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Systematic Reviews /Meta-analyses

Comparison of intraoperative and postoperative outcomes between open, wiltse, and percutaneous approach to traumatic thoracolumbar spine fractures without neurological injury: A systematic review and meta-analysis

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ABSTRACT

Background: Traumatic thoracolumbar fracture fixation without neurological injury can be performed using the traditional open, mini-open Wiltse, and percutaneous approaches. This systematic review and meta-analysis aims to compare perioperative outcomes between these approaches.

Methods: PubMed, Web of Science, Scopus, Embase, and the Cochrane Library were searched for all relevant observational comparative studies.

Results: 5 randomized trials and 22 comparative cohort studies were included. Compared to the traditional open approach (n=959), the Wiltse approach (n=410) was associated with significantly lower operative time, intraoperative estimated blood loss (EBL), and length of stay (LOS). There was no significant difference between the two in terms of postoperative visual analog scale (VAS) and Cobb angle. Compared to the percutaneous approach (n=980), the Wiltse approach was associated with shorter operative and fluoroscopy time, as well as significantly improved Cobb and vertebral body angles. The percutaneous approach was associated with improved vertebral body height. There was no significant difference between the two for blood loss, postoperative VAS, or LOS. Compared to the traditional open approach, the percutaneous approach was associated with shorter operative time, lower EBL, shorter LOS and better postoperative VAS and Oswestry Disability Index. There was no difference between the two in postoperative Cobb angle, vertebral angle, or vertebral body height. Overall study heterogeneity was high.

Conclusions: Utilization of minimally invasive surgical approaches holds great promise for lowering patient morbidity and optimizing care. A prospective trial is needed to assess outcomes and guide surgical decision making.

FDA device/drug status: Not applicable.

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Background

Surgical management of traumatic spinal fractures commonly includes fixation of the fractured vertebra and stabilization of the spine [1]. Three primary invasive surgical approaches exist for the treatment of traumatic thoracolumbar spine fractures (TTSFs): the traditional open approach, the mini-open Wiltse approach, and the percutaneous approach. The traditional approach is the most invasive, and involves surgical fixation of the fractured spine, typically using pedicle screw fixation via posterior access [2]. The less invasive mini-open Wiltse approach, proposed in 1968, is a paraspinal approach, in which the surgeon accesses the fractured spine in between the multifidus and longissimus muscles [3]. The approach is thought to decrease intraoperative bleeding and surgical trauma by maintaining posterior ligament complex (PLC) integrity [4]. The percutaneous approach was proposed less than a decade later, eliminating the need for major surgical incisions all together [5]. Both the mini-open Wiltse and the percutaneous approaches have proven safe and effective in treating traumatic spinal trauma [6].

To the best of our knowledge, no study in the literature has directly compared these 3 approaches to TTSF surgical management. The aim of this study is to perform a systematic review and meta-analysis on this subject to compare the conventional open, the Wiltse, and the percutaneous approach to traumatic TTSF repair with specific attention to intraoperative and postoperative outcomes.

Methods

Literature search

A systematic literature search was performed on April 1, 2023, in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to identify all comparative analyses on the management of TTSF using these 3 approaches [7]. We queried PubMed MEDLINE, Web of Science, Embase, Scopus, and the Cochrane Library for the terms “Wiltse,” “open,” “percutaneous,” “spine,” and “trauma” with appropriate Boolean operators and retrieved all articles from inception.

Inclusion and exclusion criteria

Controlled trials and comparative studies were included if they discussed TTSF with a minimum of 1 year follow-up. Studies were excluded from our analysis if the procedure being studied was a posterior lumbar interbody fusion (PLIF), transforaminal lumbar interbody fusion (TLIF), corpectomy, or spondylectomy. Additionally, studies were excluded if they were not written in English, did not contain a comparison between at least 2 groups, or if they included patients with neurologic deficits. The references of all included studies were examined to identify any additional studies that were not captured by our initial search strategy. Duplicate studies were removed, and those that met our inclusion criteria were read thoroughly and assessed for eligibility by our team (Fig. 1).

Data collection and outcomes

Variables extracted from each study included sample size, age, sex, operative approaches, and operative time, as well as outcomes including hospital length of stay (days), total blood loss (millilitres), incision length (cm), intraoperative fluoroscopy time (seconds), radiographic outcomes, pain measures, and complications.

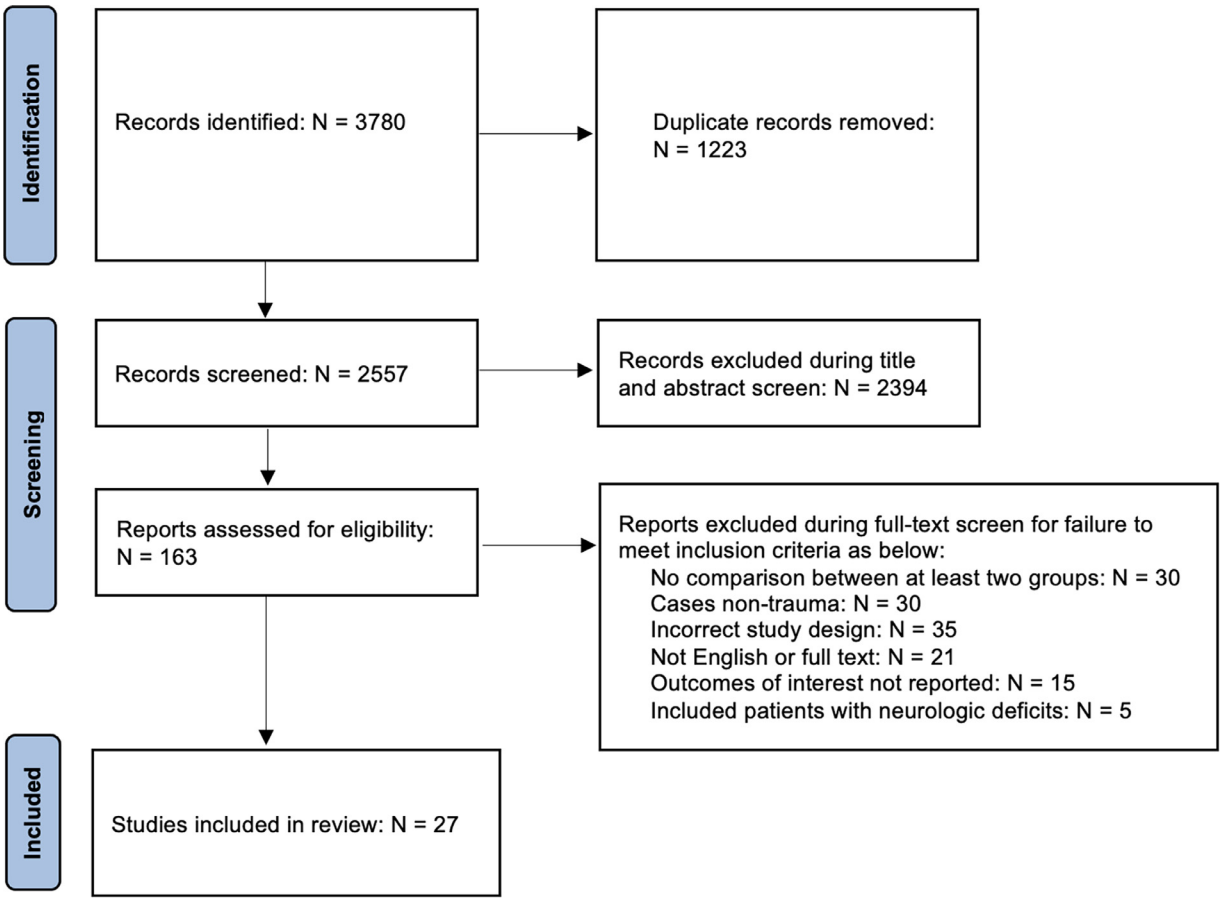


Fig. 1. PRISMA Flowchart of Inclusion and Exclusion Criteria for this Study.

Data anlaysis

Data analysis was performed using the Review Manager 5.4 software to make 3 main comparisons: Wiltse versus Open, Wiltse versus Percutaneous and Percutaneous versus Open. Results were reported in forest plots with 95% Confidence Intervals (CIs). Dichotomous outcomes were reported qualitatively while Standardized Mean Differences (SMDs) was calculated between groups for quantitative outcomes. Significance was established when p<.05. A random effects model was used for studies with heterogeneity over 50%. Studies with a lower heterogeneity were analysed using a fixed effects model.

Sensitivity analysis

To investigate the impact of individual studies on the significance of a given forest plot for a given outcome, a sensitivity screen was performed via a 'leave-one-out' analysis. For each forest plot, 1 study was excluded from the plot at any one time to see whether individual studies or those with a high risk of bias independently skewed the outcome analysis. Funnel plots were also used to assess for any study outliers.

Methodological quality and risk of bias analysis

The quality of included studies was assessed by 2 authors independently. Any discrepancies or disputes were resolved via discussion with a third author. The Cochrane's tool was used to assess risk of bias in randomised studies [8]. This included assessment of selection bias, attrition bias, reporting bias and performance bias. Classifications of risk include low, unclear and high. For nonrandomised studies, the Newcastle-Ottawa Scale was used for bias analysis and includes assessment of selection, comparability and outcome using a star system to evaluate risk [9].

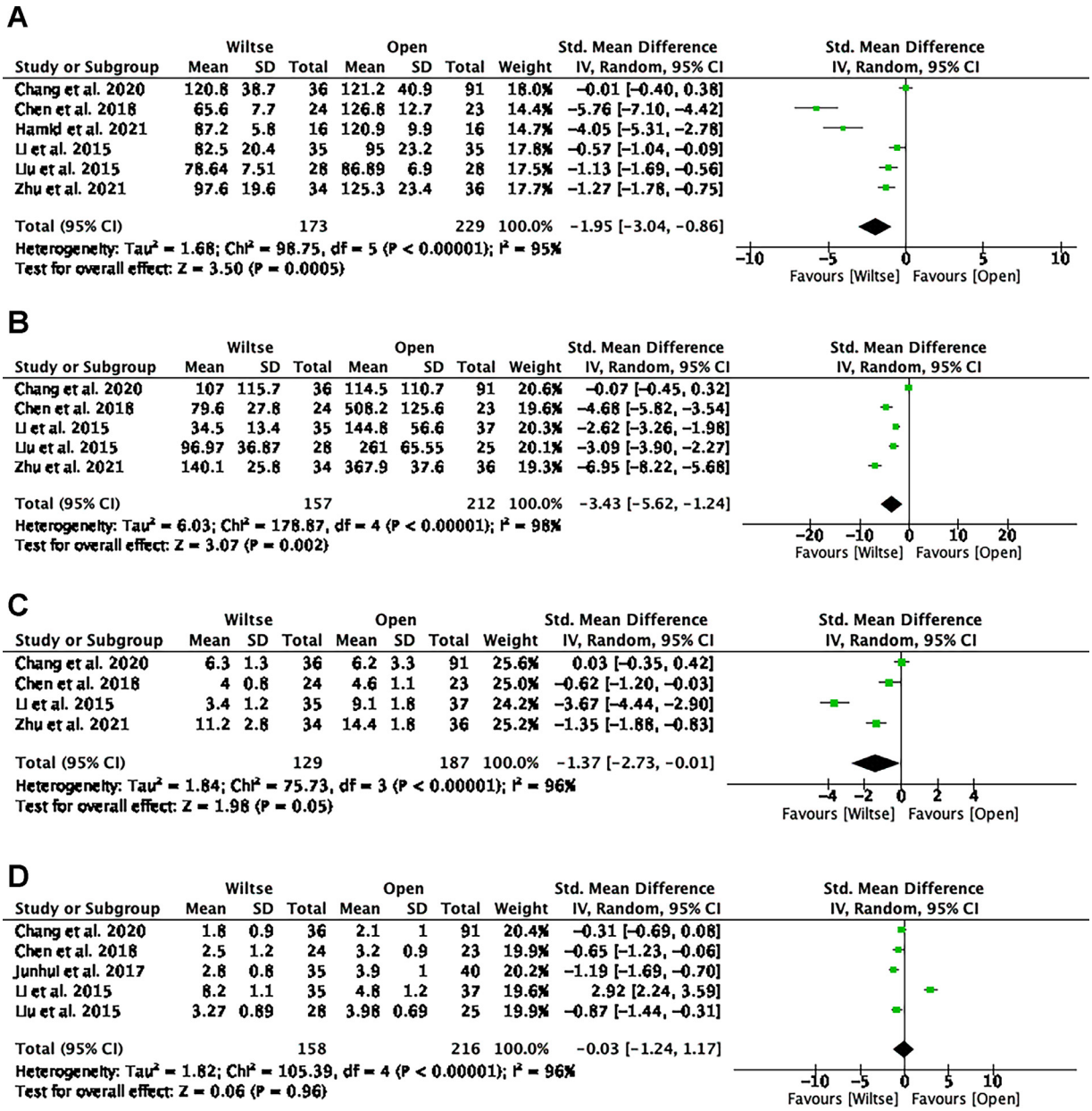


Fig. 2. Statistical Analysis of Studies Comparing the Wiltse and the Open Approach to TTSF. 2A: Operation duration, 2B: Total Blood loss, 2C: Length of Stay, 2D: Postoperative VAS score, 2E: Cobb angle.

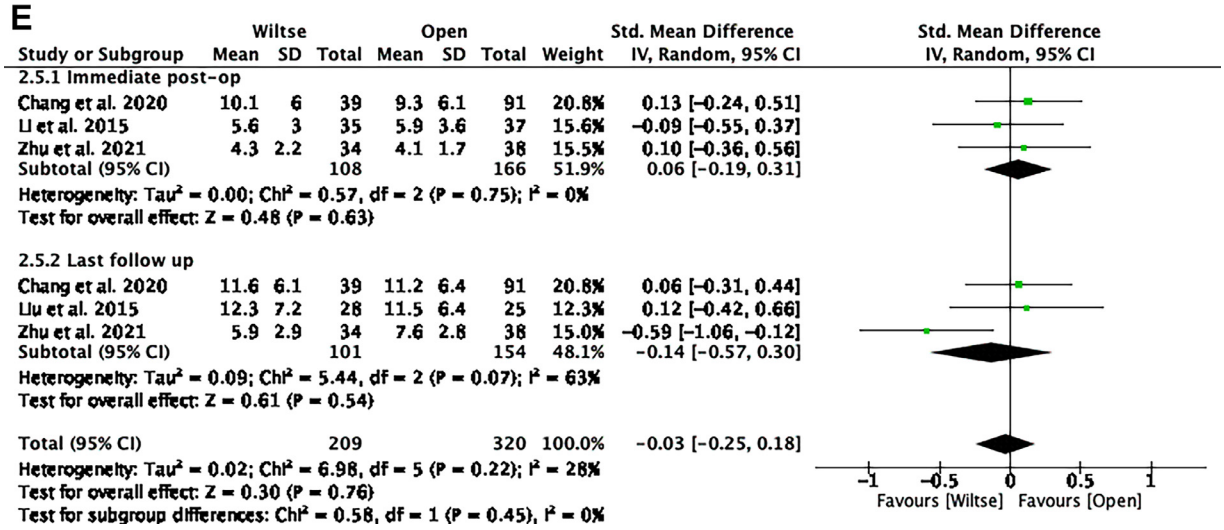


Fig. 2. Continued

Results

PRISMA flowchart

27 studies were included in the present review [1,2,6,10–33] (Fig. 1). Seven publications compared the Wiltse and the open approach (Fig. 2), 7 compared the Wiltse and the percutaneous approach (Fig. 3), 15 compared the percutaneous and the open approach (Fig. 4), and 1 compared all 3 approaches. Outcome measures used to compare surgical approaches included operation duration and hospital stay, total blood loss, postoperative VAS and ODI scores, fluoroscopy time, incision length, vertebral body height and angle, and Cobb angle. No outliar studies were identified following sensitivity analysis and none were excluded.

Length of operation

Among the 7 studies that compared the Wiltse approach to the open approach, Six reported operation duration (Fig. 2A). The mean operation duration for the Wiltse approach group was significantly shorter than that of the open approach group (SMD=−1.95; 95% CI, −3.04 to 0.86; I^2=95%; p=.005).

All 7 studies that compared the Wiltse approach to the percutaneous approach, reported operation duration (Fig. 3A). Again, the mean operation duration for the Wiltse approach group was significantly lower than that of the percutaneous approach group (SMD=−0.81; 95% CI, −1.58 to −0.03; I^2=94%; p=.04).

Finally, all 15 studies that compared the percutaneous versus the open approach reported operation duration (Fig. 4A). The group undergoing percutaneous fixation had significantly lower mean operation duration than the open approach group (SMD=−0.82; 95% CI, −1.19 to −0.44; I^2=91%; p<.0001).

Total blood loss

Between the 7 studies that compared the Wiltse versus the open approach, 5 reported total blood loss (Fig. 2B). The mean estimated blood loss for the Wiltse approach group was significantly lower than that of the open approach group (SMD=−3.43; 95% CI, −5.62 to −1.24; I^2=98%; p<.00001).

Among the 7 studies that compared the Wiltse versus the percutaneous approach, 6 reported total blood loss (Fig. 3B). Notably, the mean estimated blood loss for the Wiltse approach group was significantly higher than the percutaneous approach group (SMD=0.68; 95% CI, 0.09–1.27; I^2=88%; p<.00001).

Of the 15 studies that compared the percutaneous versus the open approach, 7 reported total blood loss (Fig. 4B). The group undergoing percutaneous fixation had significantly lower mean estimated blood loss than the open approach group (SMD=−3.60; 95% CI, −4.99 to −2.22; I^2=96%; p<.00001).

Fluoroscopy time

Of all the included studies, only 3 reported fluoroscopy time. All studies which reported fluoroscopy time length compared the Wiltse approach to the percutaneous approach (Fig. 3C). Analyzing the data using a random effects model, the Wiltse approach group was found to a significantly lower mean fluoroscopy time was found when compared to the percutaneous approach groups (SMD=−4.08; 95% CI, −6.08 to −2.09; I^2=95%; p<.0001).

Hospital length of stay

Of the 7 studies that compared the Wiltse versus the open approach, 4 reported length of hospital stay (Fig. 2C). The Wiltse approach group had a significantly lower mean hospital stay than the open approach group (SMD=−1.37; 95% CI, −2.73 to −0.01; I^2=96%; p=.05).

Between the 7 studies that compared the Wiltse versus the percutaneous approach, 5 reported length of hospital stay (Fig. 3E). The mean length of stay for the Wiltse approach group was not significantly different from the percutaneous approach group (SMD=0.27; 95% CI, −0.09 to 0.62; I^2=67%; p=.14).

Among the 15 studies that compared the percutaneous versus the open approach, 13 reported length of hospital stay (Fig. 4C). The mean hospital length of stay for the Percutaneous fixation group was significantly lower than then that of the open approach group (SMD=−1.15; 95% CI, −1.69 to −0.61; I^2=94%; p<.00001).

Postoperative visual analog scale (VAS)

The differences in postsurgical visual analog scale scores between the Wiltse and open approach groups is displayed in Fig. 2D. Random effect analysis of the 5 studies that reported VAS found that there was no difference in the mean VAS between the 2 groups (SMD=−0.03; 95% CI, −1.24 to −1.17; I^2=96%; p=.96).

In the 7 studies that compared the Wiltse versus the percutaneous approach, 5 reported postoperative VAS for pain (Fig. 3D). The mean postoperative VAS score for Wiltse approach group was not significantly

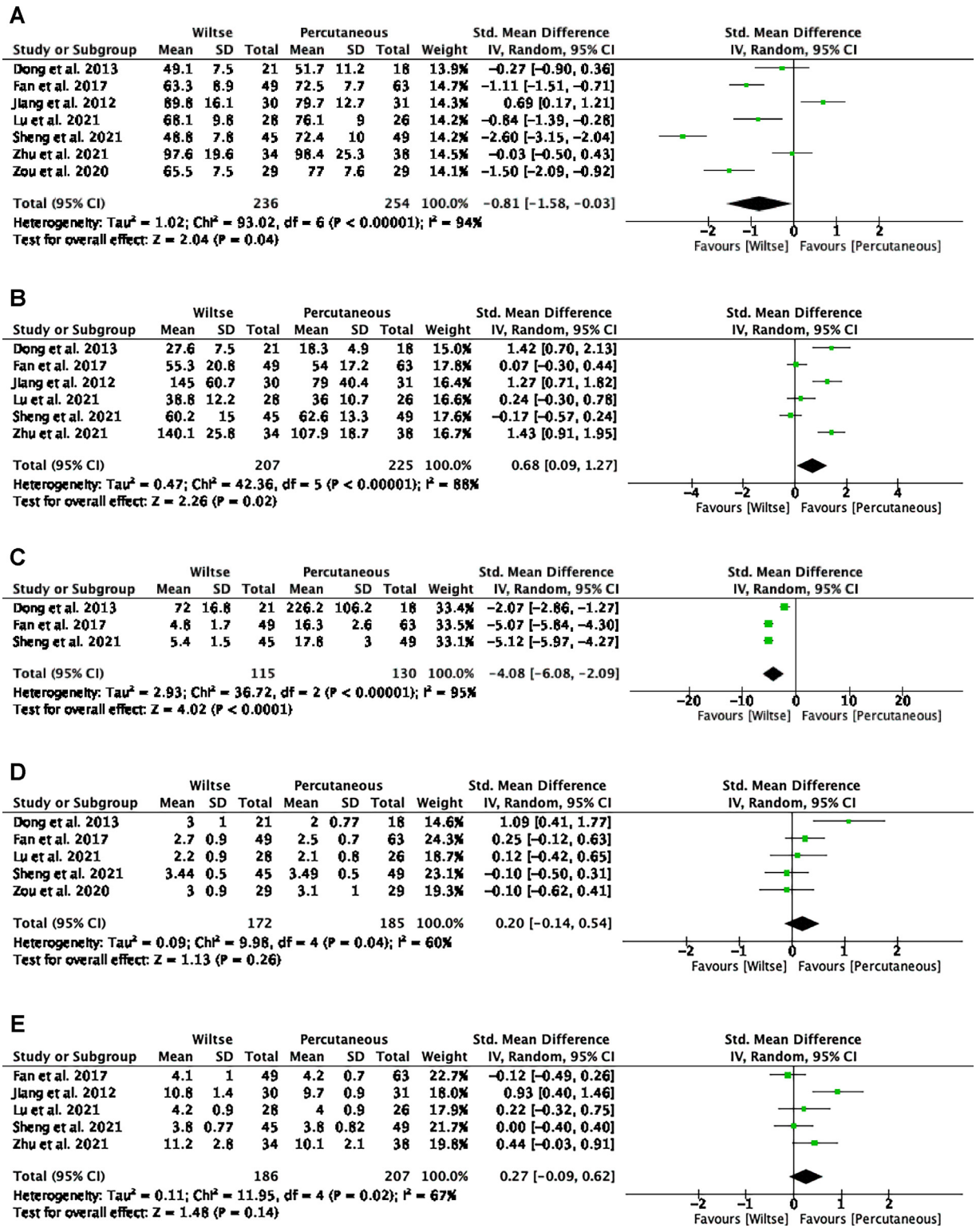


Fig. 3. Statistical Analysis of Studies Comparing the Wiltse and the Percutaneous Approach to TTSF. 3A: Operation duration, 3B: Total Blood loss, 3C: Fluoroscopy time, 3D: Postoperative VAS score, 3E: Length of Stay, 3F: Cobb angle; 3G: Vertebral body angle; 3H: Vertebral body height.

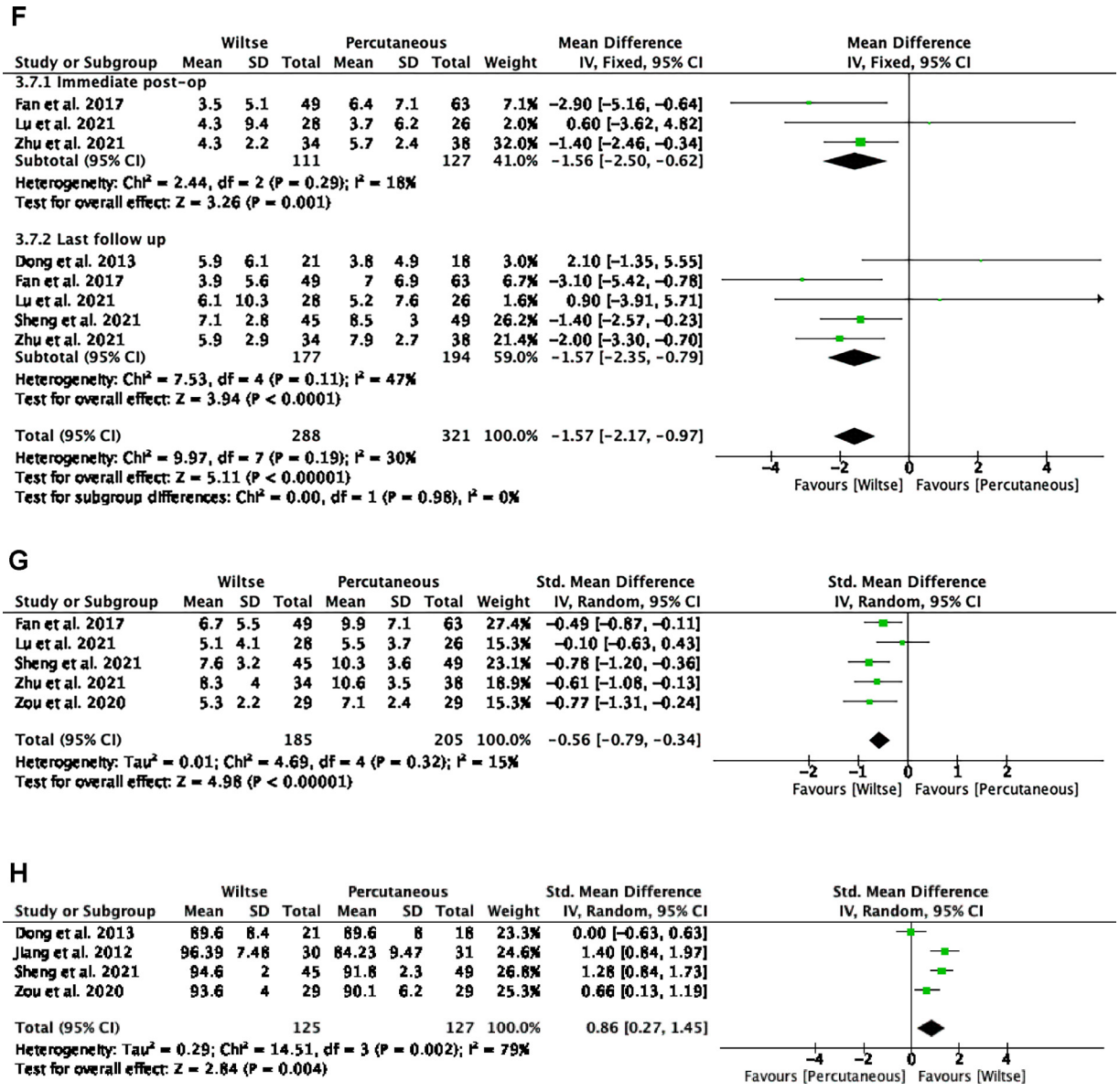


Fig. 3. Continued

different from the percutaneous approach group (SMD=0.20; 95% CI, −0.14 to 0.54; I^2=60%; p=.26)

Of the 15 studies that compared the percutaneous versus the open approach, 7 reported postoperative VAS for pain (Fig. 4D). The Percutaneous fixation group experienced significantly lower mean VAS scores than the open group (SMD=−0.81; 95% CI, −1.13 to 0.49; I^2=67%; p<.00001).

Postoperative oswestry disability index (ODI) scores

Five studies examined the ODI scores of patients who underwent surgical repair of TTSF, with 1 study comparing all 3 surgical approaches, 2 studies comparing percutaneous and open approaches, and 2 studies comparing Wiltse and percutaneous approaches. The results of our random effects model indicate that the percutaneous approach was significantly better than the open approach for postoperative ODI scores (SMD=−0.88; 95% CI, −1.57 to 0.19; I^2=90%; p<.00001) (Fig. 4E). In contrast, the Wiltse approach did not show a significant difference in ODI scores compared to either the percutaneous (p=.26) or open (p=.31) approach, based on data from 2 studies each.

Cobb angle

Nineteen studies compared the effect of different surgical approaches on the sagittal Cobb angle, measured as the angle between the superior endplate of the upper and the inferior endplate of the lower vertebrae. Our random effects model found that the Wiltse Cohort displayed no significant difference in Cobb angle when compared to the open cohort at immediate postoperative follow up (I^2=0%, p=.63) or last known follow up (I^2=63%, p=.54) (Fig. 2E).

When comparing the Wiltse and percutaneous approaches however, the Wiltse cohort had significantly improved Cobb angles at both immediate postoperative follow up and last known follow up (Fig. 3F). When comparing the percutaneous approach with the open approach, no significant difference in Cobb angle was found (p>.05) (Fig. 4F).

Vertebral body height and angle

6 studies examined the effect of different surgical approaches on vertebral body height percentage, and 7 studies examined ver-

tebral body angle. Of the 7 studies that compared the Wiltse versus the percutaneous approach, 5 reported vertebral body angles and 4 presented vertebral body height. The Wiltse approach group had a significantly lower mean vertebral angle (SMD=−0.55; 95% CI, −0.78 to −0.32; I^2=22%; p<.00001; Fig. 3G) and a higher vertebral body height (SMD=0.89; 95% CI, 0.35 to 1.43; I^2=75%; p<.001; Fig. 3H).

Of 15 studies that compared the percutaneous versus the open approach, 7 reported vertebral body angles and 6 presented vertebral body height. There was no significant difference between the percutaneous and open approach group when comparing mean vertebral angle (SMD=−0.22; 95% CI, −0.54 to 0.11; I^2=65%; p=.19; Fig. 4G) or vertebral body height (SMD=−0.11%; 95% CI, −0.41 to 0.19; I^2=61%; p=.49; Fig. 4H).

Quality assessment

Risk of bias aassessment for randomised studies can be seen in Table 1. All studies had a low risk of bias across most domains. Non-randomised study assessment using the NOS can be seen in Table 2.

Discussion

Thoracolumbar fractures are common traumatic spinal fractures, with surgical intervention serving as the primary treatment modality [4-6]. Traditional open approaches to the thoracolumbar spine provide surgeons with a comprehensive view, facilitating the identification of anatomical landmarks for pedicle screw placement, and are essential when spinal cord decompression is required [34]. However, these larger incisions are associated with increased risk of adverse postoperative

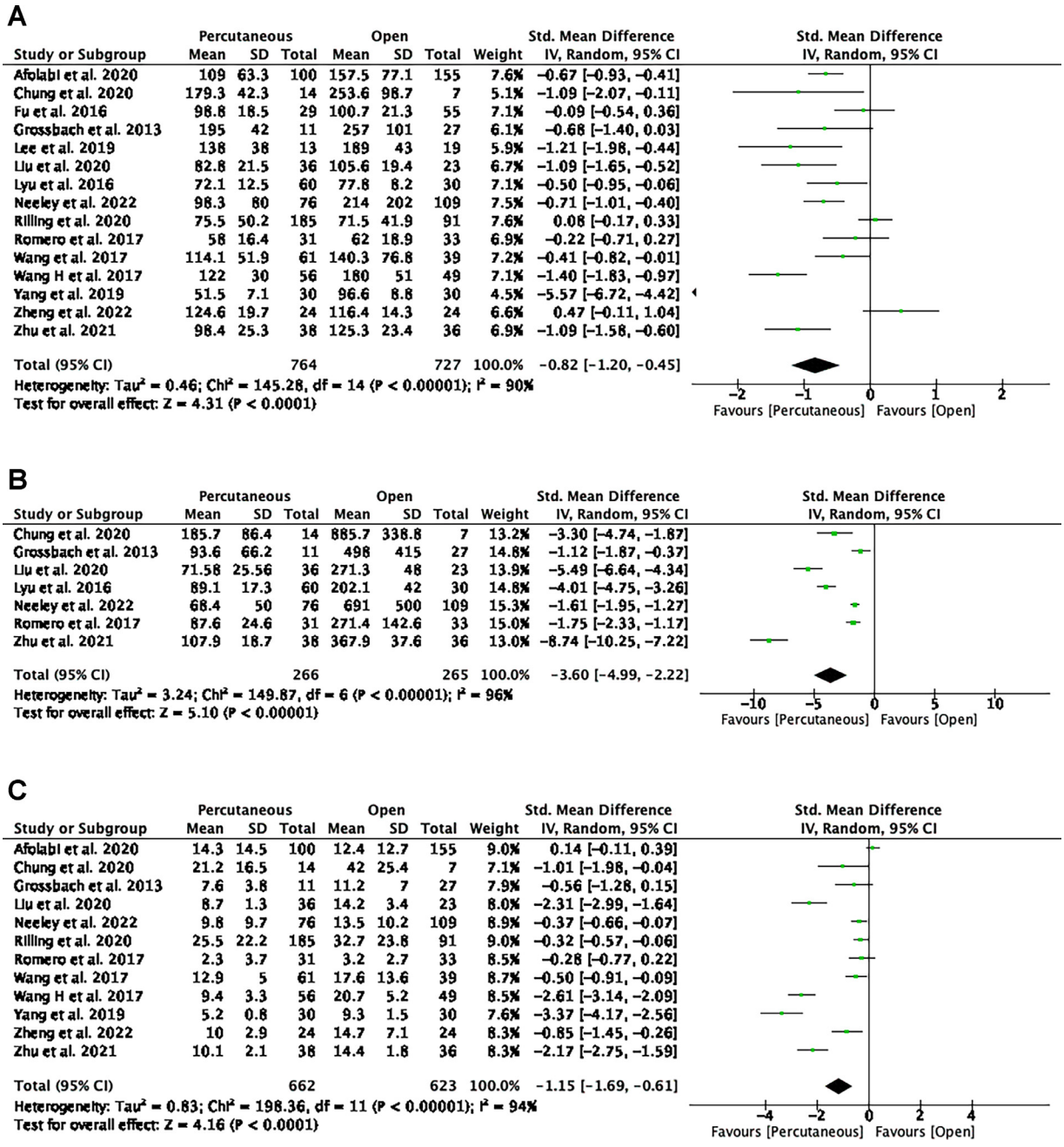
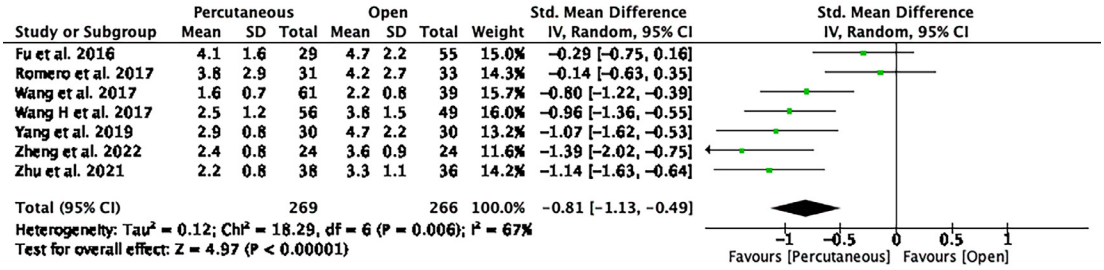


Fig. 4. Statistical Analysis of Studies Comparing the Percutaneous and the Open Approach to TTSF. 4A: Operation duration, 4B: Total Blood loss, 4C: Length of Stay, 4D: Postoperative VAS score, 4E: Postoperative ODI score, 4F: Cobb angle; 4G: Vertebral body angle; 4H: Vertebral body height.

D



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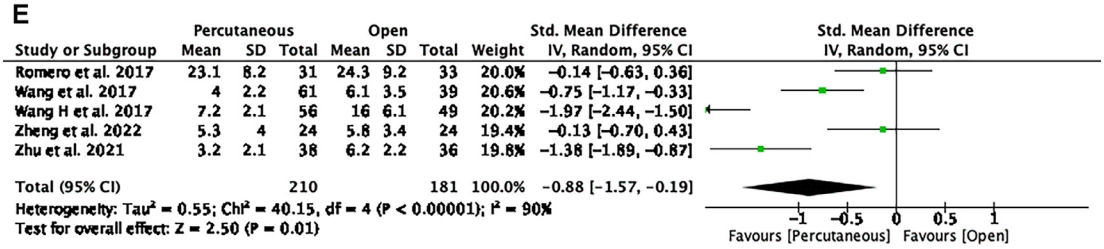

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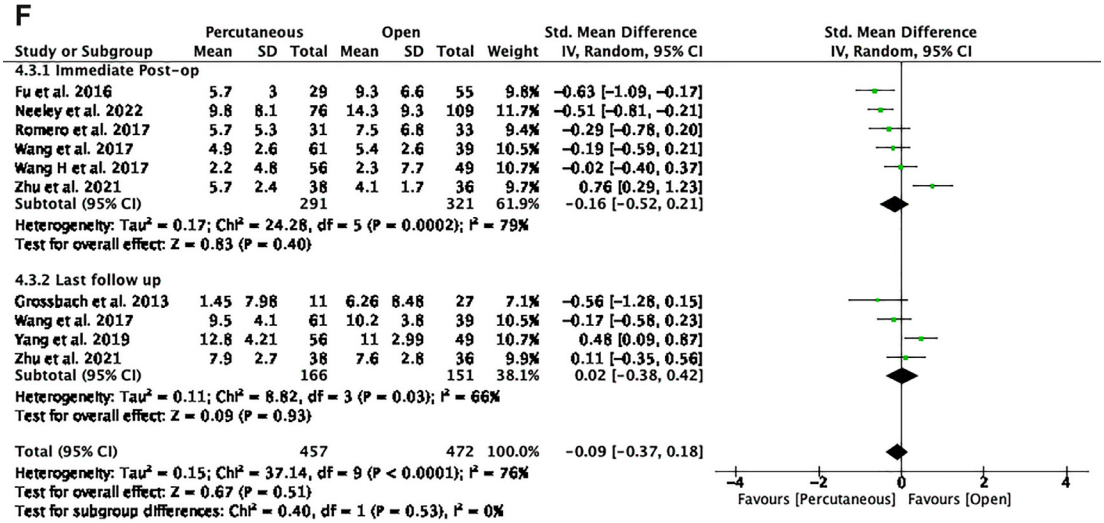

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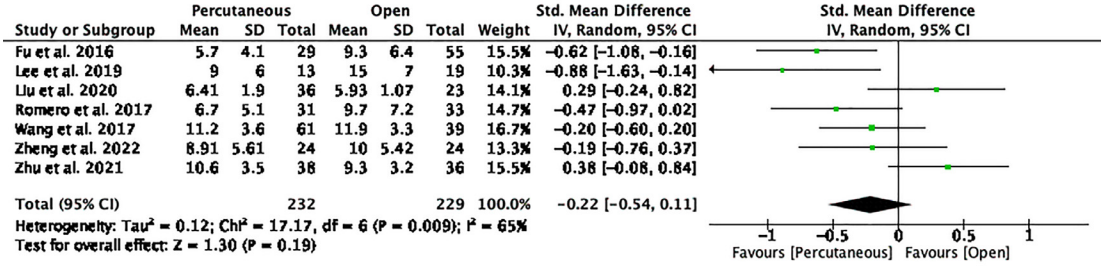

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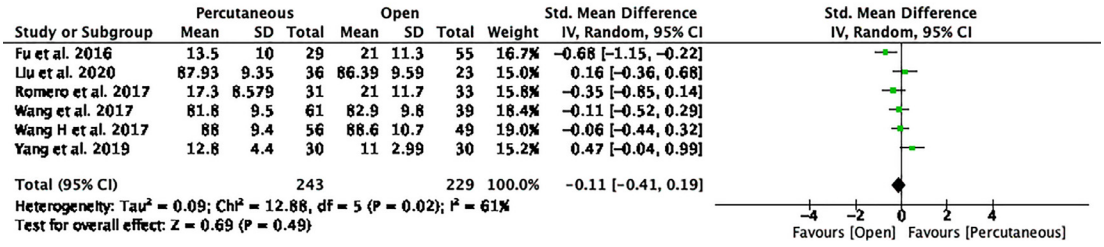

Fig. 4. Continued

Table 1
Assessment of risk of bias for randomised studies using the Cochrane collaboration's tool.

First author	Bias	Authors' judgement	Support for judgement
Lyu et al. [10]	Random sequence generation (selection bias)	Low	Patients randomized
	Allocation concealment (selection bias)	Low	Patients randomized
	Blinding of participants and personnel (performance bias)	Unclear risk	No information provided
	Blinding of outcome assessment (detection bias)	Unclear risk	No information provided
	Incomplete outcome data (attrition bias)	Low	All patients seen at follow up.
	Selective reporting (reporting bias)	Low	Clear reporting of baseline demographics and outcome measures.
	Other bias	NA	Study protocol was clear.
Jiang et al. [11]	Random sequence generation (selection bias)	Low	Patients randomized
	Allocation concealment (selection bias)	Low	Patients randomized
	Blinding of participants and personnel (performance bias)	Unclear risk	No information provided
	Blinding of outcome assessment (detection bias)	Unclear risk	No information provided
	Incomplete outcome data (attrition bias)	Low	All patients seen at follow up.
	Selective reporting (reporting bias)	Low	Clear reporting of baseline demographics and outcome measures.
	Other bias	NA	Study protocol was clear.
Zou et al. [12]	Random sequence generation (selection bias)	Low	Patients randomized
	Allocation concealment (selection bias)	Low	Patients randomized
	Blinding of participants and personnel (performance bias)	Unclear risk	No information provided
	Blinding of outcome assessment (detection bias)	Unclear risk	No information provided
	Incomplete outcome data (attrition bias)	Low	All patients seen at follow up.
	Selective reporting (reporting bias)	Low	Clear reporting of baseline demographics and outcome measures.
	Other bias	NA	Study protocol was clear.
Chen et al. [2]	Random sequence generation (selection bias)	Low	Patients randomized
	Allocation concealment (selection bias)	Low	Patients randomized
	Blinding of participants and personnel (performance bias)	Unclear risk	No information provided
	Blinding of outcome assessment (detection bias)	Unclear risk	No information provided
	Incomplete outcome data (attrition bias)	Low	All patients seen at follow up.
	Selective reporting (reporting bias)	Low	Clear reporting of baseline demographics and outcome measures.
	Other bias	NA	Study protocol was clear.
Liu et al. [13]	Random sequence generation (selection bias)	Low	Patients randomized
	Allocation concealment (selection bias)	Low	Patients randomized
	Blinding of participants and personnel (performance bias)	Unclear risk	No information provided
	Blinding of outcome assessment (detection bias)	Unclear risk	No information provided
	Incomplete outcome data (attrition bias)	Low	All patients seen at follow up.
	Selective reporting (reporting bias)	Low	Clear reporting of baseline demographics and outcome measures.
	Other bias	NA	Study protocol was clear.

Table 2
Newcastle-Ottawa scale to assess the quality of nonrandomised studies.

Study	Selection	Comparability	Outcome
Chang et al. [19]	****	**	***
Dong et al. [20]	****	**	**
Wang et al. [16]	****	**	***
Junhui et al. [22]	****	**	***
Li et al. [25]	****	**	***
Hamid et al. 2015	****	**	***
Lee et al. [31]	****	**	***
Lu et al. [18]	****	**	***
Wu et al. [6]	****	**	**
Yang et al. [21]	****	**	***
Zheng et al. 2022	****	**	***
Zhu et al. [27]	****	**	***
Chung et al. [29]	****	**	***
Liu et al. 2020	***	**	**
Rillig et al. [15]	****	**	***
Wang H et al. [17]	****	**	***
Afolabi et al. [1]	****	**	***
Fan et al. [24]	****	**	***
Fu et al. [28]	****	**	**
Grossbach et al. [30]	****	**	**
Romero et al. [32]	****	**	**
Neeley et al. [14]	****	**	***

outcomes such as surgical site infections, postoperative disabilities, and intraoperative blood loss [35,36]. This study aimed to conduct a quantitative review of the current literature on the surgical management of thoracolumbar fractures in patients without neurological deficits, assessing the impact of these 3 operative techniques on postoperative patient outcomes.

A 2015 study by Li et al., which compared 72 cases at a single institution (37 open and 35 Wiltse), reported decreased operative time, blood loss, postoperative drainage, postoperative hospitalization time, and improvement in postoperative VAS with the Wiltse approach [25]. Our study corroborates these findings, with the Wiltse approach outperforming the open approach in terms of operative duration, blood loss, hospital stay, and Cobb angle. However, no significant differences were observed in postoperative VAS and ODI scores. It is important to note that the study by Li et al. was the only one in our cohort to report an improvement in VAS score for the Wiltse approach.

A study by Jiang et al. found the Wiltse approach to be associated with shorter OR and fluoroscopy times, lower total hospital costs, better postoperative vertebral body angles, improved percentage of vertebral body height, and reduced perioperative blood loss compared to percutaneous fixation [4]. Our study supports these findings, also reporting significant improvements in operation time, fluoroscopy time, postoperative vertebral body angle, vertebral body height and perioperative blood loss for the Wiltse approach cohort. Additionally, we present data indicating that the Wiltse approach promotes better sagittal Cobb angles during immediate postoperative period.

Retrospective analyses conducted by Vanek et al. and Lee et al. compared the percutaneous approach to open techniques [6,26]. Both studies identified significant differences in VAS scores in the immediate postoperative period, which diminished during subsequent outpatient appointments. Moreover, in alignment with our study, these prior reports highlighted a considerable reduction in OR time for patients treated with the percutaneous approach [31,37]. However, our study found no difference in postoperative biomechanical outcomes, specifically Cobb angle, vertebral body angle, and vertebral body height, for patients receiving surgical intervention using the percutaneous approach.

Notably, Cobb angle, vertebral body angle, and vertebral body height, varied amongst the 3 techniques. While the percutaneous approach significantly impacted Cobb angle compared to the open technique, no significant differences were found in our comprehensive

comparison of the Wiltse and open approaches regarding Cobb angle. This contradicts earlier studies suggesting that percutaneous screws offer less stability than axial screws during open surgery [37]. Our study also identified significant improvements in vertebral body angle and height percentage when comparing the Wiltse and percutaneous approaches, but no difference in these metrics when comparing percutaneous and open approaches. Several prior studies have reported similar findings, suggesting that variations in postoperative posterior compression stem from the incision points and separation of back muscles during spine access [28,29,36].

The role and indications of minimally invasive techniques (MIT) in the management of thoracic spinal trauma has evolved significantly over the past decade [38]. Despite the positive results, MIT are not without limitations. The restricted field of view with MIT means that open surgery is sometimes preferrable in complex cases where more extensive work is needed. Indications for MIT mainly depend on the pattern of bone and ligament injury, presence of neurological deficits, surgeon's experience, and patient demographics [39]. However, this is a topic of significant debate and continues to evolve as experience with MIT grows [38,39]. The limited tissue exposure and inability to visualize key anatomical landmarks with MIT, also mean that there a steep learning curve [40]. In theory, surgical inexperience can result in screw malposition, greater operation durations and radiation exposure [37–40]. One study looking at pedicle screw position found that around 10% of screws were out of place when minimally invasive techniques were used, with 75% of them occurring in lower lumbar levels where there is poor visualization [41]. A systematic review by Sclafani et al. demonstrated that the complication rate with MIT was significantly reduced after a surgeon had carried out 30 consecutive cases [42]. Previous literature suggests that the complexity of minimally invasive techniques leads to differences in operation length and fluoroscopy time, primarily influenced by the lead surgeon's experience [43].

Our pooled analyses of patients treated with the percutaneous and Wiltse approach found that both minimally invasive techniques had significantly reduced operative time and perioperative blood loss compared to open techniques. This observation is supported by earlier literature, which found that percutaneous fixation and Wiltse techniques facilitate less invasive surgical pathways with smaller incisions. Collectively, our findings suggest that both minimally invasive techniques are associated with improved outcomes, but neither is strictly superior to the other when considering immediate peri- and postoperative outcomes.

Limitations

Literature compiled for the present study used small sample sizes, many of which came from retrospective cohort studies. Additionally, the included studies displayed significant heterogeneity in the effect sizes for reported outcome measures and variability in follow-up durations. Collectively, these limitations hinder the ability to draw definitive conclusions. Regarding baseline heterogeneity, we did attempt to limit degree of study bias by both performing a sensitivity analysis to identify any outliers and excluding any studies that reported significant baseline differences between groups; no outliar studies were identified or excluded.

Conclusion

In conclusion, our meta-analysis suggests that all 3 surgical approaches are viable options for TTSF repair, and the choice of approach should be made based on the individual needs of the patient. The Wiltse approach may be preferred for cases where shorter operative times, less intraoperative bleeding, and better postoperative vertebral body angle are desired. The percutaneous approach may be preferred for cases where shorter operative times and a lower risk of perioperative complications are desired.

Declaration of conflicting interests

The Authors declare that there is no conflict of interest.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.xnsj.2024.100547.

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