Review Article

Combined anteroposterior fixation using a titanium cage versus solely posterior fixation for traumatic thoracolumbar fractures: A systematic review and meta-analysis

ABSTRACT

Study Design: Systematic review with meta-analysis.

Objective: Additional anterior stabilization might prevent posterior implant failure, but over time, the disadvantageous of bone grafts have become evident. The objective of this systematic review was to compare risks and advantages of additional anterior stabilization with a titanium cage to solely posterior fixation for traumatic thoracolumbar fractures.

Methods: An electronic search was performed in the literature from 1980 to March 2016. Studies comparing only posterior with anteroposterior fixation by means of a titanium cage were included in this study. Data extraction and Cochrane risk of bias assessment were done by two independent authors. In addition, the PRISMA statement was followed, and the GRADE approach was used to present results.

Results: Of the 1584 studies, two randomized controlled trials (RCTs) and one retrospective cohort study were included in the meta-analysis. The RCTs reported evidence of high quality that anteroposterior stabilization maintained better kyphosis correction than posterior stabilization alone. However, these results were neutralized in the meta-analysis by the cohort study. Implant failure was reported by one study, in the posterior group. No differences in follow-up visual analog scale scores, neurologic improvement, and complications were found. Operation time, blood loss, and hospital stay all increased in the anteroposterior group.

Conclusions: Patients with a highly comminuted or unstable fracture could benefit from combined anteroposterior stabilization with a titanium cage, for some evidence suggests this prevents loss of correction. However, large randomized studies still lack. There is a risk of cage subsidence, and increased perioperative risks have to be considered when choosing the optimal treatment.

Keywords: Anterior instrumentation, anteroposterior instrumentation, posterior instrumentation, spine, thoracolumbar fracture, titanium cage, trauma

INTRODUCTION

Posterior short segment fixation is one of the most widely used surgical stabilization techniques for spinal fractures. The posterior spine is relatively easy accessible, and posterior fixation provides kyphosis correction, indirect reduction of canal encroachment, and stabilization of the fractured vertebra. However, in specific fracture types, reported instrumentation failure up to 40% and loss of kyphosis correction[1-4] indicated the necessity of additional anterior stabilization. In 1994, the load-sharing classification (LSC) was introduced[5] to predict posterior implant failure and has been used to select patients requiring additional anterior column support.

Access this article online	
Website: www.jcvjs.com	Quick Response Code
DOI: 10.4103/jcvjs.JCVJS_8_17	

Arjen Johannes Smits, Meaghan Polack, Jaap Deunk, Frank Willem Bloemers

Department of Trauma Surgery, VU University Medical Centre, Amsterdam, The Netherlands

Address for correspondence: Dr. Arjen Johannes Smits, De Boelelaan 1117, Room 7F020, 1081 HV Amsterdam, The Netherlands.
E-mail: aj.smits@vumc.nl

How to cite this article: Smits AJ, Polack M, Deunk J, Bloemers FW. Combined anteroposterior fixation using a titanium cage versus solely posterior fixation for traumatic thoracolumbar fractures: A systematic review and meta-analysis. J Craniovert Jun Spine 2017;8:168-78.

Different methods to support the anterior column have been developed; bone strut grafts, vertebral body stents (VBS), Mesh and expandable cages, with or without additional anterolateral plating. Different techniques have their respective disadvantages. Widely used autologous bone grafts are associated with postdonor site pain,[6,7] risk of nonunion,[8] and increased correction loss.[8,9] The anterior approach is surgically invasive; however, nowadays minimally-invasive techniques such as thoracoscopy[10-12] are available. Although minimally invasive transpedicular VBS is promising,[13] long-term results and applicability to traumatic fractures are yet unknown. However, fractures with neurologic deficit and an LSC of ≥7 also have shown acceptable outcomes when treated nonoperatively[14,15] or with solely short-segment posterior fixation.[16]

Biomechanical studies have shown superior stability of anteroposterior fixation compared to posterior instrumentation alone.[17-20] While anterior stabilization mainly prevents the loss of correction, studies did not show correlation with improved functional outcomes.[9,15] In addition, long-term maintenance of correction is possibly affected by fracture type and anterior graft material.[21] Clinical studies comparing the solely posterior with anterior[22,23] or anteroposterior stabilization by means of a titanium cage are scarce or involved mainly bone strut grafts,[3,24] outdated instruments,[25] or osteoporotic fractures.[26] The titanium cage might provide additional value while it avoids risks and disadvantages associated with other anterior stabilization techniques.

Yet, the exact value of an additional anterior cage remains unclear. The aim of this systematic review is to provide the evidence in the current literature of additional anterior stabilization with a titanium cage compared to solely posterior fixation for traumatic thoracolumbar fractures.

MATERIALS AND METHODS

The systematic review was conducted according to the PRISMA statement.[27] Electronic searches were performed in PubMed and Embase from January 1980 to January 2017. Published articles as well as accepted and drafts in English, German, French, Dutch, and Chinese were deemed eligible. Authors of articles in languages other than English were contacted for English translation, and if they not responded, articles were translated by a medical professional translator. The search consisted of general and Mesh (medical subject heading) terms and variants of "Spinal Fractures," "spine," "vertebrae," "fracture*," "injury," "anterior," "posterior,*" "stabilization," and "fixation" [Table 1]. Furthermore, references of articles retrieved after the first selection was searched for eligible studies. Inclusion criteria consisted of (1) Clinical trials or cohort studies involving, (2) Patients with traumatic thoracolumbar fractures and comparing, (3) Solely posterior fixation using pedicle screws with, and (4) Combined anteroposterior stabilization by means of a titanium cage and pedicle screws. Excluded were articles comparing treatment for (1) Patients with a degenerative, pathologic, or osteoporotic indication, (2) Studies not comparing both treatments, (3) Editorials and letters to the editor, and (4) Articles in languages other than mentioned. Two authors independently selected articles based on title and abstract. Full texts of the remaining articles were then read, if disagreement existed on inclusion, this was solved through discussion or with a tertiary independent author.

Data collection

Data extraction from included articles was done using a standardized extraction form created for this study. If data were insufficient, authors were contacted for additional information. Data were extracted for (1) Patient characteristics (age, sex, fracture type, and level), (2) Number of patients, (3) Surgical techniques, (4) Reported outcomes (visual analog scale [VAS], loss of kyphosis correction, neurological improvement, and complications, SF-36), and (5) Follow-up duration. Loss of kyphosis correction was defined as the difference in kyphosis directly postoperative and at final follow-up. One study used the VAS-spine score, 19 questions concerning fracture-related back pain and is

Table 1: Full electronic search strategy for at least one database as in concordance with the PRISMA statement

#	Search terms
1	("Spinal Fractures"[Mesh] OR ((spine[tiab] OR spinal[tiab] OR vertebrae[tiab] OR vertebral[tiab]) AND (fractur*[tiab] OR injury[tiab] OR injuries[tiab]))) AND (anterior*[tiab] AND posterior*[tiab] AND (stabili* [tiab] OR fixat*[tiab]))
2	(("Spinal Fractures"[Mesh] OR ((spine[tiab] OR spinal[tiab] OR vertebrae[tiab] OR vertebral[tiab]) AND (fractur*[tiab] OR injury[tiab] OR injuries[tiab]))) AND (anterior*[tiab] AND posterior*[tiab] AND (stabili* [tiab] OR fixat*[tiab]))) AND (cage[tiab] OR synex[tiab] OR obelisk[tiab])
3	((("Spinal Fractures"[Mesh] OR ((spine[tiab] OR spinal[tiab] OR vertebrae[tiab] OR vertebral[tiab]) AND (fractur*[tiab] OR injury[tiab] OR injuries[tiab]))) AND (anterior*[tiab] AND posterior*[tiab] AND (stabili* [tiab] OR fixat*[tiab]))) AND (randomized controlled trial[pt] OR controlled clinical trial[pt] OR randomized[tiab] OR placebo[tiab] OR drug therapy[sh] OR randomly[tiab] OR trial[tiab] OR groups[tiab])) OR ((("Spinal Fractures"[Mesh] OR ((spine[tiab] OR spinal[tiab] OR vertebrae[tiab] OR vertebral[tiab]) AND (fractur*[tiab] OR injury[tiab] OR injuries[tiab]))) AND (anterior*[tiab] AND posterior*[tiab] AND (stabili* [tiab] OR fixat*[tiab]))) AND (systematic[sb]))

The presented search was used in the PubMed database in the systematic review and meta-analysis rated from 0 to 100 with 100 being no disability/pain. To compare this score to the regular VAS scores of the other studies, it was inverted to 0 being no disability/pain and 100 being maximum pain.

Risk of bias assessment

The risk of bias was assessed at the study level for randomized studies using the Cochrane risk of bias tool. Cohort studies were assessed at the outcome level using the Cochrane risk of bias assessment tool: For nonrandomized studies of interventions, outcomes are reported in Tables 2 and 3. Pooled results are presented integrating the risk of bias using the GRADE approach (GRADEpro GDT, McMaster University, 2015).

Statistical analysis

Results from included studies were pooled for a meta-analysis where possible. If not reported, standard deviations were calculated from *P* values or confidence intervals (CIs), if these were not available the range was used.[28] Random effects models were used since heterogeneity was suspected. To estimate the total treatment effect, standardized mean differences (SMD) were calculated for studies using different scoring scales. Mean differences were calculated if studies used the same continuous outcome scale. To compare dichotomous outcomes, risk ratios (RRs) with 95% CIs were calculated to estimate total effect. To test whether observed differences in results could be due to chance alone, a Chi-square test was used (with $P < 0.1$ considered significant). The I^2-test was used to estimate the percentage of variability in effect estimates that is due to heterogeneity, with a value of >70% considered as substantial heterogeneity. Using a funnel plot to determine publication bias was not feasible due to the small amount of included studies.

Analyses were done using Review Manager 5.3 (Copenhagen, Denmark: The Nordic Cochrane Centre, the Cochrane Collaboration, 2014).

RESULTS

Study selection

The initial search resulted in 1584 articles after duplicates were removed. After the selection based on title and abstract, nine articles seemed eligible for inclusion. After full-text was assessed, two randomized controlled trials (RCTs) and one retrospective cohort study remained eligible for qualitative analysis and could[29-31] be included in the meta-analysis [Figure 1].

Included studies consisted of a total of 134 patients, 69 of which underwent anteroposterior stabilization with pedicle screws and a titanium cage and 65 patients solely posterior stabilization

Table 2: Cochrane risk of bias assessment for cohort studies, concerning the study of Weiner *et al*.[31]

Domain	Correction loss	Postoperative VAS score
Confounding bias	Serious	Serious
Selection bias	Moderate	Moderate
Bias in measurements of intervention	Low	Low
Bias due to departures from intended interventions	Low	Moderate
Bias due to missing data	Moderate	Moderate
Bias in measurement of outcomes	Low	Moderate
Bias in selection of reported result	Moderate	Moderate
Overall	Serious	Serious

VAS - Visual analog scale

Table 3: Cochrane risk of bias assessment for randomized controlled studies

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Korovessis et al.	?	?	−	?	+	−	+
Wang et al.	+	?	−	+	+	−	+
Weiner et al.	Not applicable						

with pedicle screws. All three studies described groups ranging from 20 to 28 patients. Patient characteristics, generally comparable among studies, are summarized in Table 4. All studies included more males compared to females. Noticeable differences are fracture levels; one study[29] only assessed the mid-lumbar region (L2–L4), whereas other studies assessed the thoracolumbar region (T11–L2).[30,31] The longest mean follow-up was 70 months.[30] Wang and Liu[30] also included very severe fractures while Korovessis *et al*.[29] used an LSC of 6 as upper boundary for inclusion.

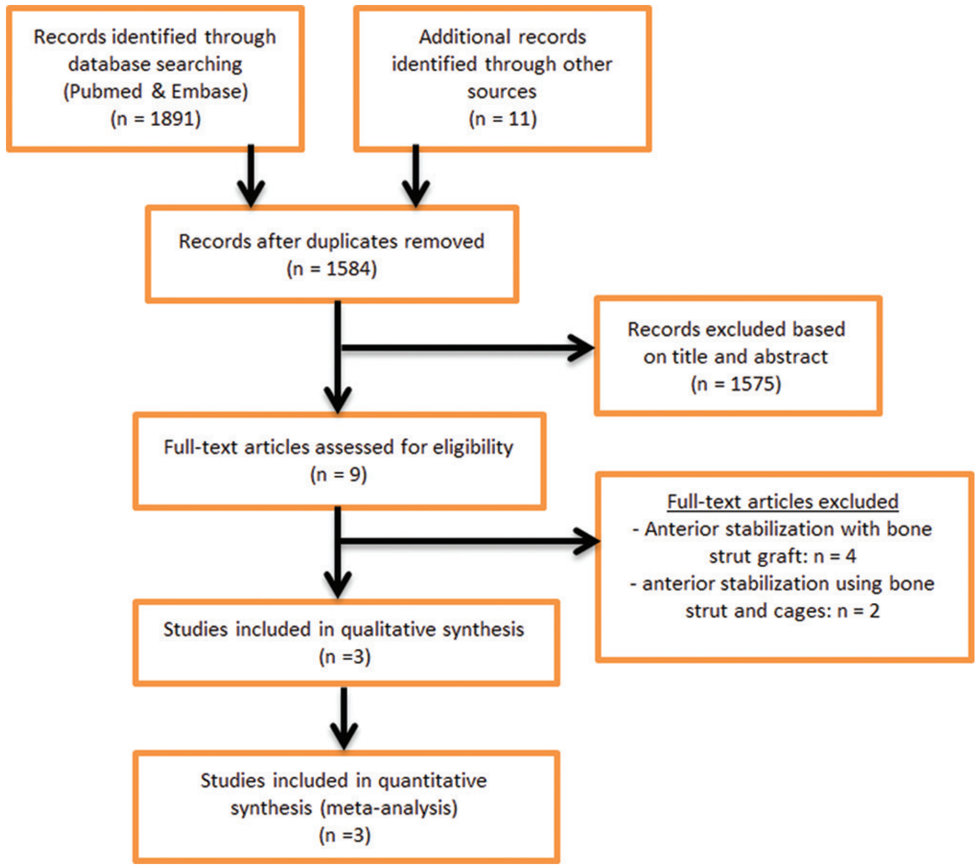


Figure 1: Flow chart of the study selection according to the PRISMA-statement

Table 4: Summary of study characteristics and outcomes

Author	Year	Study type	Outcome*	Inclusion	Exclusion	Approach	*n*	Age years (SD)	Male: female	Fract level	Follow-up (months, SD)
Wang *et al*.	2015	RCT	VAS, complications, Frankel, Cobb-angle, surgery time, and BL	Burst fracture with >50% VHL, or >20° kyphosis, or >50% SCE	>1 level fracture, concomitant surgical injuries, history of spinal surgery	AP P	21 23	41 (13) 41 (14)	16:5 15:8	T12-L2 T12-L2	71 (9) 69 (9)
Korrovessis *et al*.	2006	RCT	VAS, complications, Frankel, Gardner-angle, surgery time and BL, SF36	AO A3 fracture with LSC ≤6, fracture within 1 week	>1 level fracture, polytraumatized, osteoporosis, other spinal disease or surgery	AP P	20 20	39 (19) 44 (16)	16:4 15:5	L2-L4 L2-L4	46 (?) 48 (?)
Weiner *et al*.	2013	Cohort	VAS-spine, Cobb-angle, SF36	Magerl ≥A3 or looming neurological deficit through SCE or Kyphosis >15°-20°	Pathologic fracture, complete SCI, ≤18 months follow up, age <16 and >65, lost to follow-up	AP P	28 22	45 (?)	6:4	Thoracolumbar	41 (?)

*Only outcomes that are used in this review are reported. VHL - Vertebral height loss; SCE - Spinal canal encroachment; AP - Anterior-posterior; P - Posterior; BL - Blood-loss; LSC - Load sharing classification; SCI - Spinal cord injury; SD - Standard deviation; VAS - Visual analog scale; RCT - Randomized controlled trial; SF - Short form

Surgical technique

Two studies used a titanium mesh cage filled with autogenous bone,[29,30] the other study used a titanium expandable cage.[31] One study used posterior instrumentation with pedicle screws in the fractured vertebra in both groups,[29] whereas the other two,[30,31] only used pedicle screws in both groups one level above and below the fractured vertebra. Wang and Liu[30] additionally performed posterolateral fusion with autogenous bone graft. Only Weiner *et al*.[31] described the removal of posterior implant in a few patients in both groups before final follow-up.

Outcomes

All studies reported kyphosis angles and VAS scores although one study reported the VAS-spine score.[31] Two studies[29,30] reported complication rates for wound infections and deep venous thrombosis, neurologic improvement on Frankel scale, operation time, bloodloss, and hospital stay. Two studies[29,31] reported different domains of the SF-36 and were, therefore, not comparable. Outcomes are reported in Table 4.

Quality assessment

The risk of bias of the RCTs is shown in Table 3. Both studies scored a generally low to unclear risk of bias. For both studies, it was very unlikely that participants were blinded to intervention. Wang and Liu[30] reported less types of complications compared to Korovessis *et al*.[29] In addition, Korovessis *et al*.[29] did not report the method of randomization and blinding nor did they report all items of the SF-36.

In the cohort study of Weiner *et al*.,[31] a selection bias may have occurred for both outcomes, as treatment allocation depended on fracture type. In addition, the start of follow-up and start of intervention did not coincide for most subjects. Of the 46 patients that went missing to follow-up, it was unclear to which group they belonged, and these were neither included in their analysis. The exact time frame of the last measurement was unclear. Overall, both correction loss and VAS-spine score scored a serious risk of bias [Table 2].

Meta-analysis

Visual analog scale scores

Anteroposterior treatment had a moderate effect on lowering the postoperative VAS score compared to the solely posterior approach (SMD - 0.64; 95% CI: 1.69–0.41; P = 0.23). The substantial heterogeneity (I^2 = 88%; χ^2: P <0.01) did not decrease using stratified analysis for RCT's and the cohort study [Figure 2]. The quality of evidence for this outcome was graded very low, using all three studies due to the risk of bias and imprecision of the cohort study, and indirectness of the RCT's. Using only the RCT's, the quality of evidence was graded moderate due to inconsistency.

Radiologic evaluation

Although the anteroposterior group maintained more kyphosis correction on final follow-up compared to the posterior group, this was not significant (MD - 2.50; 95% CI: 6.56–1.51; P = 0.22). With stratified analyses for all studies, heterogeneity decreased from substantial to moderate, I^2 from 84% to 44%, and χ^2 from P = 0.002 to P = 0.18. The RCT group showed significantly more kyphosis maintenance in favor of the anteroposterior group (MD - 4.59; 95% CI: 6.95–2.22; P < 0.01) [Figure 3]. Using all three studies, the quality of evidence for correction loss was graded very low due to risk of bias and indirectness from inclusion of the cohort study and inconsistency. Excluding the cohort study and including only the RCT's, the quality of evidence was graded high.

Neurologic improvement

The neurologic improvement was graded as at least one grade improvement on Frankel scale. The anteroposterior group had a higher, though not significant, relative risk of neurologic improvement (RR - 1.15; 95% CI: 0.92–1.43; P = 0.22) [Figure 4]. Heterogeneity was not important (I^2 = 0%, χ^2: P = 0.99). The quality of evidence of neurologic improvement was graded high.

Complications

Complications in both RCT's reported were deep venous thrombosis and wound infections. The anteroposterior group

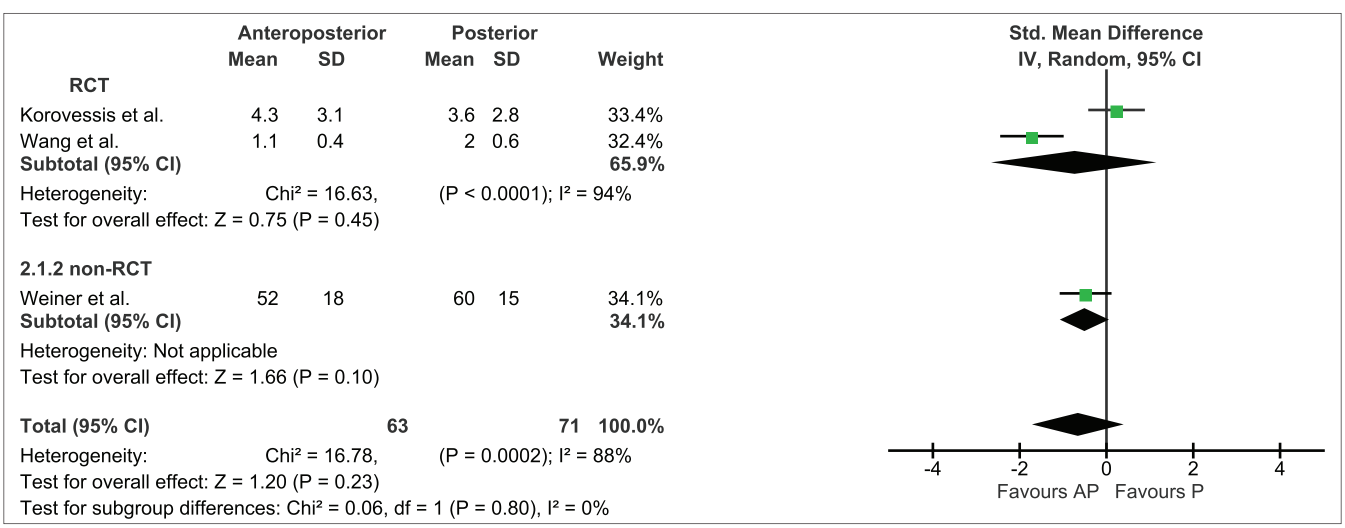


Figure 2: Forest plot of visual analog scale scores at follow-up for combined anteroposterior approach with a titanium cage versus solely posterior fixation, stratified for randomized controlled trial, and cohort studies

showed a higher risk for these complications, however, not significant (RR - 2.06; 95% CI: 0.56–7.61; $P = 0.28$) [Figure 5]. Heterogeneity was not important ($I^2 = 0\%$, χ^2: $P = 0.95$). Korovessis *et al*.[29] reported more types of complications than did Wang and Liu. The quality of evidence concerning complications was rated low due to serious risk of bias and strongly suspected publication bias due to selective reporting.

Surgical parameters

Only the RCT's reported surgical parameters. Operation time was significantly shorter in the posterior group compared to the anteroposterior group (MD - 141.61 min; 95% CI: 125.47–157.74; $P < 0.01$) [Figure 6a]. Heterogeneity was not important ($I^2 = 0\%$, χ^2: $P = 0.69$).

Intraoperative blood loss was significantly less in the posterior group compared to the anteroposterior group (MD - 515.97 mL; 95% CI: 297.54–734.41; $P < 0.01$) [Figure 6b]. With substantial heterogeneity ($I^2 = 71\%$, χ^2: $P = 0.07$).

Hospital stay was significantly shorter in the posterior group compared to the anteroposterior group (MD - 6.21 days; 95% CI: 3.41–9.02; $P < 0.01$) [Figure 6c], with moderate heterogeneity ($I^2 = 54\%$, χ^2: $P = 0.14$).

All quality of evidence concerning surgical parameters was graded high.

Grading of evidence

Quality rating of the evidence of each outcome with the GRADE approach and additional comments and explanations are presented in Figure 7.

DISCUSSION

The main indication for additional anterior stabilization is to provide support in the anterior column to prevent secondary kyphosis and posterior instrumentation failure. Our systematic review shows more persistent kyphosis correction using an additional anterior cage. No difference between groups was seen in pain scores, neurologic improvement, deep venous thrombosis, and wound infections. Operation time, blood loss, and hospital stay did increase, as expected, in the anteroposterior group.

Kyphosis and implant failure

Independent of fracture location (T12–L2 vs. L2–L4), the RCTs reported significant less correction loss using a cage. The cohort study[31] however contradicted this and

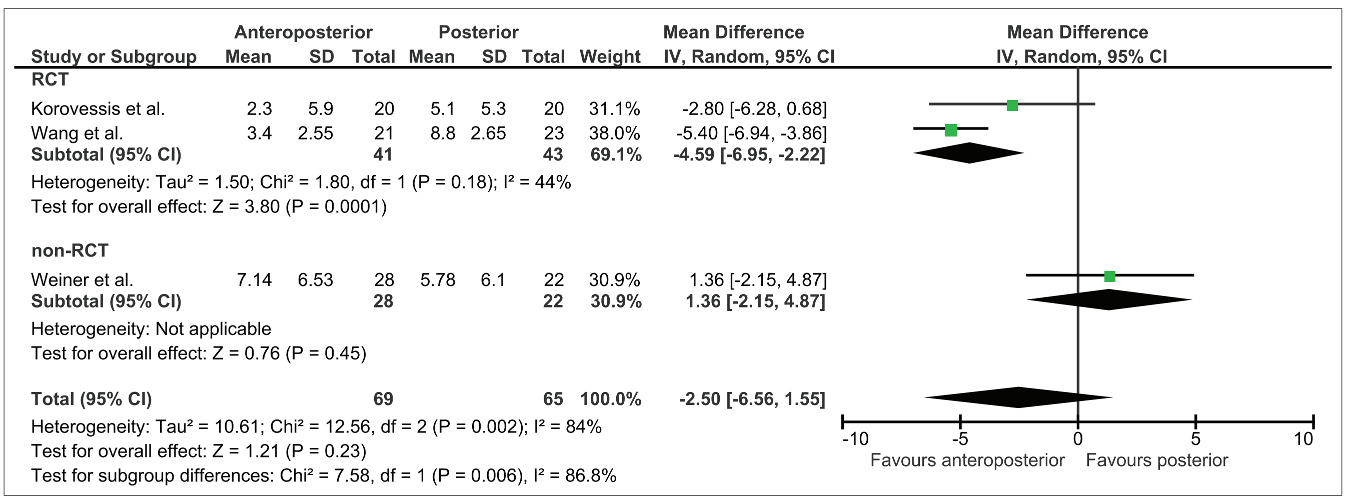


Figure 3: Forest plot of kyphosis correction loss (degrees) measured from postoperative value to final follow-up, for combined anteroposterior approach with a titanium cage versus solely posterior fixation

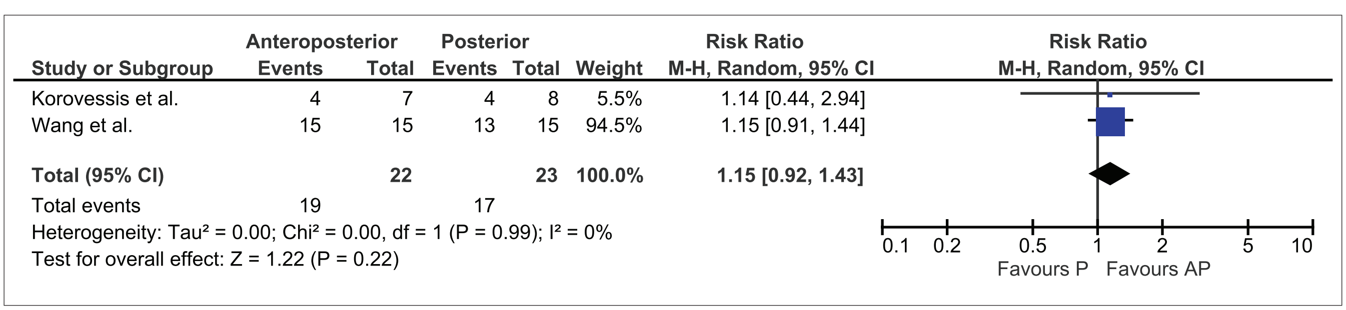


Figure 4: Forest plot of neurologic improvement on Frankel scale for combined anteroposterior approach with a titanium cage versus solely posterior fixation

Study or Subgroup	Antero-posterior Events	Antero-posterior Total	Posterior Events	Posterior Total	Weight	Risk Ratio M-H, Random, 95% CI
Korovessis et al.	4	20	2	20	68.4%	2.00 [0.41, 9.71]
Wang et al.	2	21	1	23	31.6%	2.19 [0.21, 22.43]
Total (95% CI)		**41**		**43**	**100.0%**	**2.06 [0.56, 7.61]**
Total events	6		3			

Heterogeneity: Tau² = 0.00; Chi² = 0.00, df = 1 (P = 0.95); I² = 0%
Test for overall effect: Z = 1.08 (P = 0.28)

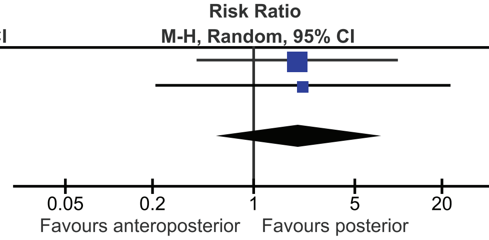
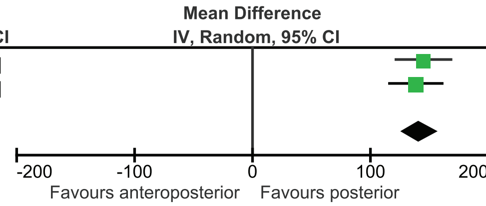


Figure 5: Forest plot of complications: Wound infections and deep venous thrombosis for combined anteroposterior approach with a titanium cage versus solely posterior fixation

Study or Subgroup	Anteroposterior Mean	Anteroposterior SD	Anteroposterior Total	Posterior Mean	Posterior SD	Posterior Total	Weight	Mean Difference IV, Random, 95% CI
Korovessis et al.	245	44	20	100	30	20	47.8%	145.00 [121.66, 168.34]
Wang et al.	248.5	43.9	21	110	29.6	23	52.2%	138.50 [116.16, 160.84]
Total (95% CI)			**41**			**43**	**100.0%**	**141.61 [125.47, 157.74]**

Heterogeneity: Tau² = 0.00; Chi² = 0.16, df = 1 (P = 0.69); I² = 0%
Test for overall effect: Z = 17.20 (P < 0.00001)



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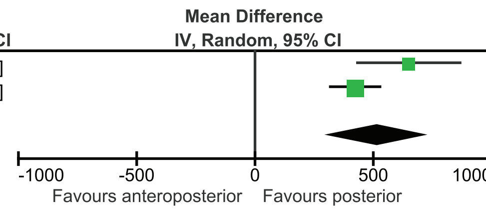
Study or Subgroup	Anteroposterior Mean	Anteroposterior SD	Anteroposterior Total	Posterior Mean	Posterior SD	Posterior Total	Weight	Mean Difference IV, Random, 95% CI
Korovessis et al.	1,500	436	20	850	234	20	40.9%	650.00 [433.14, 866.86]
Wang et al.	780.3	226.8	21	357	98.1	23	59.1%	423.30 [318.34, 528.26]
Total (95% CI)			**41**			**43**	**100.0%**	**515.97 [297.54, 734.41]**

Heterogeneity: Tau² = 18141.22; Chi² = 3.40, df = 1 (P = 0.07); I² = 71%
Test for overall effect: Z = 4.63 (P < 0.00001)



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Study or Subgroup	Anteroposterior Mean	Anteroposterior SD	Anteroposterior Total	Posterior Mean	Posterior SD	Posterior Total	Weight	Mean Difference IV, Random, 95% CI
Korovessis et al.	12	4	20	7	3	20	58.1%	5.00 [2.81, 7.19]
Wang et al.	21.4	5.9	21	13.5	4.7	23	41.9%	7.90 [4.73, 11.07]
Total (95% CI)			**41**			**43**	**100.0%**	**6.21 [3.41, 9.02]**

Heterogeneity: Tau² = 2.27; Chi² = 2.17, df = 1 (P = 0.14); I² = 54%
Test for overall effect: Z = 4.34 (P < 0.0001)

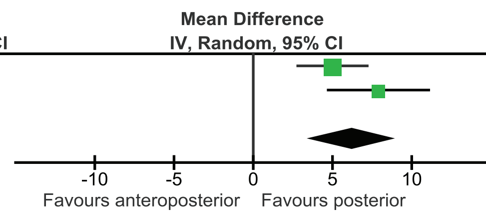

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Figure 6: Forest plots of (a) Operation time (min), (b) Peroperative blood loss (mL), and (c) Hospital stay (days) for combined anteroposterior approach with a titanium cage versus solely posterior fixation

reported a high prevalence of cage subsidence. The authors attributed the cage subsidence to small endplate surfaces of their used expendable cages. This resulted in frequent intraoperative damage of vertebral endplates during the cage distraction. Another possible explanation is that no additional anterolateral plating was used which could provide additional anterior support. Cage subsidence is an important concern although no correlation with quality of life was found.[31] Observational studies reported low rates of cage subsidence and good kyphosis correction and outcome.[32-37] We expect consistent kyphosis correction when using a cage with additional plating.

While anterior stabilization is developed to prevent posterior implant failure, only Wang and Liu[30] reported posterior implant failure, in the posterior group. An explanation could be that this was the only study that used solely posterior fixation on fractures with an LSC ≥7. Korovessis *et al.*[29] included fractures with an LSC ≤6, which according to the LSC do not need additional anterior stabilization. They, in accordance, concluded that solely posterior fixation was associated with less surgical trauma and provided better clinical outcomes. In addition, they advised to only use an additional cage in the case of high comminution and angulation. Wang and Liu[30] included fractures with an LSC over and below 7 although results were not stratified accordingly. They concluded to only use a combined approach in very comminuted unstable fractures or with posterior column injury. Due to the large selection bias in the study of Weiner *et al.*,[31] it is not possible to make a recommendation on fracture type based on this study. In conclusion, it seems that a small proportion of fractures with high comminution or instability are indicated for additional anterior stabilization using a cage. While it is not possible to appoint specific fracture types based on these studies, the LSC could be a good indicator.

Pain and neurologic improvement

Pain might be the result of posttraumatic kyphosis, neurologic injury or postdonor site pain, and complications resulting from invasive surgery. Our systematic review shows no significant difference for either group when taking all studies into account, with very low quality of evidence. The randomized studies showed conflicting results. Korovessis *et al*.[29] assigned the higher pain score in the anteroposterior group to the more invasive additional surgery. This is likely if the pain score was measured directly postoperative, however, the measuring moment remains unclear. The other studies,[30,31] both reporting less pain for the anteroposterior group, measured pain after 70 and 41 months, respectively. Interestingly, Weiner *et al*.[31] report less pain in the anteroposterior group while they report 85% cage subsidence. The anteroposterior group shows a

Figure 7: Summary of evidence graded using the GRADE approach

Summary of findings

Anteroposterior stabilization using a titanium cage compared to posterior stabilization alone for thoracolumbar fractures

Patient or population: Thoracolumbar fractures

Setting

Intervention: Anteroposterior stabilization using a titanium cage

Comparison: Posterior stabilization alone

Outcomes	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	№ of participants (studies)	Quality of the evidence (GRADE)	Comments
	Risk with posterior stabilization alone	Risk with Antero - posterior stabilization using a titanium cage				
Neurologic improvement on Frankel scale (neurologic) Assessed with: Frankel scale follow up: Mean 59 months	739/1.000	850/1.000 (680-1.000)	RR 1.15 (0.92-1.43)	45 (2 RCTs)	⊕⊕⊕⊕ High	
Blood loss assessed with (mL)	The mean blood loss was 603.5 mL	The mean blood loss in the intervention group was 515.97 mL Higher (297.54-734.41)	-	84 (2 RCTs)	⊕⊕⊕⊕ High	
Operation time assessed with (min)	The mean operation time was 105 min	The mean operation time in the intervention group was 141.61 min more (125.47-157.74)	-	84 (2 RCTs)	⊕⊕⊕⊕ High	
Hospital stay assessed with (days)	The mean hospital stay was 10 days	The mean hospital stay in the intervention group was 6.21 days more (3.4 1-9.02 more)	-	84 (2 RCTs)	⊕⊕⊕⊕ High	
VAS postoperative assessed with: Regular VAS and VAS - spine follow up: Mean 53 months	-	-	-	134 (2 RCT's and 1 cohort study)[a]	⊕○○○ Very low[b,c,d,e]	Rule of thumb considering SMD: 0.2 represents a small effect, 0.5 a moderate effect, and 0.8 a large effect. Which means that the anteroposterior approach has a moderate effect on lowering VAS score
VAS postoperative - RCT assessed with: Regular VAS follow up: Mean 59 months	-	-	-	84 (2 RCTs)	⊕⊕⊕○ Moderate[d]	Considering only the RCT's included; the anteroposterior approach has a fairly large effect on lowering the VAS score
Correction loss in degrees follow up: Mean 53 months	The mean correction loss in degrees was 6.6°	The mean correction loss in degrees in the intervention group was 2.5° lower (6.56 lower to 1.55 higher)	-	134 (2 RCT's and 1 cohort study)[a]	⊕○○○ Very low[b,e,f,g]	
Correction loss - RCT follow-up: Mean 59 months	The mean correction loss - RCT was 7°	The mean correction loss - RCT in the intervention group was 4.59° fewer (6.95-2.22)	-	84 (2 RCTs)	⊕⊕⊕⊕ High[h]	

Contd...

Figure 7: Contd...

Outcomes	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	№ of participants (studies)	Quality of the evidence (GRADE)	Comments
	Risk with posterior stabilization alone	Risk with Antero - posterior stabilization using a titanium cage				
Complications: Infections and deep venous thrombosis	70/1.000	144/1.000 (39-531)	RR 2.06 (0.56-7.61)	84 (2 RCTs)	⊕⊕○○ Low[i]	

*The risk in the intervention group (and its 95% CI) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI). CI - Confidence interval; RR - Risk ratio; SMD - Standardized mean difference; VAS - Visual analog scale; RCTs - Randomized controlled trials

GRADE working group grades of evidence

High quality: We are very confident that the true effect lies close to that of the estimate of the effect

Moderate quality: We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different

Low quality: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect

Very low quality: We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

[a]2 RCT's and 1 Cohort study, [b]Including one cohort study which scores serious risk of allocation bias because more severely injured patients were allocated to anteroposterior group, overall risk of bias in RCT's is low to unclear with both studies scoring high risk of selective reporting and Wang *et al*. did not blind participants, [c]Includes VAS and VAS-spine, [d]RCT's show inconsistent or opposite evidence, [e]All three studies include a wide variety of patients, but the cohort study shows a serious allocation bias allocating only most severe patients to anteroposterior group, [f]Cohort study by Weiner *et al*. shows opposite effect opposed to the RCT's, [g]Cohort study of Weiner *et al*. shows a relatively wide CI, [h]Korovessis *et al*. used Gardner angle to measure kyphosis while Wang *et al*. used Cobb-angle, however, method of measurement was consistent on both time points, so the difference in measurement between time points (correction loss) is comparable, [i]High risk of bias due to selective reporting for both studies, Wang *et al*. report far less complications compared to Korovessis *et al*. while they do a 5 years follow-up

trend toward less pain. Observational studies confirm this, reporting a large improvement of pain scores on long-term with the combined approach.[34,35,38]

Neurologic damage is reported to be the main cause of long-term persisting pain.[9] Neurologic improvement is reported after solely posterior fixation[39] and even after nonoperative management.[9] Our study shows that neurologic improvement is independent of using a cage so that neurologic injury by itself is not an indication for additional anterior stabilization. However, an anterior approach could be indicated when there is significant ventral bone impingement.

Additional risks of anterior surgery

We found low quality of evidence of a slightly lower risk of wound infection and deep venous thrombosis for the posterior group although this was not significant. Observational studies reported very few complications after anterior approach[38] and few posterior wound infections.[35] While Schnake *et al*.[40] reported anterior surgery-related complications of 37.5%, 26% was related to the thoracotomy itself, and most complications were not clinically significant.

We also found increased perioperative characteristics with additional anterior surgery. However, no complications needing reoperation were reported. We, therefore, think increased maintenance of kyphosis correction is more important in specific fractures at high risk of kyphosis. While it remains important to weight accompanying risks for every patient, minimally invasive but technically demanding thoracoscopic techniques can decrease blood transfusions, pain, and hospital stay.[11,12,41]

New techniques

Minimally invasive VBS also provides anterior stability, however, the few short-term results published are not yet impressive,[13,42] and applicability to severe traumatic fractures is unclear. If the stability provided is comparable to a titanium cage, it might be an alternative for anterior stabilization.

Functional outcomes

One study[31] reported no differences between groups on all SF-36 domains while Korovessis *et al*.[29] reported significant improvement on the domains physical and bodily pain in the posterior group. They attributed this to the increased morbidity of anterior surgery although it is not clear when the SF-36 was assessed. Weiner *et al*.[31] reported no difference between groups on functional outcomes of low back outcome score and Oswestry Disability Index.

Strengths and limitations

There is limited evidence available about the additional value of an anterior cage after posterior stabilization and studies that are available describe small patient groups. Therefore, we included articles in all available languages (including Chinese) and also included cohort studies comparing both groups. While cohort studies may introduce selection bias, stratified forest plots and grading of evidence are reported. Although we think the presented results are not influenced by different fracture locations, ideally results are specified according to fracture level (e.g., thoracolumbar vs. lumbar) which was not possible due to the few available studies. It is possible that studies did not report all results in full extent. Kyphosis was measured as Cobb angle and Gardner angle although these were comparable because they assessed relative kyphosis difference over time. Expandable and titanium cages were used, but literature shows no difference.[43]

CONCLUSIONS

Evidence suggests that patients with a highly comminuted or unstable fracture benefit from anteroposterior stabilization with a titanium cage due to the maintenance of kyphosis correction. Neurologic injury is not a primary indication for an additional anterior cage. There is a risk of cage subsidence, and increased perioperative risks have to be considered. Prospective studies focusing on specific patients that are indicated for an additional cage could provide stronger evidence.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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