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SYSTEMATIC REVIEW **Open Access**

Posterior Fixation and Fusion (PFF) versus Combined Anterior and Posterior Fixation and Fusion (CAPFF) for type B and C thoracolumbar spine injuries: a systematic review and meta-analysis

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Abstract

Background A literature review and meta-analysis were conducted on studies comparing posterior fixation and fusion (PFF) and combined anterior and posterior fixation and fusion (CAPFF) for type B and C thoracolumbar injuries to determine the superior technique.

Methods A search of PubMed, Ovid Medline, Scopus, and the Cochrane Central Register was conducted from inception to September 2023. Randomized controlled trials and observational studies comparing PFF and CAPFF for B and C thoracolumbar injuries in adults were included. Excluded were reviews, non-English studies, studies involving children, pregnant women, other spinal pathologies, or different surgical treatments. Out of 5,773 articles, 8 were included for data extraction, and the recorded metrics included blood loss, operative time, cost, length of stay, follow-up, visual analogue scale (VAS) score, kyphosis angle, and patient age.

Results Across the included studies, 343 patients (228 = posterior approach, 115 = combined anterior posterior approach) were included, with follow-up ranging from 27–117.7 months. The surgical approach was randomly chosen in 2 of the 8 studies. Compared with the CAPFF approach, the PFF approach resulted in significantly less blood loss (Cohen's d = -1.70, $p = 0.00$) and cost (Cohen's d = -6.60, $p = 0.01$). PFF and CAPFF had similar postoperative lengths of stay; VAS-pain scores; pre, post, and final kyphosis angles; and patient age.

Conclusions This study identifies some key differences between PFF and CAPFF for the treatment of B and C thoracolumbar injuries, including lower cost and blood loss for PFF, and no difference in pain as measured by the visual analogue scale (VAS), kyphosis angle, patient age, or postoperative length of stay. However, a lack of consistent metrics across studies underscores the need for additional research in this area. The selected data indicate that there may be benefits of PFF for patients compared with CAPFF, yet additional research is necessary to more definitively suggest a superior approach.

Keywords Thoracolumbar fracture, Spine fixation and fusion, Thoracolumbar trauma

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Introduction

Thoracolumbar injuries often arise from high-energy trauma, such as motor vehicle accidents, falls, or violence, and may present with a variety of symptoms [1]. There is regional variation in the cause of these injuries, but given the significant associated morbidity and mortality, identifying and effectively treating these patients is important [2]. Thoracolumbar spine injuries are classified into three categories according to the AO classification system—types A, B and C—with each type containing groups [3, 4]. Type A fractures are compression injuries, whereas type B fractures are flexion–distraction injuries, in which either the anterior or posterior tension band is injured, and type C injuries involve displacement of the vertebral body but may involve distraction of both the anterior and posterior components [4].

Additionally, Type B thoracolumbar injuries may involve the vertebrae, and in addition to Type C injuries, these are inherently unstable injuries, which may lead to deformity, neurological impairment, pain and disability [4]. There is a lack of consensus on the optimal surgical treatment for these injuries, given that there are different options in terms of approach, technique, implant type, and fusion status. Two main approaches are used to treat these fractures: posterior fixation and fusion (PFF) and combined anterior and posterior fixation and fusion (CAPFF). The posterior approach enables fracture reduction and indirect decompression of the spinal canal [5]. The combined approach also benefits from an anterior approach, including better direct canal decompression, canal remodelling and improved exposure of fractured vertebrae [6]. There is a paucity of evidence and thus a consensus on the optimal treatment, with these two methods being compared for the treatment of B and C thoracolumbar spine injuries. Given the significant morbidity and mortality of these fractures, particularly if not adequately treated, the lack of consensus on the optimal treatment methodology, and advancements in implants and knowledge of biomechanics, research is needed to assess the existing literature on this topic. In this review, we aimed to compare the outcomes of PFF and CAPFF for B and C thoracolumbar spine injuries and conduct a meta-analysis using metrics such as blood loss, operative time, cost, length of stay, follow-up, visual analogue scale (VAS) score, Oswestry Disability Index (ODI), pre, postop, and final kyphosis angles, and patient age.

Methods

The systematic review was performed according to the PRISMA recommendations [7, 8]. This systematic review protocol was registered with PROSPERO (CRD42023473295). A search was conducted in PubMed, Ovid Medline, Scopus, and the Cochrane Central Register of Controlled Trials from inception to September 2023. The search strategies are included in the supplemental material.

The included studies were randomized controlled trials (RCTs) and observational studies (cohort, case–control, and cross-sectional) that compared PFF with CAPFF for B and C thoracolumbar spine injuries in adults (18 years or older). Studies that met the inclusion criteria but used Denis fracture classification were included, as Denis types C and D can be considered equivalent to AO types B and C, respectively [9]. The exclusion criteria were reviews, non-English studies, studies involving children, pregnant women, patients with other spinal pathologies or injuries, or patients who received other types of surgical treatments. A risk of bias assessment was completed for each extracted study via the appropriate checklist from the CASP [10, 11].

The authors (HS, AG, JG, MC, or SG) independently screened the studies via Covidence, a web-based collaborative platform, according to the inclusion and exclusion criteria [12]. Each study was evaluated by two authors. Any conflicts were adjudicated by a third reviewer (VM or HW). The full-text references were snowballed to generate additional studies to potentially be included in the analysis.

Statistical analysis

Standardized mean differences were calculated when two or more studies reported the outcome variables of interest. The effect size and 95% confidence interval (CI) are presented via forest plots. The meta-analysis was performed via SPSS Statistics for Windows (Version 28, IBM Corporation, Armonk, NY, USA), with a p value of < 0.05 considered statistically significant.

Results

Study selection

The search process is summarized in the PRISMA diagram in Fig. 1. After screening the initial 5773 articles identified from Scopus, PubMed, MEDLINE, and Cochrane, a total of eight studies that met the inclusion criteria were included for full-text assessment. Of the eight studies, six were cohort studies, and two were randomized controlled trials.

A total of 5773 articles were identified from Scopus, PubMed, MEDLINE and Cochrane, and 1840 were identified as duplicates. The remaining 3933 articles were reviewed by two reviewers (HS, AG, JG, MC, or SG). Any conflicts were adjudicated by a third reviewer (VM or HW). A total of 3881 articles were excluded,

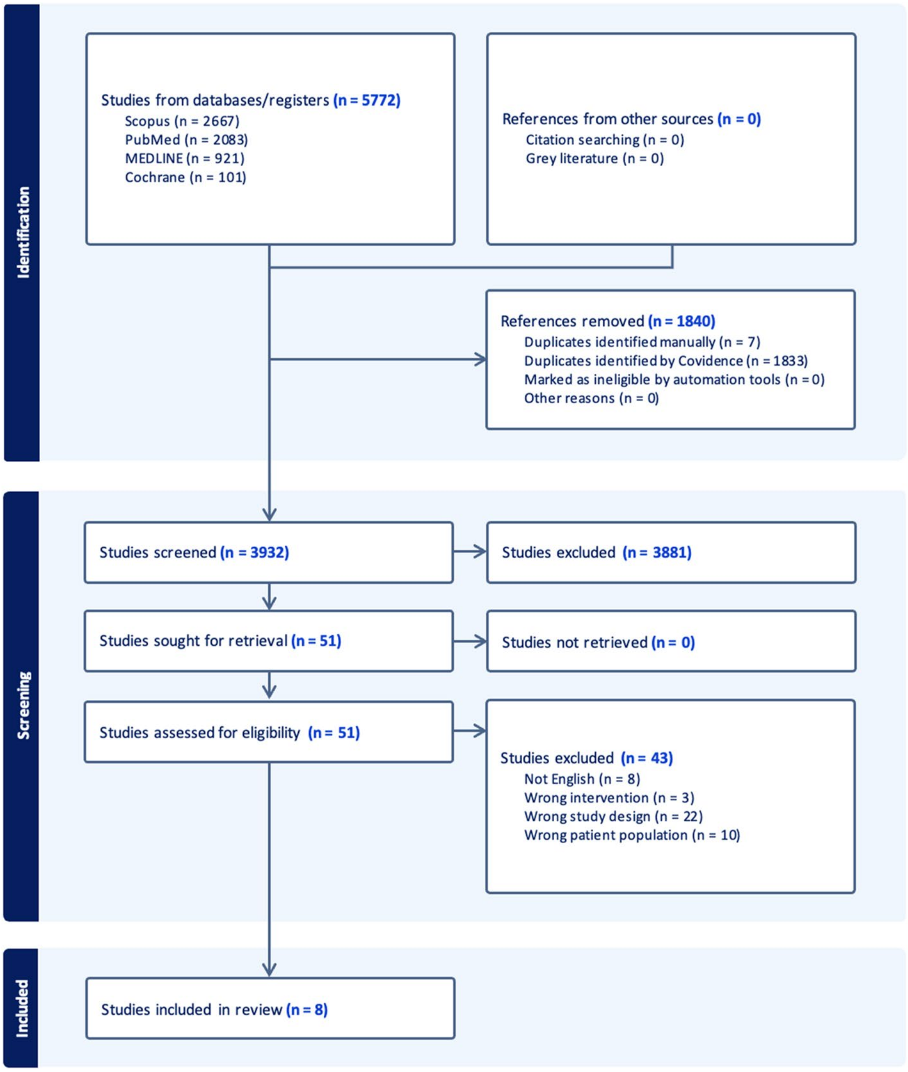


Fig. 1 PRISMA diagram of the review process

and the full-text versions of the 51 remaining articles were assessed for eligibility and risk of bias by two reviewers. Forty-three articles were excluded: 22 that were not RCTs or observational studies, 10 for incorrect patient populations (additional spinal pathologies, participants under age 18), eight for non-English texts, and three studies that did not utilize PFF or CAPFF. A total of eight studies met the inclusion criteria and were included in the full-text assessment. Among these studies, six were cohort studies, and two were randomized controlled trials (Fig. 1).

Assessment of the quality of individual studies

Each of the selected studies was subjected to the CASP checklist for risk of bias using both the RCT and the cohort study checklist for the respective study type. While the CASP does not offer specific scores or cutoffs for the quality of studies, they suggest that if you cannot answer “yes” to two out of the first three questions, this might be indicative of a poor-quality study [10, 11]. On the basis of author experience, we scored article quality as poor (< 7), medium (8–9) or good (≥ 10) for RCTs and poor (< 7), medium (7–10), or good (11–14) for cohort studies in terms of the number of “yes” responses to the checklist questions. Three studies were good (Been 1999, Danisa 1995 and Wang 2015), two were medium (Muratore 2021 and Defino 2007), and 3 were poor (Gumussuyu 2019, Zheng 2013, and Lukas 2007) (Supplemental Figs. 1, 2). Keys detailing the questions and criteria assessed by the checklists are included in Supplemental Figs. 3 and 4.

Study characteristics

The eight articles included were published from 1995–2021 and came from seven different countries (Table 1). The studies consisted of five retrospective cohort studies (level III evidence), two randomized controlled trials (level II evidence), and one prospective cohort study (level III evidence). Three studies utilized the Denis burst fracture classification (Been 1999, Danisa 1995, Gumussuyu 2019) [13–15], two utilized the AO-ASIF and load-sharing classification (Zheng 2013, Lukas 2007, Muratore 2021) [16–18], and one classified unstable thoracolumbar spine fractures according to the affected vertebral level (Wang 2015) [19]. One study investigated only neurologically nonintact patients (Zheng 2013) [16], four studies investigated both nonintact and intact patients (Been 1999, Danisa 1995, Defino 2007 and Wang 2015) [13, 14, 19, 20], and one study excluded patients with neurological deficits/spinal cord injury and osteoporosis (Lukas 2007) [17]. One study excluded patients with neurological deficits/spinal cord injury (Gumussuyu 2019) [15], and one study did not report the neurological status of each specific treatment group (Muratore 2021) [18]. A detailed summary of the patient demographics, fracture classification, neurological status, fusion rate, implant failure rate, other complications, infection rate, follow-up, and rationale for the surgical approach can be found in Tables 1, 2, 3 and 4.

Across studies, the average age ranged from 26.8–47.8 years, the percentage of males ranged from 56–87.50%, the percentage of individuals with impaired neurological status ranged from 27.72–68.20%, and the average follow-up ranged from 27–117.7 months (Table 1). The rationale for either the posterior or combined-anterior posterior approach treatment group in each study varied; in two of the studies, it was determined on the basis of individual factors related to fracture, anatomy, situation, and discretion of the attending physician (Table 2). Two studies determined treatment groups based on the fracture type and type of vertebral body involvement (Table 2). There were only two studies that randomized patients into their respective treatment groups, one utilizing a coin toss and the other using a computer-generated sequence (Table 2) [15, 19].

Qualitative and quantitative analysis

The methods of fixation, fusion, decompression, and supplemental fusion (when available) for the posterior approach and combined anterior–posterior approach for each study are described in Table 5.

Among the posterior approach groups, the standard midline approach was reported for two studies, and one utilized a posterolateral transpedicular approach. Decompression methods include dorsal decompression, posterior distraction instrumentation and stabilization, and posterior decompression. A variety of fixation and supplemental fusion methods were utilized, as shown in Table 5.

In the combined anterior–posterior approach groups, the positioning and approaches included the traditional anterior approach, direct anterior approach, posterolateral transpedicular approach, and anterior-open approach. Decompression methods include anterior decompression with direct decompression with subtotal corpectomy and direct surgical decompression when reported. A variety of fixation and supplemental fusion methods were utilized and are described in Table 5.

Quantitative analysis of operative variables, functional outcomes, and pre, post, and final kyphosis angles was conducted via SPSS statistical analysis software to perform meta-analysis via a random effects model to calculate Cohen's d (standardized mean difference), a standardized measure of effect size. Studies that were missing data for the variable being analysed were excluded from the corresponding analysis for that specific variable. The results are shown in Figs. 2, 3, 4, 5, 6, 7 and 8.

Operative variables

Blood loss

A total of 136 patients, with 62 patients in the posterior group and 63 patients in the combined group across four studies, were assessed for blood loss (milliliters, mL). The mean blood loss in the posterior approach group across the four studies was as follows: Zheng 2013: 1856 ± 388 ($p = 0.002$; $n = 12$), Danisa 1995: 1103 ± 793 ($p < 0.008$; $n = 27$), Gumussuyu 2019: 195.7 ± 63.6 ($p = 0.003$; $n = 13$), Wang 2016: 357 ± 98.1 ($p = 0.01$; $n = 23$). The mean blood loss in the combined anterior posterior approach group across the four studies was as follows: Zheng 2013: 2453 ± 485 ($p = 0.002$; $n = 14$), Danisa 1995: 2541 ± 1439 ($p < 0.008$; $n = 6$), Gumussuyu 2019: 358.5 ± 169.5 ($p = 0.003$; $n = 14$), Wang 2016: 780.3 ± 226.8 ($p = 0.01$; $n = 21$). A pooled Cohen's d meta-analysis revealed a standardized mean difference of −1.70 (95% CI −3.26, −1.68; $p = 0.00$), favouring a posterior fixation and fusion approach for B and C thoracolumbar spine fractures (Fig. 2). The effect is stronger with the posterior approach than with the combined anterior–posterior approach.

Operative time

A total of 103 patients, with 62 patients in the posterior group and 41 patients in the combined group across three studies, were assessed for operative time. The mean operative times (minutes) in the posterior approach

Table 1 Patient Demographics by Study

Study	Study Design	Country	No. of each intervention group			Age (yr)			Gender (% male)		
			Posterior	**Combined**	**Total**	**Posterior**	**Combined**	**Total**	**Posterior**	**Combined**	**Total**
Zheng 2013 [16]	RCS	China	12	14	26	NR	NR	NR	NR	NR	NR
Been 1999 [13]	RCS	The Netherlands	19	27	46	33.7 ± 13.1	26.8 ± 8.6	NR	19	55	56
Danisa 1995 [14]	RCS	USA	27	6	33	37.7	36.8	NR	70.4	66.7	69.7
Defino 2007 [20]	RCS	Brazil	18	6	24	35.36 ± 8.3	37.6	NR	94.4	66.7	87.5
Gumussuyu 2019 [15]	RCT	Turkey	13	14	27	40.07 ± 10.3	40 ± 10.3	38.5 ± 2.4	76.9	64.3	70.4
Lukas 2007 [17]	PCS	Czech Republic	20	22	42	NR	NR	42	NR	NR	65
Muratore 2021 [18]	RCS	Italy	96	5	101	NR	NR	47.8 ± 15.7	NR	NR	71.2
Wang 2015 [19]	RCT	China	23	21	44	40.5 ± 13.5	41.2 ± 12.9	NR	NR	NR	68.2

NR Not reported

Table 2 Rationale for the surgical approach by study

Study	Study Design	Rationale for Approach
Zheng 2013 [16]	RCS	Not reported (Retrospectively found patients with either intervention)
Been 1999 [13]	RCS	Surgeon's determination based on instrumentation availability and the presence of other severe organ injuries
Danisa 1995 [14]	RCS	Surgeon's determination
Defino 2007 [20]	RCS	Determined by vertebral body involvement. Intact vertebral body received posterior approach; fractured vertebral body received CAPFF
Gumussuyu 2019 [15]	RCT	Randomly by "flipping a coin"
Lukas 2007 [17]	PCS	B or C type fractures with Load-Sharing Classification (LSC) ≥ 6 received CAPFF. B or C fractures with LSC ≤ 6 received PFF
Muratore 2021 [18]	RCS	Determined on a case-by-case basis accounting for the anatomical and general situation of each patient
Wang 2015 [19]	RCT	Randomization via computer-generated sequence

group across the three studies were as follows: Zheng 2013: 214 (range 186–327; $p < 0.05$; $n = 12$), Danisa 1995: 219 ± 61 ($p < 0.0003$; $n = 27$), and Wang 2016: 110 ± 29.6 ($p < 0.03$; $n = 23$). The mean operative times (minutes) in the combined anterior posterior approach group across the four studies were as follows: Zheng 2013: 284 (range 219–423; $p < 0.05$; $n = 14$), Danisa 1995: 569 ± 121 ($p < 0.0003$; $n = 6$), and Wang 2016: 248.5 ± 43.9 ($p < 0.03$; $n = 21$). A pooled Cohen's d meta-analysis revealed a standardized mean difference of –3.12 (95% CI −5.28, −0.95; $p = 0.00$), indicating that there was no significant difference between the two approaches (Fig. 3). The strong heterogeneity in effect size estimates may be due to variation in study design, scope, etc.

Cost

A total of 77 patients, with 50 patients in the posterior group and 27 patients in the combined group across two studies, were assessed for cost (USD). The mean costs in the posterior approach group across the two studies were as follows: Danisa 1995: 45,306 ± 15,808 ($p < 0.0012$; $n = 27$) and Wang 2016: 31,456 ± 2068 ($p = 0.01$; $n = 23$). The mean costs in the combined anterior posterior approach group across the four studies were as follows: Danisa 1995: 111,750 ± 20,635 ($p < 0.0012$; $n = 6$) and Wang 2016: 64,120 ± 4579 ($p = 0.01$; $n = 21$). A pooled Cohen's d meta-analysis revealed a standardized mean difference of –6.60 (95% CI −11.85, −1.35; $p = 0.01$), favouring a posterior fixation and fusion approach for decreased cost (Fig. 4).

Length of stay

A total of 104 patients, with 63 patients in the posterior group and 41 patients in the combined group across three studies, were included in the length of stay. The mean length of stay (days) in the posterior approach group across the three studies was as follows: Danisa 1995: 4.2 ± 2.9, range 1–13; $n = 27$), Gumussuyu 2019: 7.3 ± 4.6 ($p = 0.102$; $n = 13$), and Wang 2016: 13.5 ± 4.7 ($p = 0.02$; $n = 23$). The mean length of stay in the combined anterior posterior approach group across the three studies was as follows: Danisa 1995: 6.3 ± 5.0 (range 0–14; $p < 0.05$; $n = 6$); fixation and fusion performed 9.5 days apart on average, Gumussuyu 2019: 10.6 ± 5.5 ($p = 0.102$; $n = 14$); fixation and fusion performed in one setting; Wang 2016: 21.4 ± 5.9 ($p = 0.02$; $n = 21$); and fixation and fusion performed in one setting. A pooled Cohen's d meta-analysis revealed a standardized mean difference of –1.32 (95% CI −2.01, −0.62; $p = 0.00$), indicating that there was no significant difference between the two approaches (Fig. 5).

Follow-up

A total of 50 patients, with 30 patients in the posterior group and 20 patients in the combined group across two studies, were assessed for follow-up and reported separately between the groups, with standard deviations. The mean follow-up (months) in the posterior approach group across the two studies was as follows: Zheng 2013: 27.7 ± 9.6 (range 14–56; $p > 0.05$; $n = 12$) and Defino 2007: 79.8 ± 35.5 ($n = 18$). The mean follow-up (months) in the combined anterior posterior approach group across the two studies was as follows: Zheng 2013, 29.2 ± 7.4 (range 20–60; $p > 0.05$; $n = 14$); and Defino 2007, 156 ± 25.1 ($n = 6$). A pooled Cohen's d meta-analysis revealed a standardized mean difference of –1.19 (95% CI −3.26, −1.15; $p = 0.26$), indicating a nonsignificant statistical effect size between the two approaches (Supplemental Fig. 5).

Functional outcomes

Visual analogue scale

A total of 71 patients, with 36 patients in the posterior group and 35 patients in the combined group across two studies, were assessed with the pain VAS. The mean VAS score at the final follow-up in the posterior approach

Table 3 Fracture Classification by Study

Study	Study Design	Fracture Classification and Typing (no. of patients)														
		AO Spine classification of Upper Thoracolumbar Injuries				Denis Burst Fractures Only					AO-ASIF classification and Load-sharing Classification			Unstable Thoracolumbar Burst Fractures		
Zheng 2013 [16]	RCS	Type A = 0/26 (0%)	Type B2 = 0/26 (0%)	Type C = 26/26 (100%)	-	-	-	-	-	-	-	-	-	-	-	-
>Been 1999 [13]	RCS	-	-	-	-	A = 12/46 (26%)	B = 20/46 (43%)	C = 0/46 (0%)	D (AO Type C equivalent) = 14/46 (30%)	E = 0 (0%)	-	-	-	-	-	-
Danisa 1995 [14]	RCS	-	-	-	-	A = 21/33 (64%)	B = 10/33 (30%)	C = 2/33 (6%)	D (AO Type C equivalent) = 0/33 (0%)	E = 0 (0%)	-	-	-	-	-	-
Defino 2007 [20]	RCS	Type B1 = 11/24 (45%)	Type B2 = 3/24 (12.5%)	Type B3 = 1/24 (4.2%)	Type C = 3/24 (12.5%)	-	-	-	-	-	-	-	-	-	-	-
Gumus-suyu 2019 [15]	RCT	-	-	-	-	A = 8/27 (29.6%)	B = 19/27 (70.4%)	C = 0/27 (0%)	D (AO Type C equivalent) = 0/27 (0%)	E = 0 (0%)	-	-	-	-	-	-
Lukas 2007 [17]	PCS	-	-	-	-	-	-	-	-	-	Type B = 29 (69%)	Type C = 13(31%)	-	-	-	-
Muratore 2021 [18]	RCS	-	-	-	-	-	-	-	-	-	Type A = 43	Type B = 38	Type C = 20	-	-	-
Wang 2015 [19]	RCT	-	-	-	-	-	-	-	-	-	-	-	-	T12 = 8 (18%)	L1 = 29 (66%)	L2 = 7 (16%)

Table 4 Selection of Complication Rates and Follow up Time by Study

Study	Study Design	Neurological Status (% Impaired)			Fusion Rate (%)		Implant Failure Rate (%)		Infection Rate (%)		Follow up (months)		
		Posterior	Combined	Total	Posterior	Combined	Posterior	Combined	Posterior	Combined	Posterior	Combined	Total
Zheng 2013 [16]	RCS	100			100	100	NR	NR	0	0	27.7 ±9.6	29.2 ± 7.4	NR
Been 1999 [13]	RCS	42	37	39	100	100	21.3	3.7	5.26	3.7	54	84	NR
Danisa 1995 [14]	RCS	40.7	50	42.4	96.3	100	NR	NR	7.4	0	NR	NR	27
Defino 2007 [20]	RCS	38.9	50	41.7	NR	NR	NR	NR	0	7.14	79.8 ± 35.5	156 ± 25.1	NR
Gumussuyu 2019 [15]	RCT	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	117.7 ±8.7
Lukas 2007 [17]	PCS	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Muratore 2021 [18]	RCS	NR	NR	NR	NR	NR	0	0	NR	NR	NR	NR	44.32
Wang 2015 [19]	RCT	65.2	71.4	68.2	NR	NR	8.7	0	4.3	9.5	NR	NR	60

NR Not reported

Table 5 Summary of Operative Fixation

Posterior approach

Study	Positioning/approach	Decompression	Fixation	Supplemental Fusion
Zheng 2013 [16]	NR	Dorsal decompression	Titanium mesh cage and pedicle screw fixation	Autologous graft harvested from dorsal iliac crests; dorsolateral spinal fusion
Been 1999 [13]	Standard midline approach	Posterior distraction instrumentation and stabilization	AO Internal Fixator	Schanz screws, Posterior fusion
Danisa 1995 [14]	12—Direct surgical decompression with Posterolateral transpedicular approach, 15—Indirect decompression with aid of distraction forces	12—Direct surgical decompression, 15—Indirect decompression	16 Steffee plates and pedicle screws; 4 Cotrel–Dubousset rods with a hook and claw system; 4 Harrington distraction rods with hooks; and 3 Luque rings with sublaminar wiring	Iliac crest autografts or human freeze-dried bone allografts (LifeNet Tissue Services, Virginia Beach, VA)
Defino 2007 [20]	NR	NR	Bilateral pedicular fixation using the USIS (Ulrich) system of vertebral fixation in 9 patients, 6.0 mm USS pedicular screws (Synthes) in 6 patients, and the Internal Fixator (Synthes) in 3	Autogenous corticocancellous bone graft from posterior iliac bone
Gumussuyu 2019 [15]	NR	NR	Transpedicular screws	NR
Lukas 2007 [17]	NR	NR	Internal Pedicular Fixator	NR
Muratore 2021 [18]	NR	NR	NR	NR
Wang 2015 [19]	Prone position, standard posterior midline approach	Posterior decompression	Pedicle screws	Posterolateral fusion with autogenous bone graft

Combined anterior–posterior approach

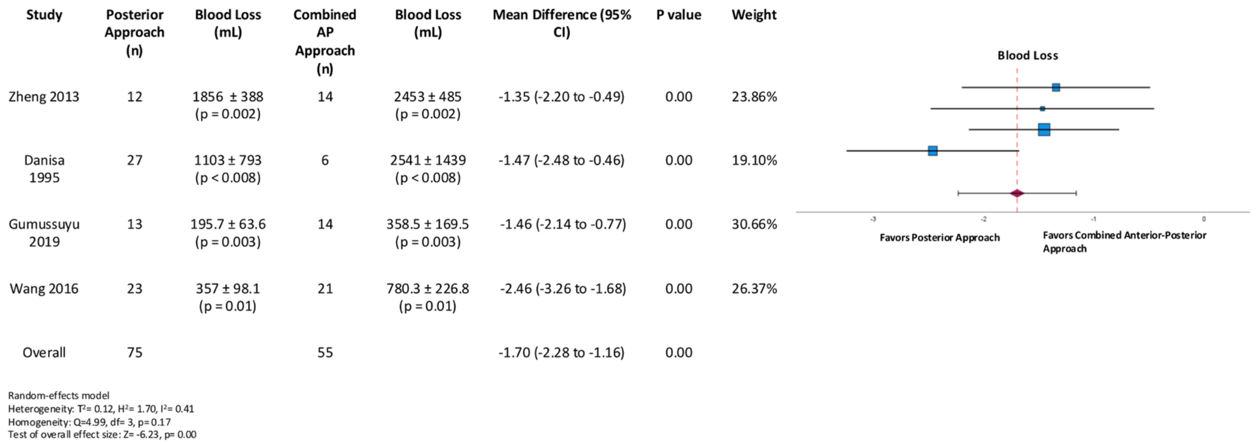
Study	Positioning/approach	Decompression	Fixation	Supplemental Fusion
Zheng 2013 [16]	Traditional anterior approach	Traditional anterior approach	NR	NR
Been 1999 [13]	Anterior decompression and stabilization combined with posterior stabilization	Anterior decompression with direct decompression with Subtotal corpectomy	Single-rod Slot-Zielke system followed by additional posterior instrumentation and spondylodesis with D.K.S system of Zielke (rods and pedicle screw system) or with the Cottrel-Dubousset compression-rod system (rods and laminar hooks system)	Iliac crest bone graft and osteosynthesis
Danisa 1995 [14]	Posterolateral transpedicular approach	Direct surgical decompression	2—Kaneda device; 1 Harrington rods with hooks; 1 had Cotrel–Doubousset rods with hooks; 2 had Luque rings with sublaminar wiring (1 of whom also had a Kaneda device anteriorly); 2 Texas Scottish Rite Hospital rods with hooks (1 of whom also had a Kaneda device anteriorly) was used for anterior internal fixation; posterior surgery was later performed	Fibular strut and/or morselized rib grafts anteriorly; Iliac crest autograft and/or human freeze-dried bone allograft were combined with posterior internal fixation
Defino 2007 [20]	Anterior open approach	Not performed (no bony compression in spinal canal)	Bilateral posterior pedicular fixation and by anterior fixation using the USIS (Ulrich) system of vertebral fixation	Autologous cortico-cancellous bone graft from iliac crest

Table 5 (continued)

Posterior approach

Study	Positioning/approach	Decompression	Fixation	Supplemental Fusion
Gumussuyu 2019 [15]	NR	NR	Transpedicular screws, anterior corpus screws to the upper and lower adjacent levels with an anterior rod and anterior corpectomy cages with bone graft to the corpectomy site were added, with application of distraction to reduce kyphotic deformity	Bone graft at corpectomy site
Lukas 2007 [17]	NR	NR	Internal Pedicular Fixator, anterior angle-stable device (MACS-TL) and a spacer	Tricortical bone graft
Muratore 2021 [18]	NR	NR	NR	NR
Wang 2015 [19]	NR	Direct Decompression of spinal canal via subtotal corpectomy, posterior decompression	Posterior rods and pedicle screw system	Cylindrical titanium mesh cage filled with autogenous bone inserted into vertebral body defect, posterolateral fusion

NR Not reported



Study	Posterior Approach (n)	Blood Loss (mL)	Combined AP Approach (n)	Blood Loss (mL)	Mean Difference (95% CI)	P value	Weight
Zheng 2013	12	1856 ± 388 (p = 0.002)	14	2453 ± 485 (p = 0.002)	-1.35 (-2.20 to -0.49)	0.00	23.86%
Danisa 1995	27	1103 ± 793 (p < 0.008)	6	2541 ± 1439 (p < 0.008)	-1.47 (-2.48 to -0.46)	0.00	19.10%
Gumussuyu 2019	13	195.7 ± 63.6 (p = 0.003)	14	358.5 ± 169.5 (p = 0.003)	-1.46 (-2.14 to -0.77)	0.00	30.66%
Wang 2016	23	357 ± 98.1 (p = 0.01)	21	780.3 ± 226.8 (p = 0.01)	-2.46 (-3.26 to -1.68)	0.00	26.37%
Overall	75		55		-1.70 (-2.28 to -1.16)	0.00	

Random-effects model
Heterogeneity: T^2= 0.12, H^2= 1.70, I^2= 0.41
Homogeneity: Q=4.99, df= 3, p= 0.17
Test of overall effect size: Z= -6.23, p= 0.00

Fig. 2 Mean difference in blood loss, Posterior vs. Combined Anterior–Posterior Approach

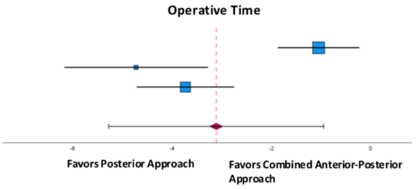
group across the two studies was as follows: Gumussuyu 2019: 16.4 ±14.8 (p= 0.685; n= 13); mean follow-up: 117.7 months ±8.7 months (range 98–132 months); Wang 2016: 2.0 ±0.6 (p= 0.03; n= 23); and mean follow-up: 60 months. The mean VAS score at the final follow-up in the combined anterior posterior approach group across the two studies was as follows: Gumussuyu 2019: 17.6 ±16.6 (p= 0.003; n= 14); mean follow-up: 117.7 months ±8.7 months (range 98–132 months); Wang 2016: 1.1 ±0.4 (p= 0.03; n= 21); and mean follow-up: 60 months. A pooled Cohen's d meta-analysis revealed a standardized mean difference of 0.84 (95% CI −0.95, −2.63; p= 0.36), indicating a nonsignificant difference in effect size between the two approaches (Fig. 6).

Preop, postop, and final kyphosis angles

Preop kyphosis angle

A total of 154 patients, with 93 patients in the posterior group and 61 patients in the combined group across five studies, were included in the assessment of the preoperative kyphosis angle. The mean preoperative kyphosis angle in the posterior approach group across the five studies was as follows: Zheng 2013: 39.8 ±6.8 (n= 12), Danisa 1995: 15.2 ±8.3 (n= 27), Defino 2007: 14.4 ±9.62 (n= 18), Gumussuyu 2019: 19.3 ±6.2 (n= 13), and Wang

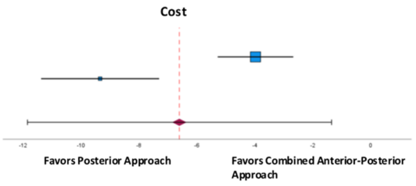
Study	Posterior Approach (n)	Operative Time (minutes)	Combined AP Approach (n)	Operative Time (minutes)	Mean Difference (95% CI)	P value	Weight
Zheng 2013	12	214 (range 186-327; p<0.05)	14	284 (range 219-423; p<0.05)	-1.05 (-1.88 to -0.23)	0.01	34.66%
Danisa 1995	27	219 ± 61 (p<0.0003)	6	569 ± 121 (p<0.0003)	-4.73 (-6.17 to -3.28)	0.00	31.39%
Wang 2016	23	110 ± 29.6 (p<0.03)	21	248.5 ± 43.9 (p<0.03)	-3.73 (-4.71 to -2.75)	0.00	33.95%
Overall	62		41		-3.12 (-5.28 to -0.95)	0.00	



Random-effects model
Heterogeneity: T^2= 3.34, H^2= 12.75, I^2= 0.92
Homogeneity: Q=27.06, df= 2, p= 0.00
Test of overall effect size: Z= -2.82, p= 0.00

Fig. 3 Mean difference in operative time, Posterior vs. Combined Anterior–Posterior Approach

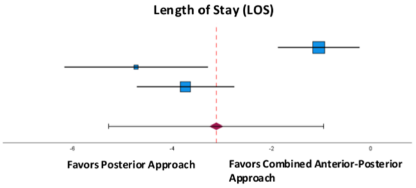
Study	Posterior Approach (n)	Cost (USD)	Combined AP Approach (n)	Cost (USD)	Mean Difference (95% CI)	P value	Weight
Danisa 1995	27	45306 ± 15808 (p<0.0012)	6	111750 ± 20635 (p<0.0012)	-3.58 (-5.29 to -2.68)	0.00	51.11%
Wang 2016	23	31456 ± 2068 (p=0.01)	21	64120 ± 4579 (p=0.01)	-9.34 (-11.38 to -7.30)	0.07	48.89%
Overall	50		27		-6.60 (-11.85 to -1.35)	0.01	



Random-effects model
Heterogeneity: T^2= 13.60, H^2= 18.81, I^2= 0.95
Homogeneity: Q=18.81, df= 1, p= 0.00
Test of overall effect size: Z= -2.46, p= 0.01

Fig. 4 Mean difference in cost, Posterior vs. Combined Anterior–Posterior Approach

Study	Posterior Approach (n)	LOS (days)	Combined AP Approach (n)	LOS (days)	Mean Difference (95% CI)	P value	Weight
Danisa 1995	27	4.2 ± 2.9 (range 1-13)	6	6.3 ± 5.0 (range 0-14)	-1.92 (-2.92 to -0.92)	0.00	26.90%
Gumussuyu 2019	13	7.3 ± 4.6 (p=0.102)	14	10.6 ± 5.5 (p=0.102)	-0.65 (-1.42 to 0.13)	0.10	34.46%
Wang 2016	23	13.5 ± 4.7 (p=0.02)	21	21.4 ± 5.9 (p=0.02)	-1.49 (-2.16 to -0.82)	0.00	38.64%
Overall	63		41		-1.32 (-2.01 to -0.62)	0.00	

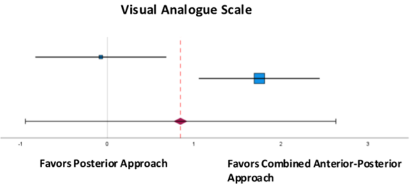


Random-effects model
Heterogeneity: T^2= 0.21, H^2= 2.27, I^2= 0.56
Homogeneity: Q=4.50, df= 2, p= 0.11
Test of overall effect size: Z= -3.69, p= 0.00

Fig. 5 Mean difference in length of stay, Posterior vs. Combined Anterior–Posterior Approach

2016: 15.9 ±3.5 (n= 23). The mean preoperative kyphosis angle in the combined anterior posterior approach group across the five studies was as follows: Zheng 2013: 34.7 ±7.5 (n= 14), Danisa 1995: 26 ±19.2 (n= 6), Defino 2007: 20.33 ±90 (n= 6), Gumussuyu 2019: 20.3 ±5.8 (n= 14), Wang 2016: 18.1 ±3.3 (n= 21). A pooled Cohen's d meta-analysis revealed a standardized mean difference estimate of −0.26 (95% CI −0.80, 0.31; p= 0.38), indicating a nonsignificant statistical effect size between the two approaches (Supplemental Fig. 6).

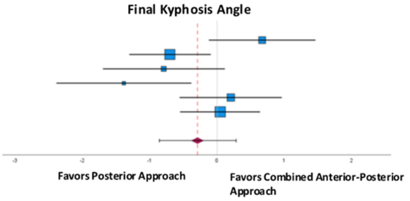
Study	Posterior Approach (n)	VAS (at final follow-up)	Combined AP Approach (n)	VAS (at final follow-up)	Mean Difference (95% CI)	P value	Weight
Gumussuyu 2019	13	16.4 ± 14.8 (p = 0.685)	14	17.6 ± 16.6 (p = 0.003)	-0.08 (-0.83 to 0.68)	0.84	49.66%
Wang 2016	23	2.0 ± 0.6 (p = 0.03)	21	1.1 ± 0.4 (p =0.03)	1.75 (1.05 to 2.44)	0.00	50.34%%
Overall	36		35		0.84 (-0.95 to 2.63)	0.36	



Random-effects model
Heterogeneity: T^2= 1.53, H^2= 12.14, I^2= 0.92
Homogeneity: Q=12.14, df= 1, p= 0.00
Test of overall effect size: Z= 0.92, p= 0.36

Fig. 6 Mean difference in VAS, Posterior vs. Combined Anterior–Posterior Approach

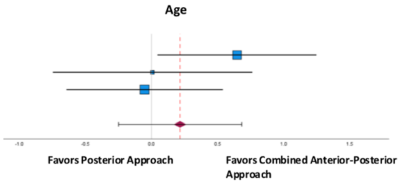
Study	Posterior Approach (n)	Final kyphosis angle	Combined AP Approach (n)	Final kyphosis angle	Mean Difference (95% CI)	P value	Weight
Zheng 2013	12	4.9 ± 3.6	14	2.8 ± 2.3	0.71 (-0.09 to 1.50)	0.08	16.69%
Been 1999	19	4.1 ± 12.4	27	3.3 ± 7.7	0.08 (-0.51 to 0.67)	0.79	17.74%
Danisa 1995	27	9.5 ± 6.8	6	18.5 ± 17	-0.97 (-1.89 to -0.06)	0.04	16.01%
Defino 2007	18	7.72 ± 7.73	6	19.5 ± 10.5	-1.40 (-2.40 to -0.39)	0.01	15.49%
Gumussuyu 2019	13	7.2 ± 3.3	14	5.5 ± 4.9	0.40 (-0.36 to 1.17)	0.30	16.86%
Wang 2016	23	9.8 ± 3.1	21	4.3 ± 3.2	1.75 (1.05 to 2.44)	0.00	17.21%
Overall	112		88		0.13 (-0.77 to 1.03)	0.78	



Random-effects model
Heterogeneity: T^2= 1.10, H^2= 8.19, I^2= 0.88
Homogeneity: Q=36.65, df= 5, p= 0.00
Test of overall effect size: Z= 0.28, p= 0.78

Fig. 7 Mean difference in final kyphosis, Posterior vs. Combined Anterior–Posterior Approach

Study	Posterior Approach (n)	Age	Combined AP Approach (n)	Age	Mean Difference (95% CI)	P value	Weight
Been 1999	19	33.7 ± 13.1	27	26.8 ± 8.6	0.65 (0.04 to 1.25)	0.04	36.20%
Gumussuyu 2019	13	40.1 ± 10.3	14	40.0 ± 10.3	0.01 (-0.75to 0.76)	0.99	26.87%
Wang 2016	23	40. 5 ± 13.5	21	41.2 ± 12.9	-0.05 (-0.64 to 0.54)	0.86	36.93%
Overall	55		62		0.22(-0.25 to 0.68)	0.36	



Random-effects model
Heterogeneity: T^2= 0.06, H^2= 1.57, I^2= 0.36
Homogeneity: Q=3.05, df= 2, p=0.22
Test of overall effect size: Z= 0.91, p= 0.36

Fig. 8 Mean difference in age, Posterior vs. Combined Anterior–Posterior Approach

Postoperative kyphosis angle

A total of 200 patients, with 112 patients in the posterior group and 88 patients in the combined group, were included across the six assessed preoperative kyphosis angles. The mean postoperative kyphosis angle in the posterior approach group across the six studies was as follows: Zheng 2013: 4.8 ± 3.7 (*n* = 12), Been 1999: −4.1 ± 9.9 (*n* = 19), Danisa 1995: 6.5 ± 5.9 (*n* = 27), Defino 2007: 3.72 ± 6.73 (*n* = 18), Gumussuyu 2019: 5.0 ± 4.3 (*n* = 13), and Wang 2016: 1 ± 2.3 (*n* = 23). The mean postoperative kyphosis angle in the combined anterior posterior approach group across the six studies was as follows: Zheng 2013: 2.8 ±2.2 (*n*= 14), Been 1999: 1.2 ±5.5 (*n*= 27), Danisa 1995: 12.0 ±11.0 (*n*= 6), Defino 2007: 12.3 ±4.0 (*n*= 6), Gumussuyu 2019: 4.2 ±3.5 (*n*= 14), Wang 2016: 0.9 ±1.9 (*n*= 21). A pooled Cohen's d meta-analysis revealed a standardized mean difference of –0.29 (95% CI –0.85, 0.28; *p*= 0.32), indicating a nonsignificant difference in effect size between the two approaches (Supplemental Fig. 7).

Final kyphosis angle

A total of 200 patients, with 112 patients in the posterior group and 88 patients in the combined group across six studies, were included in the assessment of the final kyphosis angle at the final follow-up. The mean final kyphosis angle in the posterior approach group across the six studies was as follows: Zheng 2013: 4.9 ±3.6 (*n*= 12); mean follow-up: 27.7 ±9.6 months (range 14–56 months); Been 1999: 4.1 ±12.4 (*n*= 19); mean follow-up: 54 months; Danisa 1995: 9.5 ±6.8 (*n*= 27); mean follow-up: 27 months (range 6–54 months); Defino 2007: 7.72 ±7.73 (*n*= 18); mean follow-up: 79.8 ±3.5 months; Gumussuyu 2019: 7.2 ±3.3 (*n*= 13); mean follow-up: 117.7 months ±8.7 months (range 98–132 months); and Wang 2016: 9.8 ±3.1 (*n*= 23); mean follow-up: 60 months. The mean final kyphosis angle in the combined anterior posterior approach group across the six studies was as follows: Zheng 2013: 2.8 ±2.3 (*n*= 14); mean follow-up: 29.72 ±7.4 months (range 20–60 months); Been 1999: 3.3 ±7.7 (*n*= 27); mean follow-up: 84 months; Danisa 1995: 18.5 ±17 (*n*= 6); mean follow-up: 27 months (range 6–54 months); Defino 2007: 19.5 ±10.5 (*n*= 6); mean follow-up: 156 ±25.1 months; Gumussuyu 2019: 5.5 ±4.9 (*n*= 14); mean follow-up: 117.7 months ±8.7 months (range 98–132 months); Wang 2016: 4.3 ±3.2 (*n*= 21); and mean follow-up: 60 months. A pooled Cohen's d meta-analysis revealed a standardized mean difference of 0.13 (95% CI –0.77, 1.03; *p*= 0.78), indicating a nonsignificant difference in the final kyphosis angle between the two approaches (Fig. 7).

Age

A total of 117 patients, with 55 patients in the posterior group and 62 patients in the combined group across three studies, were included. The mean ages in the posterior approach group across the three studies were as follows: Been 1999: 33.7 ±13.1 (*n*= 19), Gumussuyu 2019: 40.1 ±10.3 (*n*= 13), and Wang 2016: 40. 5± 13.5 (*n*= 23). The mean ages in the combined anterior posterior approach group across the three studies were as follows: Been 1999: 26.8 ±8.6 years (*n*= 27), Gumussuyu 2019: 40.0 ±10.3 years (*n*= 14), and Wang 2016: 41.2 ±12.9 years (*n*= 21). A pooled Cohen's d meta-analysis revealed a standardized mean difference of 0.22 (95% CI –0.26, 0.68; *p*= 0.36), indicating a nonsignificant statistical effect size between the two approaches on age (Fig. 8).

Discussion

In this meta-analysis of 8 studies involving 343 patients (PFF: 228; CAPFF: 113), we evaluated PFF and CAPFF as viable surgical approaches for the treatment of AO type B and C thoracolumbar spine fractures.

We found that both the posterior and anterior–posterior groups performed equally well in terms of operative time, length of stay, VAS-pain scores, and pre, post, and final kyphosis angles. However, PFF was associated with significantly lower blood loss and greater financial cost (Figs. 2 and 4). These findings support the idea that while patients who undergo PFF and CAPFF for the treatment of AO type B and C thoracolumbar spine fractures have similar radiological and functional outcomes, PFF has advantages in terms of blood loss and financial cost. The reoperation rate was not reported in 7 of the 8 studies. In Zheng et al. 2013, there was no difference between the groups, as both had a 0% reoperation rate.

Previous research has focused largely on the comparative efficacies of general posterior and combined instrumentation on wider criteria of thoracolumbar burst fractures. This study is the first systematic review of PFF versus CAPFF for type B and C thoracolumbar spine injuries; as such, its comparability is limited. Nonetheless, our findings are consistent with similar investigations on posterior and combined surgical approaches for treating thoracolumbar fractures, which revealed that posterior surgery is associated with significantly less blood loss and cost [21, 22]. These findings are limited by the literature since only two studies are available for cost comparisons, highlighting the need for future studies that evaluate costs. Oprel et al. and Hughes et al. also reported that posterior surgery is associated with shorter operative times and lengths of hospital stay, but our study did not find this same relationship for PFF [21, 22]. Implant choice and combined anterior–posterior fixation via the same surgical incision may account for the differences in operative time observed in these studies.

In terms of radiological and functional outcomes, there was no significant difference between PFF and CAPFF. Neither approach yielded superior VAS scores or kyphotic correction. Similar systematic reviews have shown that combined surgical approaches are associated with lower degrees of kyphosis loss and greater vertebral height improvement; however, similar to our findings on PFF and CAPFF, they all concluded that neither posterior nor combined approaches result in superior surgical, radiological, or functional outcomes. However, contrary to these findings, Hughes et al. reported a lower degree of kyphosis loss for CAPFF [22], whereas Oprel et al. reported a minor increase in kyphotic correction and vertebral height improvement [21]. We were unable to assess ODI as the data was not available, as Defino et al. reported means and standard deviation for both groups, while Gumussuyu et al. reported only means, thus preventing us from conducting the Cohen's d analysis. Regardless of these differences, comparative systematic reviews and meta-analyses agree that neither PFF nor CAPFF results in superior surgical, radiological, or functional outcomes [21–23]. The decision to favour an approach should be based on various clinical factors, such as the severity of mechanical or neurological instability, patient characteristics, presence of comorbidities, and surgeon experience. PFF offers the advantages of high safety, simplicity, and reduced operation times [24]; however, CAPFF is better suited for cases featuring incomplete neurological injury [21, 24]. Compared with the more commonly practiced posterior approach, anterior procedures also pose greater risks of bleeding, organ damage, and lung damage because of their greater technical requirements [25]. Similar conclusions have been reached in meta-analysis studies comparing posterior-only to anterior-only approaches [25–27]; while the posterior approach generally results in reduced operative times and bleeding, surgeons should make the most appropriate decisions for specific cases. In certain instances, particular injuries may necessitate a specific surgical approach. B- or C-type fractures, characterized by burst vertebral bodies with or without canal retropulsion, may necessitate an anterior approach to address kyphosis resulting from these fractures and to achieve adequate decompression in cases of canal encroachment. Indirect decompression, which relies on kyphosis correction and ligamentotaxis, has been reported as a less efficient method for achieving spinal cord decompression, with outcomes frequently observed to be incomplete [13]. B- or C-type fractures that are purely ligamentous may be suitably managed with posterior fixation and fusion alone.

We recognize several limitations with this analysis. First, there was considerable heterogeneity among the studies included for variables such as operative time ($I^2 = 0.92$), cost ($I^2 = 0.95$), follow-up ($I^2 = 0.89$), VAS-pain score ($I^2 = 0.92$), and final kyphosis angle ($I^2 = 0.88$). While we used a random effects model to mitigate the effects of such heterogeneity, this, coupled with the lack of patient-level data, indicates that our findings may have limited generalizability to all surgical procedures for AO Type B and C thoracolumbar fractures. Additionally, several studies (Been, Danisa, Gumussuyu) reported follow-up for both the posterior and combined groups as one or did not include variability in follow-up, which meant that their studies could not be included in the statistical model. Furthermore, this analysis was conducted with a preponderance of retrospective studies featuring small sample sizes, differing primary endpoints, and a risk of confounding by indication. This thereby reduced the statistical power and ability to detect clinically relevant differences, prevented more granular subgroup analysis, and limited outcome measures to certain operative, radiological, and clinical variables. While operative and radiological outcomes are relevant, one could argue that clinical outcome measures, such as the ODI, are the most reliable indicators of successful treatment for spine fractures [28]. Finally, as data were derived from multiple studies spanning both time and global locations, there may be reduced translational capacity to healthcare settings owing to procedural selection, baseline risks inherent to the population, or the use of novel surgical techniques. Despite these limitations, our work is advantageous in that it comprises the totality of data comparing the efficacy of PFF and CAPFF in the treatment of AO type B and C thoracolumbar spine fractures.

Conclusion

This study aimed to review the literature that compares the outcomes of posterior fixation and fusion (PFF) and combined anterior and posterior fixation and fusion (CAPFF) for the treatment of B and C thoracolumbar spine injuries. This meta-analysis included articles from four different databases up to September 2023 and overall revealed that PFF resulted in less blood loss and a lower cost than did CAPFF. There was no statistically significant difference in pain as measured by the visual analogue scale (VAS), kyphosis angle, patient age, or postoperative length of stay.

Overall, this study highlights several crucial differences between PFF and CAPFF. However, given the limited data available on this topic and the varying metrics utilized in the literature included in this study, more data are necessary before specific conclusions can be drawn regarding PFF vs CAPFF. Thoracolumbar injuries are associated with high mortality and morbidity rates, and further research assessing clinical, radiological, and functional indicators may improve the treatment and outcomes of patients with B and C thoracolumbar spine injuries.

Abbreviations

PFF	Posterior fixation and fusion
CAPFF	Combined anterior and posterior fixation and fusion
RCT	Randomized controlled trial

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

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Authors' contributions

VM and HW supervised the study and provided clinical expertise in writing and editing the manuscript. Both VM and HW resolved any conflicts during the literature screening and data extraction process. HS was involved in abstract screening, data extraction, manuscript preparation and editing, and submission. AG was involved in abstract screening, data extraction, analysis and interpretation of the results for the manuscript preparation. JG and MC were involved in abstract screening, data extraction, and manuscript preparation, with a focus on discussion. SG was involved with abstract screening, data extraction, and manuscript preparation, with a focus on the conclusion. AH developed search strings and conducted a search of the databases for literature on the topic of interest. All the authors read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

Ethics approval and consent were waived in this study.

Consent for publication

No individual person's data were collected for this publication.

Competing interests

The authors declare no competing interests.

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