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 indicated the necessity of additional anterior stabilization. In 1994, the load-sharing classification (LSC) was introduced to predict posterior implant failure and has been used to select patients requiring additional anterior column support.

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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.[8,13] 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
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. 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 I²-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 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 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 only assessed the mid-lumbar region (L2–L4), whereas other studies assessed the thoracolumbar region (T11–L2). The longest mean follow-up was 70 months. Wang and Liu also included very severe fractures while Korovessis et al. used an LSC of 6 as upper boundary for inclusion.
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.

**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 kyphosis, or >50% SCE >1 level fracture, concomitant surgical injuries, history of spinal surgery | AP 21 41 (13) 16:5 AP 23 41 (14) 15:8                                                                                        |          |     | T12-L2         |              | T12-L2      | 71 (9)               |
| Korovessis 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 20 39 (19) 16:4 P 20 44 (16) 15:5                                                                 |          |     | L2-L4          |              | L2-L4       | 46 (?)               |
| Weiner et al.  | 2013 | Cohort     | VAS-spine, Cobb-angle, SF36                                              | Magnerl  ≥A3 or looming neurological deficit through SCI or Kyphosis >15°-20° Pathologic fracture, complete SCI, ≤18 months follow up, age <16 and >65, lost to follow-up | AP 28 45 (?) 6:4 P 22                                                                 |          |     | Thoracolumbar  |              |             | 41 (?)               |

*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. Two studies reported complication rates for wound infections and deep venous thrombosis, neurologic improvement on Frankel scale, operation time, bloodloss, and hospital stay. Two studies 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 reported less types of complications compared to Korovessis et al. In addition, Korovessis et al. 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., 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 \( (I^2 = 88\%; \chi^2: P <0.01) \) 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 \( \chi^2 \) 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 \( (I^2 = 0\%, \chi^2: P = 0.99) \). 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
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 (\( I^2 = 0\% \); \( \chi^2 \); \( P = 0.95 \)). 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 (\( I^2 = 0\% \); \( \chi^2 \); \( P = 0.69 \)).

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 (\( I^2 = 71\% \); \( \chi^2 \); \( P = 0.07 \)).

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 (\( I^2 = 54\% \); \( \chi^2 \); \( P = 0.14 \)).

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 study³¹ however contradicted this and
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.\textsuperscript{[31]} Observational studies reported low rates of cage subsidence and good kyphosis correction and outcome.\textsuperscript{[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\textsuperscript{[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.\textsuperscript{[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\textsuperscript{[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.,\textsuperscript{[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.

![Figure 5: Forest plot of complications: Wound infections and deep venous thrombosis for combined anteroposterior approach with a titanium cage versus solely posterior fixation](image1)

![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](image2)
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.\textsuperscript{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,\textsuperscript{30,31} both reporting less pain for the anteroposterior group, measured pain after 70 and 41 months, respectively. Interestingly, Weiner et al.\textsuperscript{31} report less pain in the anteroposterior group while they report 85% cage subsidence. The anteroposterior group shows a

\begin{table}[h]
\centering
\begin{tabular}{|l|c|c|c|c|c|}
\hline
\textbf{Outcomes} & \textbf{Anticipated absolute effects* (95\% CI)} & \textbf{Relative effect (95\% CI)} & \textbf{\# of participants (studies)} & \textbf{Quality of the evidence (GRADE)} & \textbf{Comments} \\
\hline
\textbf{Neurologic improvement on Frankel scale (neurologic) Assessed with: Frankel scale follow up: Mean 59 months} & & & & & \textbf{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}\textbf{ Considering only the RCT's included; the anteroposterior approach has a fairly large effect on lowering the VAS score} \\
\textbf{Blood loss assessed with (mL) The mean blood loss was 603.5 mL} & 739/1.000 & 850/1.000 (680-1.000) & RR 1.15 (0.92-1.43) & 45 (2 RCTs) & \textbf{High} \\
\hline
\textbf{Operation time assessed with (min) The mean operation time was 105 min} & & & & & \textbf{High} \\
\hline
\textbf{Hospital stay assessed with (days) The mean hospital stay was 10 days} & & & & & \textbf{High} \\
\hline
\textbf{VAS postoperative assessed with: Regular VAS and VAS - spine follow up: Mean 53 months} & & & & & \textbf{Very low}\textsuperscript{a,b,c,d,e} \\
\hline
\textbf{VAS postoperative - RCT assessed with: Regular VAS follow up: Mean 59 months} & & & & & \textbf{Moderate}\textsuperscript{f} \\
\hline
\textbf{Correction loss in degrees follow up: Mean 53 months The mean correction loss in degrees was 6.6°} & & & & & \textbf{Very low}\textsuperscript{a,b,c,d,g} \\
\hline
\textbf{Correction loss - RCT follow-up: Mean 59 months The mean correction loss - RCT in the intervention group was 4.59° fewer (6.95-2.22)} & & & & & \textbf{High}\textsuperscript{h} \\
\hline
\end{tabular}
\caption{Summary of findings}
\end{table}
trend toward less pain. Observational studies confirm this, reporting a large improvement of pain scores on long-term with the combined approach.\cite{34,35,38}

Neurologic damage is reported to be the main cause of long-term persisting pain.\cite{9} Neurologic improvement is reported after solely posterior fixation\cite{39} and even after nonoperative management.\cite{38} 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\cite{38} and few posterior wound infections.\cite{35}

While Schnake et al.\cite{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.\cite{31,12,41}

**New techniques**

Minimally invasive VBS also provides anterior stability, however, the few short-term results published are not yet impressive,\cite{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\cite{31} reported no differences between groups on all SF-36 domains while Korovessis et al.\cite{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.\cite{33} 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.

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**Conflicts of interest**
There are no conflicts of interest.

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