Is fusion necessary for thoracolumbar burst fracture treated with spinal fixation? A systematic review and meta-analysis

Juliete M. Diniz, MD, and Ricardo V. Botelho, PhD

Department of Neurosurgery, Hospital do Servidor Público Estadual–IAMSPE, São Paulo, Brazil

OBJECTIVE Thoracolumbar fractures account for 90% of spinal fractures, with the burst subtype corresponding to 20% of this total. Controversy regarding the best treatment for this condition remains. The traditional surgical approach, when indicated, involves spinal fixation and arthrodesis. Newer studies have brought the need for fusion associated with internal fixation into question. Not performing arthrodesis could reduce surgical time and intraoperative bleeding without affecting clinical and radiological outcomes. With this study, the authors aimed to assess the effect of fusion, adjuvant to internal fixation, on surgically treated thoracolumbar burst fractures.

METHODS A search of the Medline and Cochrane Central Register of Controlled Trials databases was performed to identify randomized trials that compared the use and nonuse of arthrodesis in association with internal fixation for the treatment of thoracolumbar burst fractures. The search encompassed all data in these databases up to February 28, 2016.

RESULTS Five randomized/quasi-randomized trials, which involved a total of 220 patients and an average follow-up time of 69.1 months, were included in this review. No significant difference between groups in the final scores of the visual analog pain scale or Low Back Outcome Scale was detected. Surgical time and blood loss were significantly lower in the group of patients who did not undergo fusion ($p < 0.05$). Among the evaluated radiological outcomes, greater mobility in the affected segment was found in the group of those who did not undergo fusion. No significant difference between groups in the degree of kyphosis correction, loss of kyphosis correction, or final angle of kyphosis was observed.

CONCLUSIONS The data reviewed in this study suggest that the use of arthrodesis did not improve clinical outcomes, but it was associated with increased surgical time and higher intraoperative bleeding and did not promote significant improvement in radiological parameters.

<https://thejns.org/doi/abs/10.3171/2017.1.SPINE161014>

KEY WORDS fusion; thoracolumbar burst fracture; meta-analysis; spinal fracture; arthrodesis; trauma

THORACOLUMBAR fractures account for 90% of spinal fractures, with the burst subtype corresponding to 20% of the total.^{1,7,8,20}

Thoracolumbar burst fracture was first described in 1963 by Sir Frank Holdsworth as an injury that results from axial loading with or without flexion and dispersion of the vertebral body fragments.³ This fracture was considered mechanically stable and treated conservatively.¹¹

However, the optimal treatment for this type of fracture is still controversial.^{16,24} Since the 1990s, the surgical approach has been introduced as a practical treatment option.

Surgery for burst fractures might shorten a patient's hospital stay and hasten mobility and ambulation.¹⁴

Arthrodesis (fusion) has been used to promote the final biological stabilization of the fracture and to protect the fixation system from material fatigue failure caused by spinal column movement at the fractured site. The failure of the fixation system would be, hypothetically, just a matter of time without the protection of arthrodesis. The need for fusion associated with internal fixation has been questioned in recent studies.^{5,6,12,13,21–23,25} The aim of this review was to evaluate the effect of arthrodesis on surgi-

ABBREVIATIONS CI = confidence interval; LBOS = Low Back Outcome Scale; VAS = visual analog scale.

SUBMITTED August 27, 2016. **ACCEPTED** January 19, 2017.

INCLUDE WHEN CITING Published online August 4, 2017; DOI: 10.3171/2017.1.SPINE161014.

TABLE 1. Baseline characteristics of the studies

Study Characteristic	Wang et al., 2006*	Dai et al., 2009	Tezeren et al., 2009	Jindal et al., 2012	Chou et al., 2014*
No. of patients per group (no-fusion/fusion)	28:30	36:37	21:21	24:23	22:24
Mean follow-up time (mos)	41.0	72	34.6	23.9	146
Mean age (yrs)	39.8	34.6	36.2	29.4	39.4
Sex (males/females)	42:16	56:17	30:12	30:17	34:12
Type of fracture	Burst	Burst	Burst	Burst	Burst
No. of levels treated	1	1	1	1	1
Denis classification	Predominantly Type B	Type B	Predominantly Type B	†	Predominantly Type B
Load-sharing score	†	≤6	†	≤6	†
Type of surgery	Open	Open	Open	Open	Open
No. of levels instrumented, fusion & no-fusion groups	1 above & 1 below fracture	1 above & 1 below fracture	2 or 3 above & 2 below fracture	1 above & 1 below fracture	1 above & 1 below fracture
Fusion					
Technique	Posterolateral	Posterolateral	Posterolateral	Posterolateral	Posterolateral
Autogenous bone graft	From iliac crest, laminae, & spinous process	From iliac crest	From iliac crest, laminae, & spinous process	From iliac crest	From iliac crest, laminae, and spinous process
Postop bracing duration (mos)	3	†	3	3	3

* To avoid duplication of results in the same sample of patients in 2 studies (Wang et al. [2006] and Chou et al. [2014]), only 220 patients were included in the final analysis.

† Not described.

cally addressed thoracolumbar burst fractures compared with that of fixation without arthrodesis.

Methods

For this systematic review, we followed the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).¹⁷ The search was performed on all data up to February 28, 2016, in the Medline and Cochrane Central Register of Controlled Trials databases. The key words “fusion” or “arthrodesis” and “burst fracture” or “thoracolumbar fracture” or “spinal fracture” were used. We imposed no region, language, or type-of-study restriction. The survey was supplemented by a manual search of spine journals and of the lists of references cited in the selected articles.

This meta-analysis included only randomized and quasi-randomized studies with the following characteristics: patients were older than 18 years, single-level traumatic burst-type thoracolumbar fractures were studied, the study involved a minimum follow-up of 12 months, at least 20 patients were evaluated in each group (fusion/no fusion), studies were consistent in their description of fixation and fusion techniques, and pre- and postoperative clinical and radiological outcome data were available.

The risk of bias of the selected works was estimated according to guidelines proposed in the *Cochrane Handbook for Systematic Reviews of Intervention*,¹⁰ which assess the risk of bias in 7 domains, each scored subjectively as high risk, low risk, or uncertain risk.

The data were grouped as study characteristics (Tables 1 and 2), clinical outcomes, outcomes related to surgery, or radiological outcomes. All stages of this research were

conducted independently by 2 investigators. Disagreements were resolved after discussion.

The meta-analysis was performed using Comprehensive Meta-Analysis 2.0 software (Biostat). Dichotomous categorical variables were analyzed by using odds ratios. Continuous variables were analyzed by using mean raw differences. Statistical heterogeneity between studies was calculated using I^2 and Q statistics. Results are reported with their 95% confidence interval (CI). The significance level was $p < 0.05$. Randomized or fixed-effect meta-analysis was performed, depending on heterogeneity of the data.

Results

Literature Search

The search strategy identified 611 articles in Medline and 767 articles in the Cochrane Central Register of Controlled Trials. From these articles, 12 in the Medline database and 8 in Cochrane Central were selected by title; 5 duplicate items were excluded. The 15 remaining articles selected by title were then evaluated fully. Five studies met the established inclusion criteria; 4 were randomized and 1 was quasi-randomized. One of the randomized trials was suggested to be a long-term follow-up study⁵ based on previous work.²⁵ Only data from the last follow-up were considered for a pooled evaluation of the Low Back Outcome Scale (LBOS)⁹ and radiological outcomes (Fig. 1).

Clinical Outcomes

Visual Analog Pain Scale

The visual analog scale (VAS) for pain was used to an-

TABLE 2. Characteristics of variables in each study

Outcome & Study	No-Fusion Group	Fusion Group
VAS score at last follow-up		
Chou et al., 2014	2.1 (0.93)	2.0 (0.91)
Dai et al., 2009	1.5 (1.3)	1.4 (1.5)
LBOS score at last follow-up		
Chou et al., 2014	65.3 (6.9)	65.8 (6.3)
Jindal et al., 2012	34.92 (16.2)	15.2 (23)
Tezeren et al., 2009	55.7 (10.6)	57.8 (8.8)
Wang et al., 2006	66.9 (4.4)	65.6 (7)
Duration of hospitalization (days)		
Tezeren et al., 2009	10.8 (2.8)	10.2 (2.8)
Dai et al., 2009	13.0 (6.1)	11.9 (3.3)
Wang et al., 2006	16.6 (6.9)	14.6 (10.7)
Surgical time (mins)		
Tezeren et al., 2009	155.7 (32.3)	245.2 (78)
Jindal et al., 2012	107.5 (11)	142.2 (27.8)
Dai et al., 2009	102.6 (53.4)	152 (62.4)
Wang et al., 2006	162 (44)	224 (63.1)
Intraop blood loss (ml)		
Tezeren et al., 2009	290.4 (124)	519 (152)
Jindal et al., 2012	378 (140)	486.5 (175)
Dai et al., 2009	310.4 (53.1)	423.7 (72.8)
Wang et al., 2006	303 (148)	572 (367)
Segmental motion (°)		
Wang et al., 2006	4.8 (2.8)	1.0 (1.2)
Chou et al., 2014	4.2 (1.9)	0.9 (1.0)
Preop kyphotic angle (°)		
Tezeren et al., 2009	20.9 (2.8)	20.0 (2.4)
Jindal et al., 2012	16.98 (11.7)	18.46 (7.4)
Dai et al., 2009	18.7 (10.7)	18.2 (11.3)
Wang et al., 2006	16.8 (6.8)	19.8 (8.3)
Chou et al., 2014	16.4 (6.6)	19.5 (8.1)
Postop kyphotic angle (°)		
Tezeren et al., 2009	4.7 (2.2)	5.1 (2.2)
Jindal et al., 2012	4.93 (8.7)	5.03 (6.1)
Dai et al., 2009	0.5 (1.0)	0.6 (0.7)
Wang et al., 2006	1.6 (5.3)	4.1 (6.6)
Chou et al., 2014	1.5 (5.3)	4.0 (6.5)
Kyphotic angle at last follow-up (°)		
Tezeren et al., 2009	7.9 (1.5)	7.4 (2.2)
Jindal et al., 2012	8.51 (9.4)	10.51 (6.9)
Dai et al., 2009	1.7 (1.3)	1.4 (1.6)
Wang et al., 2006	9.8 (6.7)	11.5 (8.1)
Chou et al., 2014	13.8 (6.6)	14.7 (7.1)
Vertebral body height correction (%)		
Tezeren et al., 2009	36.0 (8.87)	35.5 (8.51)
Wang et al., 2006	32.0 (11.2)	33.9 (10.9)
No. of system failures		
Tezeren et al., 2009	1	1

CONTINUED IN NEXT COLUMN »

» CONTINUED FROM PREVIOUS COLUMN

TABLE 2. Characteristics of variables in each study

Outcome & Study	No-Fusion Group	Fusion Group
No. of system failures (<i>continued</i>)		
Jindal et al., 2012	1	2
Dai et al., 2009	0	0
Wang et al., 2006	3	5
No. of system removals		
Tezeren et al., 2009	1	0
Dai et al., 2009	0	0
Chou et al., 2014	18	9

Values are presented as the mean (SD) unless otherwise indicated.

alyze functional outcomes in 2 studies. The average VAS score at the final follow-up visit was assessed for both groups. The mean difference in VAS pain scores between the groups was 0.1 points (95% CI −0.31 to 0.51; $p = 0.63$; $I^2 = 0$), which did not favor the no-fusion group (result not significant) (Fig. 2).

Low Back Outcome Scale

Four of the 5 studies described the functional outcomes based on the LBOS. The average LBOS scores for both groups at the final follow-up visit were assessed. This scale consists of 9 factors. The summary effect was 4.03 favoring the no-fusion group (95% CI −4.97 to 13.05; $p = 0.38$; $I^2 = 49.37$), but it was not statistically significant (Fig. 3).

Outcomes Related to Surgery

Surgical Time

Four studies evaluated the difference in durations of surgery. Surgical time was significantly shorter in the no-fusion group. The summary effect was −54.9 minutes (95% CI −77.27 to −32.65; $p < 0.05$; $I^2 = 0$) (Fig. 4).

Intraoperative Blood Loss

Four trials compared intraoperative blood loss. Blood loss was significantly lower in the no-fusion group. The summary effect was −164.45 ml (95% CI −236.64 to −92.26; $p < 0.05$; $I^2 = 6.6$) (Fig. 5).

Length of Hospital Stay

Lengths of hospital stay were evaluated in 3 trials. The summary effect was 0.88 days (95% CI −0.42 to 2.17; $p = 0.18$; $I^2 = 0$), which did not favor the no-fusion group. The benefit of a gain of less than 1 day is questionable. The difference was not statistically significant (Fig. 6).

Outcomes Related to the Fixation System

Failures of the Fixation System

Breaking, loosening, bending, and displacement of the screws were considered fixation system failures.

In the 5–7 years of follow-up, no case of system failure was described in the report by Dai et al.⁶ Jindal et al.¹³ reported 2 cases of implant failure 11 and 15 months after surgery in the fusion group and 1 case 7 months after sur-

FIG. 1. PRISMA flow diagram for selection of articles in the meta-analysis. Figure is available in color online only.

gery in the no-fusion group. Tezeren et al.²² found 1 case in each group in a mean of 34.6 months. In 41 months of follow-up in a study by Wang et al.,²⁵ 5 failures occurred in the fusion group and 3 occurred in the no-fusion group; afterward, no other case was described.⁵ In general, implant failure was not a common adverse event in either of the 2 groups.

The overall incidence of system failure was 5.9%. In the no-fusion group, a total of 5 (4.6%) faults occurred. In the fusion group, a total of 8 (7.2%) failures occurred. The summary effect was 0.687 (95% CI 0.211–2.238; $p = 0.53$; $I^2 = 0$). The result favors the no-fusion group, but the difference was not statistically significant (Fig. 7).

Removal of the Fixation System

Removal of the fixation system was defined as the removal of the implant secondary to a complication. The obtained summary effect was 4.09 (95% CI 0.67–25.02; $p = 0.127$; $I^2 = 0$). These data favor the fusion group (Fig. 8).

Radiological Outcomes

Mobility in the Fractured Segment

Mobility in the fractured segment was assessed by the angular variation at the level of the fracture using flexion/extension profile radiographs according to a method described by Mumford et al.¹⁸ Two studies evaluated mobility in the fractured segment. Both of these studies were performed with the same patient sample. Only the last follow-up data were described. The no-fusion group had a mean ($\pm$ SD) 4.2° ($\pm$ 1.9°) and the fusion group had 0.9° ($\pm$ 1.0°) of segmental motion after 10 years.

Correction of Kyphosis in the Affected Segment

Kyphosis correction in the affected segment was calculated as the difference between preoperative and immediately postoperative kyphotic angles. Five studies evaluated kyphosis correction. The summary effect was 0.86° (95% CI –0.37° to 2.09°; $p = 0.17$; $I^2 = 0$) in favor of the no-fusion group, but the difference was not statistically significant (Fig. 9).

Loss of Kyphosis Correction in the Affected Segment

The loss of kyphosis correction in the affected segment was calculated as the difference between the kyphotic angle immediately after surgery and that at the last follow-up visit. Five studies evaluated the loss of kyphosis correction. The summary effect was 0.38° (95% CI –0.40° to 1.18°; $p = 0.33$; $I^2 = 15.67$), which indicates a greater loss of kyphosis correction in the no-fusion group. However, a less than 1° difference in correction loss suggests a clinically irrelevant effect (Fig. 10).

Final Kyphosis in the Affected Segment

The final kyphosis in the affected segment was calculated as the difference between the preoperative kyphotic angle and that at the final follow-up visit. Five studies evaluated the final kyphotic angle in the affected segment; the pooled average angle was 0.06° higher in the no-fusion group (95% CI –1.13° to 1.25°; $p = 0.92$; $I^2 = 0$) (Fig. 11).

Height Correction of Fractured Vertebral Bodies

Correction in the height of the fractured vertebral bodies was calculated as the difference between the pre- and

FIG. 2. Forest plot for meta-analysis of the VAS for pain.

FIG. 3. Forest plot for meta-analysis of the LBOS.

FIG. 4. Forest plot for meta-analysis of surgical time.

FIG. 5. Forest plot for meta-analysis of intraoperative blood loss.

postoperative fractured vertebral body heights. The method of Mumford et al.¹⁸ was used. We found no significant difference between the groups (0.60% [95% CI -4.47% to 3.25%]; $p = 0.759$; $I^2 = 0$) (Fig. 12).

Risk of Bias

Four studies used appropriate methods of randomization, and 1 was quasi-randomized on the basis of the order of hospital admission. None of the reports described alloca-

FIG. 6. Forest plot for meta-analysis of hospital length of stay.

FIG. 7. Forest plot for meta-analysis of fixation system failure.

FIG. 8. Forest plot for meta-analysis of fixation system removal.

FIG. 9. Forest plot for meta-analysis of correction of kyphosis.

tion-concealment methods; thus, they were all considered to be at uncertain risk for bias. Because of the surgical nature of the studies, it was impossible to perform blinding of the participants in all the studies, and this was considered a high-risk domain for all studies. Outcome blinding was

reported for just 2 trials, and so they were considered to be at low risk for bias, whereas the risk of bias in the remaining studies was uncertain. All the studies were considered to be at low risk for selective reporting. The methodological quality assessment of all included trials is shown in Fig. 13.

FIG. 10. Forest plot for meta-analysis of loss of kyphosis correction.

FIG. 11. Forest plot for meta-analysis of final kyphotic angle.

FIG. 12. Forest plot for meta-analysis of vertebral body height correction.

Discussion

Treatment of thoracolumbar burst fractures has been the subject of extensive discussion, and a number of conflicting proposals exist in the literature.^{2,14,15,20} Among the available surgical approaches, fixation with arthrodesis is still considered by many authors to be the gold standard for correcting this type of trauma. Arthrodesis is an additional step in the procedure usually believed to be necessary for satisfactory long-term results. Those who advocate it propose that fusion protects the metal fixation systems and prevents fatigue of the material subjected to movement cycles throughout the patient's life.

The value of adjuvant fusion for spinal fixation has been questioned. Some studies that compared surgical treatment of thoracolumbar burst fractures with fusion and surgical treatment without fusion pointed to similar results between groups. We found 5 reports in the litera-

ture of randomized or quasi-randomized studies^{5,6,13,22,25} that were designed to answer this question. Among them, 4 were randomized and 1 was quasi-randomized. A total of 220 patients were evaluated, and the average follow-up period was 69.1 months. This follow-up time seemed sufficient to reveal treatment failures that resulted from a lack of arthrodesis.

Most studies used the VAS for pain or LBOS instruments as a method for measuring functional differences. In this review, the clinical outcome results were not different between the groups.

Another clinical advantage of posterior instrumentation without fusion might be the avoidance of autogenous bone graft donor site-related complications. Most of the patients who underwent fusion complained of postsurgical pain that would compromise their mobility.

Regarding outcomes related to the surgical procedure, both surgical time and amount of intraoperative bleeding

FIG. 13. Risk of bias assessment. Figure is available in color online only.

were significantly lower in the no-fusion group ($p < 0.01$). We found no difference in the lengths of hospital stay ($p = 0.186$). Tezeren et al.²² reported shorter surgical time and less intraoperative blood loss for their no-fusion group but no significant difference in the hospital lengths of stay between groups. Wang et al.²⁵ also found significantly better results in their no-fusion group.

Failures of the fixation system, including fracture, dislocation, and screw loosening, were not different between groups. Sanderson et al.²¹ described a 14% system-failure rate in their no-fusion group, a result similar to that of the series that indicated an association between fusion and the transpedicular screw.²² Tezeren and Kuru²³ reported that the failure rate is considerably lower when a long, rather than a short, fixation is performed, but concerning its association with fusion, no difference was apparent between the groups.²⁴

In our review, implant removals that resulted from system failure were evaluated.^{4,21} The odds ratio for removal of a fixation system was 4.09 higher in the no-fusion group than in the fusion group; however, a sensitivity analysis in a study by Chou et al.⁵ found a high relative weight. The evaluation of this variable was also limited because part of the system removal described in the trials was found to be related to cultural factors and not failure only.^{5,25}

Regarding the radiological outcomes, segmental motion in the fractured levels was evaluated in 2 studies.^{5,25} These data suggest that mobility was preserved in the no-fusion group, even after 10 years of follow-up, without reaching instability.

The loss of kyphosis correction had a better result in the fusion group, but the difference was not statistically significant, and its magnitude suggests that this effect is clinically irrelevant. Other authors reported that the average loss of kyphotic angle was not significantly different between groups.^{6,13} Defino and Canto⁸ reported progressive kyphosis at the final follow-up visit even when instrumentation was associated with fusion and pointed out that progressive kyphosis might be inevitable despite fusion. Mumford et al.¹⁸ pointed out that residual deformity did not correlate with symptoms at follow-up.

No significant difference was observed in the degree of kyphosis correction or in the final kyphotic angle, al-

though the degree of kyphosis correction favored the no-fusion group.

The appearance of data suggesting the absence of clinical or radiological benefit with fusion associated with internal fixation in the treatment of burst fractures highlights the possibility of treating these injuries with less invasive procedures. In this context, the use of percutaneous pedicle screws is gaining popularity as a therapeutic alternative. Less morbidity would result if victims of trauma were treated with percutaneous pedicle screws, and the results would be the same as those of open surgery. Percutaneous pedicle screws have been used by some authors and were found to have satisfactory results.^{15,19}

Conclusions

We found no clear clinical benefit of arthrodesis as evaluated by the VAS and LBOS. Surgical time and intraoperative blood loss were significantly lower in the no-fusion group. We found no difference in hospital lengths of stay, and the fixation-system failure rate did not differ between the groups. The no-fusion patients had greater mobility in their fractured segment. For the other radiological parameters, performing arthrodesis resulted in no significant difference. These results raise questions about the real need for fusion in the treatment of thoracolumbar burst fractures.

References

1. Avanzi O, Landim E, Meves R, Caffaro MF, de Albuquerque Araujo Luyten F, Faria AA: Thoracolumbar burst fracture: load sharing classification and posterior instrumentation failure. *Rev Bras Ortop* 45:236–240, 2010
2. Avilés C, Flores S, Molina M: Conservative versus operative treatment for thoracolumbar burst fractures without neurologic deficit. *Medwave* 16 (Suppl 1):e6383, 2016
3. Bazan PL, Borri AE, Torres PU, Consentino JS, Games MH: [Classification of thoracolumbar fractures: comparison between AO and Vaccaro classifications.] *Coluna/Columna* 9:165–170, 2010 (Portuguese)
4. Chou PH, Ma HL, Liu CL, Wang ST, Lee OK, Chang MC, et al: Is removal of the implants needed after fixation of burst fractures of the thoracolumbar and lumbar spine without fusion? A retrospective evaluation of radiological and functional outcomes. *Bone Joint J* 98-B:109–116, 2016

5. Chou PH, Ma HL, Wang ST, Liu CL, Chang MC, Yu WK: Fusion may not be a necessary procedure for surgically treated burst fractures of the thoracolumbar and lumbar spines: a follow-up of at least ten years. **J Bone Joint Surg Am** **96**:1724–1731, 2014
6. Dai LY, Jiang LS, Jiang SD: Posterior short-segment fixation with or without fusion for thoracolumbar burst fractures. A five to seven-year prospective randomized study. **J Bone Joint Surg Am** **91**:1033–1041, 2009
7. de Assunção Filho CAA, Veloso RP, Meves R, Bergamaschi JP, Caffaro FS, Avanzi O: Thoracolumbar burst fractures: radiographic evaluation on differences between Margerl's A and B. **Acta Ortop Bras** **20**:240–242, 2012
8. Defino HL, Canto FR: Low thoracic and lumbar burst fractures: radiographic and functional outcomes. **Eur Spine J** **16**:1934–1943, 2007
9. Greenough CG, Fraser RD: Assessment of outcome in patients with low-back pain. **Spine (Phila Pa 1976)** **17**:36–41, 1992
10. Higgins JPT, Green S (eds): **Cochrane Handbook for Systematic Reviews of Interventions, Version 5.1.0**. London: The Cochrane Collaboration, 2011 (<http://handbook.cochrane.org>) [Accessed June 22, 2017]
11. Holdsworth F: Fractures, dislocations and fracture-dislocations of spine. **J Bone Joint Surg [Br]** **45**:6–20, 1963
12. Hwang JH, Modi HN, Yang JH, Kim SJ, Lee SH: Short segment pedicle screw fixation for unstable T11–L2 fractures: with or without fusion? A three-year follow-up study. **Acta Orthop Belg** **75**:822–827, 2009
13. Jindal N, Sankhala SS, Bachhal V: The role of fusion in the management of burst fractures of the thoracolumbar spine treated by short segment pedicle screw fixation: a prospective randomised trial. **J Bone Joint Surg Br** **94**:1101–1106, 2012
14. Kumar A, Aujla R, Lee C: The management of thoracolumbar burst fractures: a prospective study between conservative management, traditional open spinal surgery and minimally interventional spinal surgery. **SpringerPlus** **4**:204, 2015
15. Lee JK, Jang JW, Kim TW, Kim TS, Kim SH, Moon SJ: Percutaneous short-segment pedicle screw placement without fusion in the treatment of thoracolumbar burst fractures: is it effective?: comparative study with open short-segment pedicle screw fixation with posterolateral fusion. **Acta Neurochir (Wien)** **155**:2305–2312, 2013
16. Lee JY, Vaccaro AR, Lim MR, Oner 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** **10**:671–675, 2005
17. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JPA, et al: The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. **PLoS Med** **6**:e1000100, 2009
18. Mumford J, Weinstein JN, Spratt KF, Goel VK: Thoracolumbar burst fractures. The clinical efficacy and outcome of non-operative management. **Spine (Phila Pa 1976)** **18**:955–970, 1993
19. Palmisani M, Gasbarrini A, Brodano GB, De Iure F, Cappuccio M, Boriani L, et al: Minimally invasive percutaneous fixation in the treatment of thoracic and lumbar spine fractures. **Eur Spine J** **18** (Suppl 1):71–74, 2009
20. Sadatsune DA, da Costa PP, Caffaro MFS, Umata RS, Meves R, Osmar A: Thoracolumbar burst fractures: correlation between residual kyphosis and function after surgery. **Rev Bras Ortop** **47**:474–478, 2012
21. Sanderson PL, Fraser RD, Hall DJ, Cain CM, Osti OL, Potter GR: Short segment fixation of thoracolumbar burst fractures without fusion. **Eur Spine J** **8**:495–500, 1999
22. Tezeren G, Bulut O, Tukenmez M, Ozturk H, Oztumur Z, Ozturk A: Long segment instrumentation of thoracolumbar burst fracture: fusion versus nonfusion. **J Back Musculoskeletal Rehabil** **22**:107–112, 2009
23. Tezeren G, Kuru I: Posterior fixation of thoracolumbar burst fracture: short-segment pedicle fixation versus long-segment instrumentation. **J Spinal Disord Tech** **18**:485–488, 2005
24. Tisot RA, da Silveira Vieira J, dos Santos RT, Badotti AA, da Silva Collares D, Stumm LD, et al: Burst fracture of the thoracolumbar spine: correlation between kyphosis and clinical result of the treatment. **Coluna/Columna** **14**:129–133, 2015
25. Wang ST, Ma HL, Liu CL, Yu WK, Chang MC, Chen TH: Is fusion necessary for surgically treated burst fractures of the thoracolumbar and lumbar spine?: a prospective, randomized study. **Spine (Phila Pa 1976)** **31**:2646–2653, 2006

Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: both authors. Acquisition of data: both authors. Analysis and interpretation of data: both authors. Drafting the article: both authors. Critically revising the article: both authors. Reviewed submitted version of manuscript: both authors. Approved the final version of the manuscript on behalf of both authors: Botelho. Statistical analysis: both authors. Administrative/technical/material support: both authors. Study supervision: both authors.

Correspondence

Ricardo V. Botelho, Department of Neurosurgery, Hospital do Servidor Público do Estado de São Paulo, Tuim 525, Apto 122A, São Paulo 040-102, Brazil. email: bitbot@uol.com.br.