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META-ANALYSIS

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Efficacy of Vertebroplasty in Short-Segment Pedicle Screw Fixation of Thoracolumbar Fractures: A Meta-Analysis

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Data Interpretation D
Manuscript Preparation E
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Background: Short-segment pedicle screw instrumentation provides superior outcomes in treating thoracolumbar fractures. Nevertheless, the effect of intermediate screws on the outcome of short-segment instrumentation at the fracture level has not been specifically analyzed. We performed an update meta-analysis of the effect of additional vertebroplasty on the outcome of short-segment instrumentation to determine the role of screws for patients with fractured vertebra.

Material/Methods: A systematic literature search was conducted, updated to January 2019, in terms of the efficacy of additional vertebroplasty on the outcome of short-segment instrumentation at the fracture level. After rigorous quality review, we extracted the data from qualified clinical studies. We further analyzed odds ratios (ORs) of the endpoints of interest based on the included trials.

Results: Compared with the control group, short-segmental fixation combined with intermediate screws restored Cobb angle ($P<0.001$) and reduced anterior vertebral height compression ($P=0.001$). However, our results did not reveal statistically significant differences in operative time ($P=0.28$) or estimated blood loss ($P=0.23$). A statistically significant difference was observed in mean hospital stay ($P=0.02$).

Conclusions: Reinforcement with fracture-level screw combination can help stabilize the fractures and restore the anatomy. Nevertheless, additional trials and studies with longer follow-ups and on larger populations are warranted to confirm the current findings.

MeSH Keywords: Bone Screws • Meta-Analysis • Vertebroplasty

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Background

Thoracolumbar fractures, which are the constriction of traumatic fractures, account for 30% to 60% of all spinal fracture cases [1]. Considering the crucial role of spinal stability and neurological function of patients, surgical management or intervention is necessary [2].

The commonly used pedicle screw technology has led to profound clinical progress of posterior short-segmental fixation as a reliable approach for surgical treatment of thoracolumbar fractures [3,4]. The posterior short-segmental fixation technique is easy to use, preserves segment motion, and provides superior kyphosis correction via an indirect reduction technique, all contributing to its great popularity in clinical practice [5,6]. However, debates exist concerning the loss of the corrective angle and postoperative failure of internal fixation [7].

To prevent the abovementioned failures, additional transpedicular procedures such as grafting and vertebroplasty have been introduced and are well demonstrated to augment the anterior columns [8,9]. Moreover, previous reports have shown that additional vertebroplasty increases construct stiffness and reduces the failure rate of short-segment pedicle instrumentation [10,11]. Nevertheless, the use of additional vertebroplasty is still a subject of debate. Surgeons usually make the decision based on their preference and experience.

The present meta-analysis was designed to provide moderate-to-strong evidence of the efficacy of additional vertebroplasty versus traditional short-segment pedicle screw instrumentation at the fracture level for use in clinical practice.

Material and Methods

Search strategy

An electronic search was conducted of 3 online databases (Embase, PubMed, and the Cochrane Libraries) by 2 reviewers up to January 2019 to identify publications based on the following MeSH terms and free keywords: "thoracolumbar fracture" AND "short-segment" AND "vertebroplasty" AND "intermediate screws". The literature was also searched using reference lists and materials.

Selection criteria

For trials to be eligible for the current meta-analysis, the following criteria had to be met: (1) the studies were designed as comparative studies; (2) the research subjects were patients who were treated with additional vertebroplasty at the fracture level versus traditional short-segment pedicle screw instrumentation; (3) patients diagnosed with thoracolumbar fracture; (4) the outcomes of interest included Cobb angle, anterior vertebral height compression, estimated blood loss, operative time, and mean hospital stay, along with hazards ratios (HRs) and 95% confidence intervals (CIs); and (5) the publications were only available with their full texts.

Evaluation of study quality

All identified studies were evaluated by 2 reviewers to assess eligibility. Study eligibility was further assessed using of the Newcastle-Ottawa Scale.

Data extraction

We independently extracted data from each trial based on predefined inclusion criteria, and any differences were settled through discussion to reach consensus. We included the main categories on the basis of the following parameters: publication year, family name of first author, patient numbers, median age, and follow-up duration. The corresponding mean difference (MDs) and risk ratios (RRs) were extracted with 95% CI to describe the endpoints of interest.

Statistics analysis

Statistical analysis was done using Review Manager version 5.3 software (RevMan; The Cochrane Collaboration, Oxford, UK). Sensitivity analysis was conducted for impact examination on overall results, on the basis of heterogeneity across the included studies. The I^2 statistic was applied for assessing heterogeneity in the trial results to select an ideal analysis model [12]. The use of the fixed-effects model reflected insignificant heterogeneity ($I^2 \leq 50\%$). $I^2 > 50\%$ reflected high heterogeneity and the random-effects model was utilized for further analysis [13]. A P value less than 0.05 was regarded as a statistically significant difference for all analyses. We also used forest plots to summarize the findings of the present meta-analysis.

Results

Study characteristics

We screened 218 publications for eligibility for inclusion in the meta-analysis. On the basis of the predefined inclusion criteria, 210 publications were excluded due to failure to provide adequate details of outcomes. Therefore, 8 studies [11,14–20] were included in the current meta-analysis for efficacy evaluation of additional vertebroplasty versus placebo (Figure 1). Table 1 lists the basic information of the included clinical studies.

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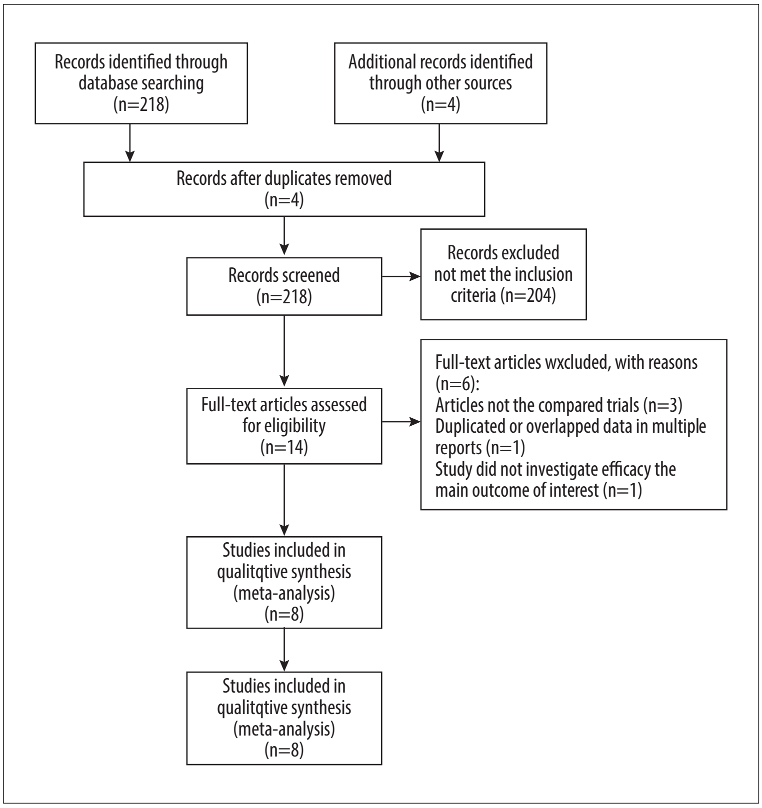

Figure 1. PRISMA flow chart of the selection process to identify studies eligible for pooling.

Table 1. The primary characteristics of the eligible studies in more detail.

Author year	Follow-up period	Patient number		Median age	
		With vertebroplasty	Without vertebroplasty	With vertebroplasty	Without vertebroplasty
Tian 2011	3 months	27	35	43.7	44.4
Huang 2013	12 months	14	16	/	/
Zhao 2015	12 months	32	35	43.6	45.8
Guven 2009	50 months	18	18	37.4	39.7
Farrokhi 2010	37 months	38	42	34.9	34.0
Aono 2017	96 months	29	33	36.8	43.0
Ye 2017	24 months	20	24	38.7	39.6
Sun 2016	48 months	35	34	41.86	40.67

Clinical and methodological heterogeneity

Pooled analysis of Cobb angle comparing additional vertebroplasty with placebo

The pooled data on Cobb angle showed that the additional vertebroplasty group had better restoration of Cobb angle (MD=–2.46, 95% CI=–3.25 to –1.66, P<0.00001) versus the placebo group (Figure 2) at the preoperative stage (MD=–2.02, 95% CI=–3.09 to –0.94, P=0.0002) and during the follow-up (MD=–3.08, 95% CI=–4.18 to –1.98, P<0.00001).

Pooled analysis of anterior vertebral height compression comparing additional vertebroplasty versus placebo

Compared to the placebo group, patients receiving additional vertebroplasty showed significantly better anterior vertebral height compression (MD=3.92, 95% CI=1.92 to 5.93, P=0.0001)

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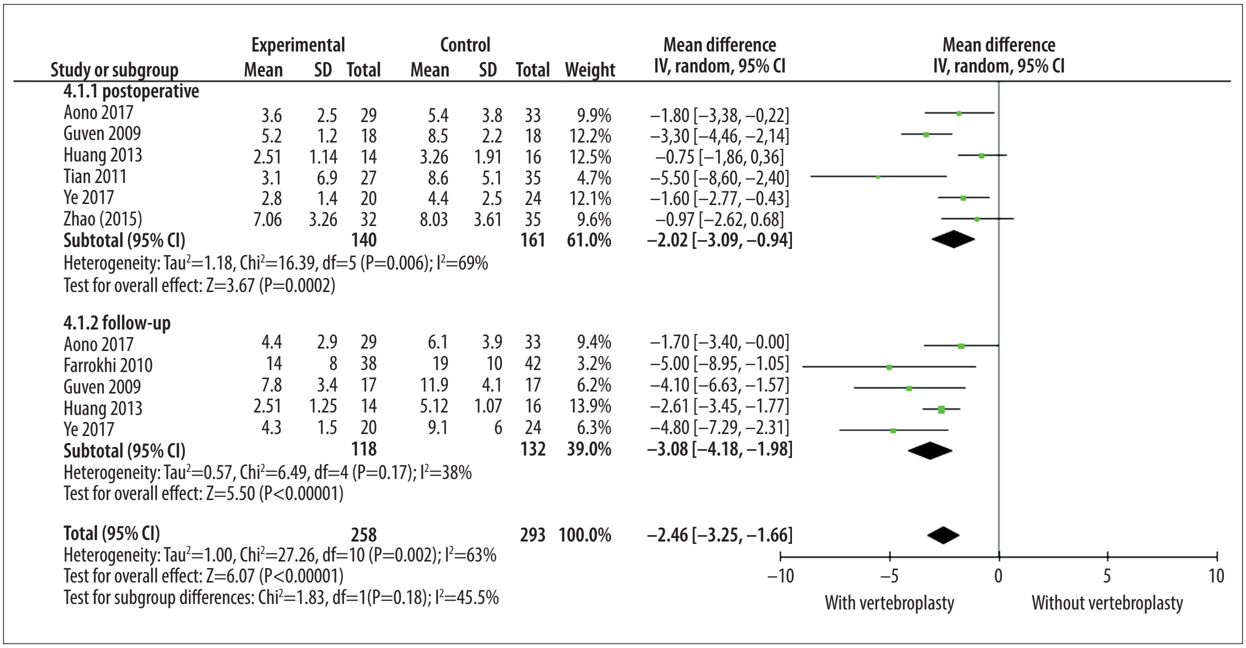

Figure 2. Pooled analysis of Cobb angle comparing additional vertebroplasty versus the placebo.

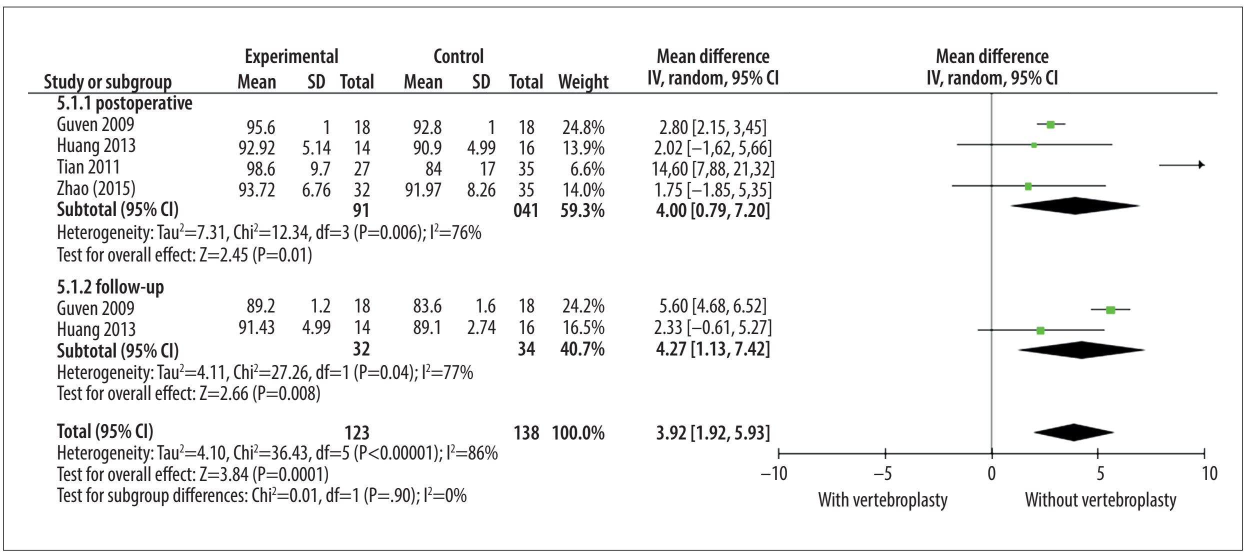

Figure 3. Pooled analysis of anterior vertebral height compression comparing additional vertebroplasty versus the placebo.

(Figure 3) at the preoperative stage (MD=4.00, 95% CI=0.79 to 7.20, P=0.01) and during the follow-up period (MD=4.27, 95% CI=1.13 to 7.42, P=0.008).

Pooled analysis of operative time comparing additional vertebroplasty versus placebo

Data on operative time were available for 6 trials, which failed to show any significant differences between the additional vertebroplasty group and the placebo group (MD=6.46, 95% CI: –5.14 to 18.05, P=0.28) (Figure 4).

Pooled analysis of estimated blood loss comparing additional vertebroplasty versus the placebo

The random-effects model was used to pool the data due to high heterogeneity among the studies. According to the pooled data, no difference in estimated blood loss was identified between the additional vertebroplasty group versus the placebo group (MD=33.00, 95% CI: –20.36 to 86.36, P=0.23). The data are shown in Figure 5.

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Study or subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean difference IV, random, 95% CI
Aono 2017	153.7	61.7	29	100.8	29.2	33	11.6%	52.90 [28.33, 77.47]
Farrokhi 2010	169	59	38	168	72	42	9.7%	1.00 [−27.74, 29.74]
Guven 2009	128	15	18	132	15	18	20.7%	−4.00 [−13.80, 5.80]
Sun 2016	150	18	35	136	11	34	22.3%	14.00 [6.98, 21.02]
Tian 2011	52	11	27	51	10	35	23.1%	1.00 [−4.31, 6.31]
Ye 2017	142	30	20	160.2	45.7	24	12.7%	−18.20 [−40.72, 4.32]
Total (95% CI)			**167**			**186**	**100.0%**	**6.46 [−5.14, 18.05]**

Heterogeneity: Tau²=144.50, Chi²=30.46, df=5 (P<0.0001); I²=84%
Test for overall effect: Z=1.09 (P=0.28)

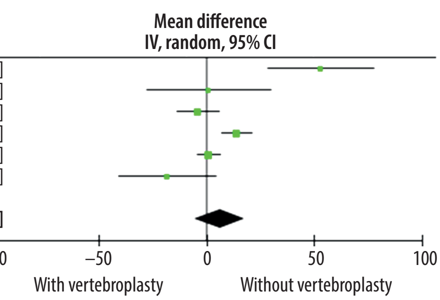

Figure 4. Pooled analysis of operation time comparing additional vertebroplasty versus the placebo.

Study or subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean difference IV, random, 95% CI
Aono 2017	578.1	458.4	29	152.9	131.6	33	7.1%	425.20 [252.43, 597.97]
Farrokhi 2010	430	305	38	515	485	42	7.0%	−85.00 [−260.84, 90.84]
Guven 2009	442	50	18	430	60	18	25.2%	12.00 [−24.08, 48.08]
Sun 2016	425	85	35	400	55	34	25.6%	25.00 [−8.69, 58.69]
Tian 2011	250	65	27	245	62	35	25.9%	5.00 [−26.98, 36.98]
Ye 2017	483.5	186.6	20	507.5	300	24	9.2%	−24.00 [−169.24, 121.24]
Total (95% CI)			**167**			**186**	**100.0%**	**33.00 [−20.36, 86.36]**

Heterogeneity: Tau²=2597.98, Chi²=23.87, df=5 (P=0.0002); I²=79%
Test for overall effect: Z=1.21 (P=0.23)

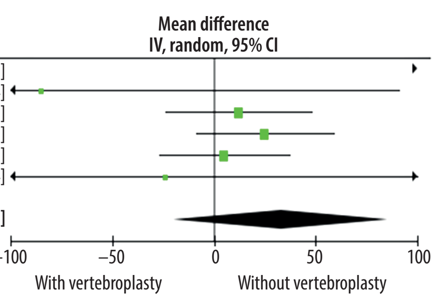

Figure 5. Pooled analysis of blood loss comparing additional vertebroplasty versus the placebo.

Study or subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean difference IV, fixed, 95% CI
Farrokhi 2010	13	10	38	9	7	42	6.1%	4.00 [0.18, 7.82]
Guven 2009	9	2	18	8	3	18	31.8%	−1.00 [−0.67, 2.67]
Sun 2016	13.1	2.9	35	12.2	2.1	34	62.1%	0.90 [−0.29, 2.09]
Total (95% CI)			**91**			**94**	**100.0%**	**1.12 [0.18, 2.06]**

Heterogeneity: Chi²=2.33, df=2 (P=0.31); I²=14%
Test for overall effect: Z=2.33 (P=0.02)

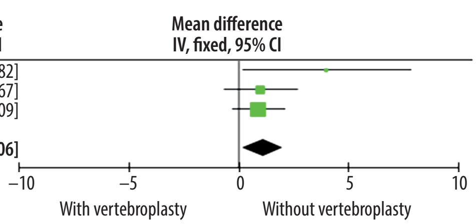

Figure 6. Pooled analysis of the mean hospital stay comparing additional vertebroplasty versus the placebo.

Pooled analysis of mean hospital stay comparing additional vertebroplasty versus placebo

There was a significant difference in hospital stay between the additional vertebroplasty group and the placebo group (MD=1.12, 95% CI=0.18 to 2.06, P=0.02) (Figure 6).

Discussion

Vertebral fractures are not usually accompanied with significant injuries of the anterior and posterior longitudinal ligaments or intervertebral tears, which is associated with poor bone restoration. Decompression of the spinal canal and restoration of the vertebral column stability are considered to be the main goals of surgical therapy for thoracolumbar fractures [21,22]. With one vertebra above and the other below the fracture level, traditional short-segment fixation shows several advantages, such as decreasing involvement of motion segments as compared to fixation with longer instrumentation, and sparing healthy mobile segments in fusion; hence, mobility is preserved [23].

Nevertheless, debates still exist regarding the results of traditional short-segment pedicle screw instrumentation at the fracture level. In spite of the fixation of normal upper and lower vertebral bodies of the fractured area through traditional short-segment fixation, there are several disadvantages that should be acknowledged. On one hand, the fractured vertebra does not have weight-bearing capacity, as do its upper and lower clearances. Moreover, the load is conducted mainly through internal fixation. On the other hand, a parallelogram effect has been found in fixation, which is associated with

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lateral instability. Therefore, the stability and capacity of the spinal axial are insufficient for surgery, which can increase the failure rate of internal fixation and postoperative corrective loss. Moreover, fixation can increase recession of the intermediate fractured vertebrae and decrease the distance between the upper and lower anterior vertebral bodies, which is regarded as the "suspension effect". Hence, the addition of transverse connection fixation is usually required.

Compared with traditional short-segment fixation, additional vertebroplasty is associated with higher biomechanical stability. Firstly, additional fractured screw-setting exerted much more pressure stress toward the abdomen on the fractured vertebra. It showed a beneficial effect in reducing screw load, improving stress distribution of screws, and resisting the "suspension effect" [24]. Secondly, the lateral stability of fixation was improved by the procedure, which can significantly enhance the stability of fixation [25]. Lastly, additional fixation was strongly linked to higher screw pullout force and reduced micro-movements on the bone-metal interface, which plays a vital role in maintaining the physiological curvature of fixed parts postoperatively and in preventing screws from loosening [11]. In summary, additional fixation provides stronger biomechanical stability of the vertical stress screw [25,26].

The present meta-analysis has several limitations. We were only able to include retrospective reports with short-term follow-up and small sample sizes, which may have affected the comparison of outcomes of interest. In addition, due to lack of data, we did not analyze the subgroups of different surgical treatments of thoracolumbar fractures. Further research and multicenter studies with longer follow-ups and larger sample sizes are needed to reach more solid conclusions to guide clinical practice.

Conclusions

This meta-analysis evaluated the best available evidence from comparisons of short-segment instrumentation with additional vertebroplasty and the control group. The study found that hospital stay was significantly longer (P=0.02) in the additional vertebroplasty group. However, this method demonstrated no increase in operative time (P=0.28) and estimated blood loss (P=0.23). Additional fixation showed beneficial effects in stabilizing the fractures and restoring the anatomy. More studies with larger patient populations and longer follow-up are warranted to assess the efficacy of additional vertebroplasty.

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