (36, 37). The importance of the PLC to vertebral stability has become clearer in recent years, with a greater focus being placed on assessing damage to and stabilization of this structure, particularly in patients with compression fractures (38). Although most of our patients did not have a neurological deficit, nearly all of them had suspected or confirmed PLC injuries, suggesting that vertebral instability was likely and that surgical therapy with fusion was indicated.

Regarding the surgical technique, most patients in our study underwent surgery via the posterior approach. Compared to the anterior approach, the posterior approach has some advantages. It offers the ability to perform surgery a safe distance away from the lungs and other visceral organs, resulting in lower morbidity and mortality rates (39). In addition, one study has shown that use of posterior approach takes less time and is associated with a lower risk of bleeding (40). We looked at which approach was performed in the subset of our patients with thoracolumbar vertebral fractures who had associated neurologic deficits (according to the TLISS) and showed an improvement of at least one grade in the Frankel scale postoperatively. Of three patients with preoperative nerve root compression, two demonstrated Frankel scale improvement after surgery; of these, one underwent posterior instrumentation and fusion, while the other underwent anterior instrumentation and fusion. Only one of three patients with total cord compression demonstrated improvement in the Frankel scale improvement postoperatively, and this patient had posterior instrumentation and fusion with the posterior approach alone. The other two patients had combined anterior and posterior approaches.

**Study limitations**

The implications of this study are limited by its retrospective design and the relatively small number of patients. In addition, given the divergent directions of clinical and radiological outcome trends between the postoperative and final visits, measuring these outcome variables at various points between the postoperative and final visits may have provided additional valuable insights.

## Conclusion

Trends in clinical and radiological outcomes after surgery for thoracolumbar vertebral fractures may differ. Although considerable progress has been made in the treatment of thoracolumbar vertebral fractures, the lack of standardized, verified clinical and radiological outcome measures continues to pose a challenge to the accurate assessment of the results of management.

**Ethics Committee Approval:** Ethics committee approval was received for this study from the ethics committee of Ankara University School of Medicine.

**Informed Consent:** Written informed consent was obtained from patient who participated in this study.

**Peer-review:** Externally peer-reviewed.

**Conflict of Interest:** No conflict of interest was declared by the authors.
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## References

1. Schlegel J, Bayley J, Yuan H, Fredricksen B. Timing of surgical decompression and fixation of acute spinal fractures. J Orthop Trauma 1996; 10: 323-30. [CrossRef]
2. Singh K, Vaccaro A. Thoracic and lumbar trauma. In: Bono C, Garfin S, eds. Orthopaedic Surgery Essentials: Spine. Philadelphia: Lippincott, Williams& Wilkins; 2004.p.45-57.
3. Weringer P, Schultz A, Hertz H. Conservative management of thoracolumbar and lumbar spine compression and burst fractures: functional and radiographic outcomes in 136 cases treated by closed reduction and casting. Arch Orthop Trauma Surg 2009; 129: 207-19. [CrossRef]
4. Verlaan JJ, Diekerhof CH, Buskens E, van der Tweel I, Verbout AJ, Dhert WJA, et al. Surgical treatment of traumatic fractures of the thoracic and lumbar spine: a systematic review of the literature on techniques, complications, and outcome. Spine 2004; 29: 803-14. [CrossRef]
5. Denis F. The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. In: Banaszkiewicz P, Kader D, eds. Classic Papers in Orthopaedics. London: Springer-Verlag; 2014.p.289-92.
6. Zdeblick TA, Sasso RC, Vaccaro AR, Chapman JR, Harris MB. Surgical treatment of thoracolumbar fractures. Instr Course Lect 2009; 58: 639-44.
7. Stambough JL. Posterior instrumentation for thoracolumbar trauma. Clin Orthop Relat Res 1997; 335: 73-88.
8. Altay M, Ozkurt B, Aytekin CN, Ozturk AM, Doğan O, Tabak AY. Treatment of unstable thoracolumbar junction burst fractures with short- or long-segment posterior fixation in Magerl type A fractures. Eur Spine J 2007; 16: 1145-55. [CrossRef]
9. Zdeblick TA, Sasso RC, Vaccaro AR, Chapman JR, Harris MB. Surgical treatment of thoracolumbar fractures. Instr Course Lect 2009; 58: 639-44.
10. Vaccaro AR, Lehman RA, Hurlbert RJ, Anderson PA, Harris M, Hedlund R, et al. A new classification of thoracolumbar injuries: the importance of injury morphology, the integrity of the posterior ligamentous complex, and neurologic status. Spine 2005; 30: 2325-33. [CrossRef]
11. Andress HJ, Braun H, Helmberger T, Schürmann M, Hertlein H, Hartl WH. Long-term results after posterior fixation of thoracolumbar burst fractures. Injury 2002; 33: 357-65. [CrossRef]
12. Accosta FL, Buckley JM, Xu Z, Lotz JC, Ames CP. Biomechanical comparison of three fixation techniques for unstable thoracolumbar burst fractures – laboratory investigation. J Neurosurg Spine 2008; 8: 341-6. [CrossRef]
13. Disch AC, Knop C, Schaser KD, Blauth M, Schmoetz W. Angular stable anterior plating following thoracolumbar corpectomy reveals superior segmental stability compared to conventional polyaxial plate fixation. Spine 2008; 33: 1429-37. [CrossRef]
14. Hseih CT, Chen GJ, Wu Cc, Su YH. Complete fracture - dislocation of the thoracolumbar spine without paraplegia. Am J Emerg Med 2008; 26: 633.e5-7.
15. Kerwin AJ, Frykberg ER, Schinco MA, Griffen MM, Arce CA, Nguyen TQ, et al. The effect of early surgical treatment of traumatic spine injuries on patient mortality. J Trauma Inj Infect Crit Care 2007; 63: 1308-13. [CrossRef]
16. Copay AG, Glassman SD, Subach BR, Berven S, Schuler TC, Carreon LY. Minimum clinically important difference in lumbar spine surgery patients: a choice of methods using the Oswestry Disability Index, Medical Outcomes Study questionnaire Short Form 36, and Pain Scales. Spine J 2008; 8: 968-74. [CrossRef]
17. van Middendorp JJ, Goss B, Urquhart S, Atresh S, Williams RP, Schuetz M. Diagnosis and prognosis of traumatic spinal cord injury. Global Spine J 2011; 1: 1-8. [CrossRef]
18. Keynan O, Fisher CG, Vaccaro A, Fehlings MG, Öner FC, Dietz J, et al. Radiographic measurement parameters in thoracolumbar fractures: a systematic review and consensus statement of the spine trauma study group. Spine 2006; 31: E156-65.
19. Bono CM, Vaccaro AR, Hurlbert RJ, Arnold P, Öner, FC, Harrop J, et al. Validating a newly proposed classification system for thoracolumbar spine trauma: looking to the future of the thoracolumbar injury classification and severity score. J Orthop Trauma 2006; 20: 567-72. [CrossRef]
20. Lee JY, Vaccaro AR, Lim MR, Öner FC, Hulbert RJ, Hedlund R, et al. Thoracolumbar injury classification and severity score: a new paradigm for the treatment of thoracolumbar spine trauma. J Orthop Sci 2005; 10: 671-5. [CrossRef]

21. Vaccaro AR, Baron EM, Sanfilippo J, Jacoby S, Steuve J, Grossman E, et al. Reliability of a novel classification system for thoracolumbar injuries: the Thoracolumbar Injury Severity Score. Spine 2006; 31(Suppl 11): S62-9, S104.
22. Schoenfeld A, Bono CM. Measuring spine fracture outcomes: Common scales and checklists. Injury 2011; 42: 265-70. [CrossRef]
23. Knop C, Fabian HF, Bastian L, Blauth M. Late results of thoracolumbar fractures after posterior instrumentation and transpedicular bone grafting. Spine 2001; 26: 88-99. [CrossRef]
24. Oner FC, Ramos LMP, Simmermacher RKJ, Kingma P, Diekerhof C, Dhert W, et al. Classification of thoracic and lumbar spine fractures: problems of reproducibility - A study of 53 patients using CT and MRI. Eur Spine J 2002; 11: 235-45. [CrossRef]
25. He QY, Xu JZ. Short segmental pedicle screw fixation combined with percutaneous vertebroplasty in treatment of nonadjacent thoracolumbar fractures. Chin J Traumatol 2009; 12: 138-41.
26. Liao JC, Fan KF, Chen WJ, Chen LH, Chen LH, Kao HK. Transpedicular bone grafting following short-segment posterior instrumentation for acute thoracolumbar burst fracture. Orthop 2009; 32: 493. [CrossRef]
27. Sasso RC, Renkens K, Hanson D, Reilly T, McGuire RA, Best NM. Unstable thoracolumbar burst fractures: anterior-only versus short-segment posterior fixation. J. Spinal Disord Tech 2006; 19: 242-8. [CrossRef]
28. Tezeren G, Gumus C, Bulut O, Tukenmez M, Oztemur Z, Sever G. Anterior versus modified combined instrumentation for burst fractures of the thoracolumbar spine: a biomechanical study in calves. J Orthop Surg 2008; 16: 281-4. [CrossRef]
29. Wang XY, Dai LY, Xu HZ, Chi YL. Kyphosis recurrence after posterior short-segment fixation in thoracolumbar burst fractures. J Neurosurg Spine 2008; 8: 246-54. [CrossRef]
30. Liu S, Li H, Liang C, Long H, Yu B, Chen B. Monosegmental transpedicular fixation for selected patients with thoracolumbar burst fractures. J Spinal Disord Tech 2009; 22: 38-44. [CrossRef]
31. Toyone T, Tanaka T, Kato D, Kaneyama R, Otsuka M. The treatment of acute thoracolumbar burst fractures with transpedicular intracorporeal hydroxyapatite grafting following indirect reduction and pedicle screw fixation: a prospective study. Spine 2006; 31: E208-14.
32. Glasser JA, Estes WJ. Distal short segment fixation of thoracolumbar and lumbar injuries. Iowa Orthop J 1998; 18: 87-90.
33. Oda T, Panjabi MM. Pedicle screw adjustments affect stability of thoracolumbar burst fracture. Spine 2001; 26: 2328-33. [CrossRef]
34. Ferguson RL, Allen BJ. A mechanistic classification of thoracolumbar spine fractures. Clin Orthop Relat Res 1984; 189: 77-88.
35. Boerger TO, Limb D, Dickson RA. Does 'canal clearance' affect neurological outcome after thoraco lumbar burst fractures? Bone Joint J 2000; 82: 629-35.
36. Ağuş H, Kayali C, Arslantaş M. Nonoperative treatment of burst-type thoracolumbar vertebral fractures: clinical and radiological results of 29 patients. Eur Spine J 2005; 14: 536-40. [CrossRef]
37. Dai L, Jia L, Zhao D, Xu Y. Remodeling of the spinal canal after thoracolumbar burst fractures: significance of nonoperative management. Zhonghua Wai Ke Za Zhi 2000; 38: 610-2.
38. Mikles MR, Stchur RP, Graziano GP. Posterior instrumentation for thoracolumbar fractures. J Am Acad Orthop Surg 2004; 12: 424-35. [CrossRef]
39. Vaccaro AR, Kim DH, Brodke DS, Harris M, Chapman JR, Schildhauver T. Diagnosis and management of thoracolumbar spine fractures. Instr Course Lect 2004; 53: 359-73.
40. Danisa OA, Shaffrey CI, Jane JA, Whitehill R, Wang GJ, Szabu TA, et al. Surgical approaches for the correction of unstable thoracolumbar burst fractures: a retrospective analysis of treatment outcomes. J Neurosurg 1995; 83: 977-83.[CrossRef]