NEUROCIRUGIA. 2025;36(2):112–128

NEUROCIRUGÍA

www.elsevier.es/neurocirugia

Clinical Research

Is anterior fusion still necessary in patients with neurologically intact thoracolumbar burst fractures? A systematic review and meta-analysis

Andrey Grin, Vasily Karanadze, Ivan Lvov,◊, Aleksandr Talypov, Anton Kordonskiy, Rinat Abdrafiev*

Department of Neurosurgery, Sklifosovsky Research Institute for Emergency Medicine, Moscow, Russia

ARTICLE INFO

Article history:
Received 5 September 2024
Accepted 26 October 2024

Keywords:
Neurologically intact thoracolumbar fracture
Burst spine fracture
Anterior spine fusion
Posterior spine fusion
Pedicle screw fixation

ABSTRACT

Objectives: To conduct a systematic review and single-arm meta-analysis to evaluate and compare radiological indicators, as well as short-term and long-term outcomes, in patients with neurologically intact thoracolumbar burst fractures (TLBF) who underwent anterior fusion, combined anterior-posterior procedure, or short-segment pedicle screw fixation (PSF).

Methods: A systematic review following PRISMA guidelines was conducted. Inclusion criteria comprised articles published between 2004 and 2023, full-text availability in English, burst fractures without spinal cord or nerve root injuries at admission, short-segment PSF without fusion, anterior or combined fusion methods, patients aged 18 or older, and a minimum 12-month follow-up.

Meta-analysis was carried out using Comprehensive Meta-Analysis software. Using a single-arm meta-analysis method, pooled indicators of short- and long-term outcomes for each studied group were determined. The obtained data were then compared using simple comparison.

Results: The pooled mean Cobb angle at admission for the anterior, combined, and PSF groups was 18.2° (95% CI, 14.6–21.8), 11.7° (95% CI, 9.7–13.5), and 17.1° (95% CI, 15.1–19.1), respectively. Anterior fusion achieved a greater degree of kyphosis correction across all groups, but only the combined group showed a nonsignificant loss of correction after discharge (SMD = 0.809 [95% CI, 0.270, 1.348]). The anterior vertebral body compression rate at admission was 55.2% (95% CI, 46.3–64.0) in the combined group and 37.8% (95% CI, 33.7–41.9) in the PSF group.

Operative time, blood loss, and hospitalization duration were lowest in the percutaneous PSF group, with means of 96.5 min (95% CI, 82.4–110.6), 83.8 ml (95% CI, 71.7–95.9), and 6.6 days (95% CI, 4.7–8.5), respectively. All techniques demonstrated a similar incidence of deep wound infections and implant-related complications.

DOI of original article: https://doi.org/10.1016/j.neucir.2024.10.010.
* *Corresponding author*.
E-mail address: dr.speleolog@gmail.com (I. Lvov).
◊ Present address: Calle Democracia 29, pta 7, 46018 Valencia, Spain.
https://doi.org/10.1016/j.neucie.2024.11.006

The pooled Oswestry Disability Index (ODI) scores were 17.2 (95% CI, 10.4–23.9) for the anterior group, 15.4 (95% CI, 11.5–19.3) for the combined group, and 13.4 (95% CI, 10.4–16.3) for the PSF group.
Conclusions: For patients with neurologically intact thoracolumbar burst fractures, with a kyphotic angle of less than 19.1° and an anterior vertebral body compression rate of less than 41.9%, short-segment pedicle screw fixation without fusion may be preferable option due to reduced intraoperative blood loss, shorter operation duration, shorter hospital stay, and better ODI scores at final follow-up. Routine anterior fusion has demonstrated high potential for kyphosis correction. The loss of the Cobb angle from surgery to final follow-up was nonsignificant only in patients who underwent combined surgery. When determining the surgical approach, surgeons should carefully weigh the advantages of anterior and combined fusion against the significantly higher surgical trauma compared to standard PSF.

¿Sigue siendo necesaria la fusión anterior en pacientes con fracturas por estallido toracolumbares neurológicamente intactas? Una revisión sistemática y un metaanálisis

Palabras clave:
Fractura toracolumbar neurológicamente intacta
Fractura por estallido
Fusión espinal anterior
Fusión espinal posterior
Fijación con tornillos pediculares

RESUMEN

Objetivos: Realizar una revisión sistemática y un meta análisis de un solo brazo para evaluar y comparar los indicadores radiológicos, así como los resultados a corto y largo plazo, en pacientes con fracturas por estallido toracolumbar (TLBF) sin déficit neurológico que se sometieron a fusión anterior, procedimientos combinados de fusión anterior-posterior o fijación con tornillos pediculares de segmento corto (PSF).
Métodos: Se llevó a cabo una revisión sistemática siguiendo las directrices PRISMA. Los criterios de inclusión incluyeron artículos publicados entre 2004 y 2023, disponibilidad del texto completo en inglés, fracturas por estallido sin lesiones de la médula espinal o raíces nerviosas al ingreso, PSF de segmento corto sin fusión, métodos de fusión anterior o combinada, pacientes de 18 años o más, y un seguimiento mínimo de 12 meses.
El metanálisis se realizó utilizando el software Comprehensive Meta-Analysis. Mediante un método de metanálisis de un solo brazo, se determinaron los indicadores combinados de los resultados a corto y largo plazo para cada grupo estudiado. Los datos obtenidos se compararon luego mediante una comparación simple.
Resultados: El ángulo medio de Cobb combinado al ingreso para los grupos de fusión anterior, combinada y PSF fue de 18,2° (IC del 95%, 14,6-21,8), 11,70° (IC del 95%, 9,7-13,5) y 17,1° (IC del 95%, 15,1-19,1), respectivamente. La fusión anterior logró una mayor corrección de la cifosis en todos los grupos, pero solo el grupo combinado mostró una pérdida no significativa de la corrección después del alta (SMD = 0,809 [IC del 95%, 0,270, 1,348]). La tasa de compresión del cuerpo vertebral anterior al ingreso fue del 55,2% (IC del 95%, 46,3-64,0) en el grupo combinado y del 37,8% (IC del 95%, 33,7-41,9) en el grupo PSF.
El tiempo operatorio, la pérdida de sangre y la duración de la hospitalización fueron más bajos en el grupo PSF percutáneo, con medias de 96,5 minutos (IC del 95%, 82,4-110,6), 83,8 ml (IC del 95%, 71,7-95,9) y 6,6 días (IC del 95%, 4,7-8,5), respectivamente. Todas las técnicas demostraron una incidencia similar de infecciones profundas de heridas y complicaciones relacionadas con los implantes.
Los puntajes combinados del Índice de Discapacidad de Oswestry (ODI) fueron 17,2 (IC del 95%, 10,4-23,9) para el grupo de fusión anterior, 15,4 (IC del 95%, 11,5-19,3) para el grupo combinado y 13,4 (IC del 95%, 10,4-16,3) para el grupo PSF.
Conclusiones: Para pacientes con fracturas por estallido toracolumbar sin déficit neurológico, con un ángulo cifótico menor de 19,10° y una tasa de compresión del cuerpo vertebral anterior menor de 41,9%, la fijación con tornillos pediculares de segmento corto sin fusión puede ser la opción preferida debido a la menor pérdida de sangre intraoperatoria, la duración más corta de la operación, la estancia hospitalaria más breve y mejores puntajes ODI en el seguimiento final. La fusión anterior de rutina ha demostrado un alto potencial para corregir

la cifosis. La pérdida del ángulo de Cobb desde la cirugía hasta el seguimiento final fue no significativa solo en los pacientes que se sometieron a una cirugía combinada. Al determinar el abordaje quirúrgico, los cirujanos deben sopesar cuidadosamente las ventajas de la fusión anterior y combinada frente al trauma quirúrgico significativamente mayor en comparación con la PSF estándar.

Introduction

Despite over 40 years of experience with decompressive and fusion surgeries in the thoracic and lumbar spine, the question of selecting the optimal surgical approach for thoracolumbar burst fractures (TLBF) without neurological deficit remains unresolved. Currently, these approaches can be categorized into three types: posterior, anterior, and combined interventions. Most authors who have utilized anterior and combined approaches highlight several advantages over standard pedicle screw fixation (PSF): greater potential for angular correction, shorter length of spinal fusion, higher fusion rates, and broader possibilities for decompression.[1–5] However, current recommendation protocols[6,7] do not provide clear data on the advantages or disadvantages of anterior versus posterior approaches. Consequently, the choice of treatment method is primarily based on the surgeon's personal experience and the standards adopted in their neurosurgical clinic.

Over the past 14 years, ten systematic reviews and meta-analyses comparing anterior and posterior approaches for TLBF have been published, indicating the sustained high interest of surgeons in this issue.[8–17] However, these meta-analyses have a significant limitation: they compare heterogeneous patient samples, including both cases with and without neurological deficits. We did not find any comparative or single-arm meta-analyses specifically dedicated to the choice of surgical treatment method for patients with neurologically intact TLBF.

Objectives

To conduct a systematic review and single-arm meta-analysis to evaluate and compare radiological indicators, as well as short-term and long-term outcomes, in patients with neurologically intact TLBF who underwent anterior fusion, combined anterior-posterior procedure, or short-segment PSF.

Material and methods

Study selection

A systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[18] The search strategy for the PubMed database included the following keywords: (Lumbar vertebrae [MeSH] OR Thoracic vertebrae [MeSH] OR spine [MeSH] OR Thoracolumbar [TIAB] OR thoraco-lumbar [TIAB] OR thoraco lumbar [TIAB] OR burst [Title]) AND (Injur* [TIAB] OR trauma* [TIAB] OR fractur* [TIAB] OR dislocation* [TIAB]) NOT animal [MeSH] NOT comment [PT] NOT letter [PT] NOT editorial [PT] NOT news [PT] NOT "newspaper article" [PT] NOT osteoporosis [MH] NOT osteoporotic fractures [MH] NOT osteoporo* [TITLE] NOT spinal neoplasms [MH] NOT tumor* [TITLE] NOT malignan* [TITLE].

The inclusion criteria were as follows: 1) articles published between January 1, 2004, and December 31, 2023; 2) full-text availability in English; 3) fractures classified as type A3 or A4 according to the AOSpine classification, or types A, B, or C burst fractures as per the Denis classification, or instances where the author explicitly identifies the presence of a "burst fracture," irrespective of classification; 4) no spinal cord or nerve root injuries present at the time of patient admission; 5) short-segment PSF without fusion, anterior or combined fusion methods; 6) patient age of 18 years or older; 7) description of treatment outcomes or complications; 8) a minimum mean follow-up period of 12 months. Articles failing to meet these criteria were excluded from the systematic review.

The article search and selection process is illustrated in Fig. 1.

Data collection

Data from each article were recorded in the corresponding cells of a table. Basic information included sample size, average patient age, gender distribution, diagnosis, and mechanism of injury. The primary data block included details on the surgical method (anterior, posterior, or combined), PSF techniques (percutaneous or midline approaches), surgery duration, blood loss, radiological indicators at admission, post-surgery, and during the final follow-up, complications, length of hospital stay, severity of pain using the Visual Analogue Scale (VAS), and quality of life at the final follow-up as measured by the Oswestry Disability Index (ODI).

For radiological assessments, recorded parameters included the degree of kyphotic deformation of the affected segment using the Cobb angle, the percentage of compression of the anterior margin of vertebral body (AVBCR) relative to unaffected segments, and the degree of spinal canal stenosis determined by the mid-sagittal diameter.[19]

Statistical analysis

Statistical analysis was performed using the PC STATISTICA software (Version 10) (StatSoft® Inc., USA). The normality of data distribution was assessed using the Shapiro-Wilk test.

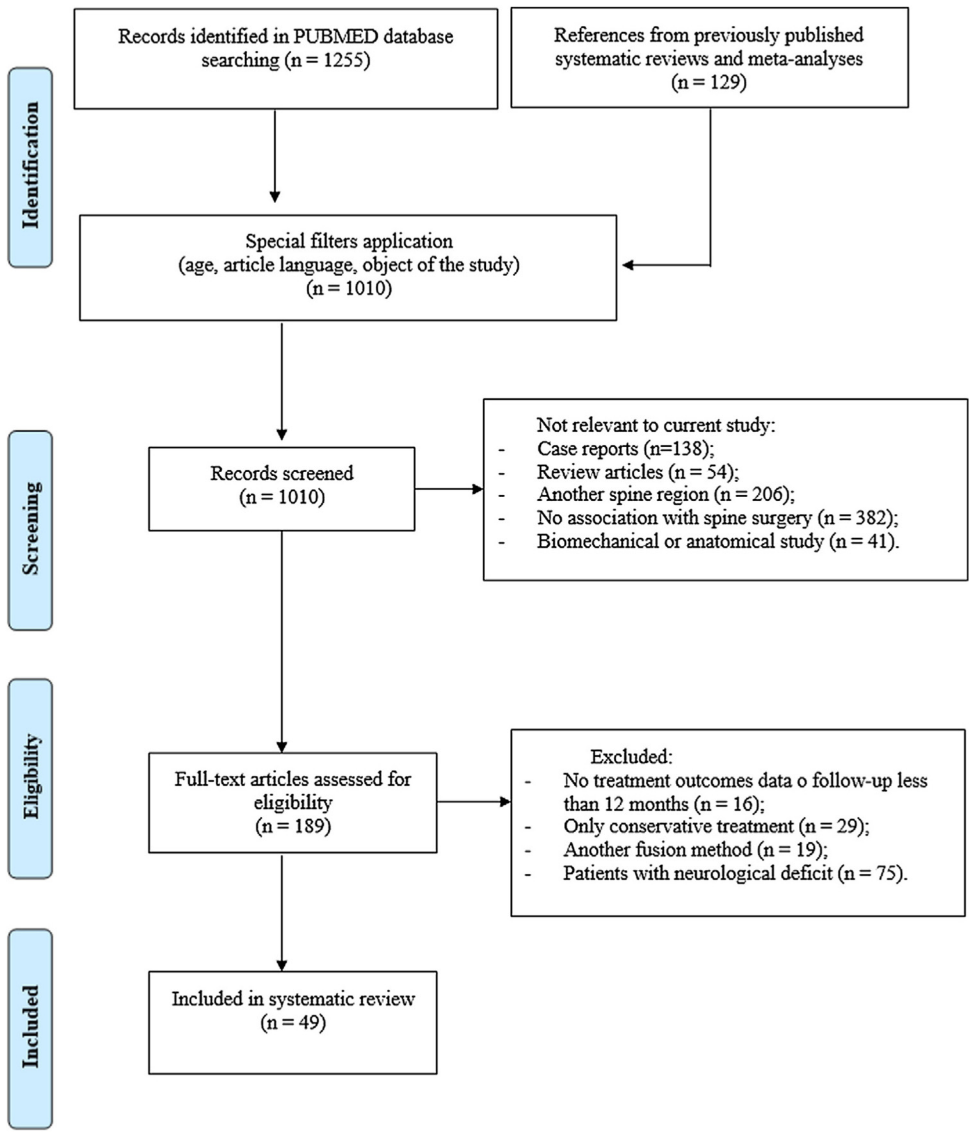

Fig. 1 – PRISMA flowchart for study selection.

Comparison of continuous data with non-normal distribution was conducted using the Kruskal-Wallis test. Statistical hypothesis testing was performed at a critical significance level of $p = 0.05$.

Meta-analysis was carried out using Comprehensive Meta-Analysis software, version 2.2.064 (Biostat, Englewood, NJ, USA). Heterogeneity was assessed using the I^2 test. Heterogeneity was considered low if I^2 was below 50%, moderate between 50%–75%, and high above 75%.[20] If there was no evidence of significant statistical heterogeneity among studies (Cochrane Q-test, $p > 0.10$), a fixed-effects model was used. Otherwise, a random-effects model (DerSimonian and Laird) was applied. Publication bias was acknowledged if Begg's test yielded $p < 0.05$. In the absence of publication bias, results were presented as forest plots. If publication bias was detected, it was addressed using the trim-and-fill method.[21]

When comparing radiological indicators at admission, post-surgery, and final follow-up, the standardized mean difference (SMD) was used, with results presented as 95% confidence intervals (CI). A statistically significant difference was considered if the entire interval was strictly greater than or less than zero.

Results

An initial search in the PubMed database identified 1255 articles. After applying filters for age and language, the remaining abstracts were reviewed. As a result of the initial search, 189 studies were selected for full-text review, and 49 studies were included in the present analysis. Of these, 35 articles (57 groups, 1552 patients) described the experience of short-segment PSF without fusion,[22–55] 9 articles (11 groups, 212 patients) followed combined fusion,[3,4,56–62] and 5 articles (6 groups, 93 patients) presented the anterior approach.[1,2,5,63,64]

In all compared groups, most patients were male. The median value for average age across all groups ranged between 40–45 years (Table 1). The main demographic indicators in

Table 1 – General characteristics of patient groups.

Parameters	Anterior fusion	Combined fusion	PSF	p*
Demographics				
Number of patients groups	6	11	57	–
Number of patients	93	212	1552	–
Male/female, %	65.5/34.5	56.6/43.4	62.6/37.4	0.310
Median age [Q1–Q3]	42.0 [40.7–44.4]	42.5 [37.1–44.6]	44.8 [41.4–49.1]	0.428
Injury mechanism				
RTA, %	56.9	18.9	43.6	0.014
Catatrauma, %	41.4	40.0	42.1	0.887
Sports trauma, %	0	26.7	4.3	0.002
Others, %	1.7	14.4	10.0	0.203

PSF, pedicle screw fixation; RTA, road traffic accident.

* Kruskal–Wallis test.

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Wood et al., 2003 ANT	-0.462	0.585	0.342	-1.608	0.685	-0.789	0.430
Wood et al., 2005 anterior	-0.521	0.322	0.103	-1.151	0.110	-1.619	0.105
Eleraky et al., 2011 Group 1	-1.210	0.385	0.148	-1.964	-0.456	-3.146	0.002
Eleraky et al., 2011 Group 2	-1.270	0.388	0.150	-2.030	-0.511	-3.277	0.001
Wu et al., 2013 anterior	0.073	0.289	0.083	-0.493	0.639	0.252	0.801
	-0.658	0.279	0.078	-1.205	-0.110	-2.355	0.019

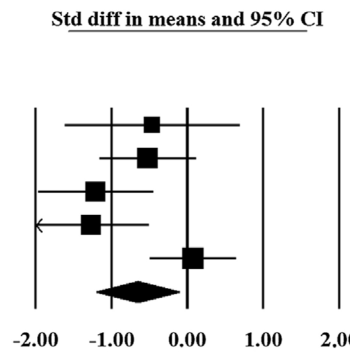

Fig. 2 – Forest plot showing the SMD for the change in Cobb angle from postoperative to final follow-up in patients after anterior approach. $I^2 = 63.8\%$; Q-test, p = 0.026; Begg's test, p = 0.142.

the anterior or combined approaches and PSF groups did not differ significantly. In the combined fusion group, sports injuries were observed more frequently; however, this may be attributed to the smaller number of patient groups included in the study. The characteristics of each study used in the meta-analysis are presented in Tables A1 and A2.

In both cases in the anterior approach group, surgery was performed using routine transthoracic or retroperitoneal approach. Following corpectomy, only one patient group[2] received an expandable cage. Two patient groups[1,2] used mesh cages with auto- and allograft bone fragments, while two others[5,64] used only auto- and allografts. One author did not specify the details of the anterior surgery.[63]

In contrast, within the combined approach group, only one author[61] utilized a routine open anterior approach. The other patient groups[3,4,56–60,62] employed thoracoscopic surgery, video-assisted techniques, or minimally invasive thoracotomy or retroperitoneal approaches. Most authors[3,4,58,59] preferred to divide the surgery into two stages, with a few days between them. In five patient groups,[57,60,62] stable patients without associated trauma or complications underwent a single-stage surgery. Two authors[56,61] did not specify the detailed sequence of the surgical treatment.

Both patients in the PSF group underwent short-segment PSF without fusion. Of these, 33 groups (921 patients) were treated using a percutaneous technique.

Meta-Analysis of radiological indicators

In the anterior approach group, the pooled mean for the Cobb angle at admission was 18.2° (95% CI, 14.6−21.8) (Tables 2 and A3). Surgery resulted in a significant reduction of kyphosis by 13.3° (SMD = 2.558 [95% CI, 0.718–4.398]). At the final follow-up, there was an increase in the pooled mean by 2.2°, though this was statistically significant (SMD = -0.658 [95% CI, −1.205, −0.110]) (Fig. 2).

For patients who underwent the combined approach, the pooled mean for the Cobb angle at admission was 11.7° (95% CI, 9.7−13.5) (Tables 2 and A4). The combined intervention significantly reduced it by 10.4° (SMD = 0.809 [95% CI, 0.270, 1.348]). Follow-up visits noted an increase in the pooled mean by 3.6°, which was nonsignificant (SMD = 0.008 [95% CI, -0.507, 0.523]) (Fig. 3).

In the PSF group, the pooled mean for the Cobb angle at admission was 17.1° (95% CI, 15.1–19.1) (Tables 2 and A5). Postoperatively, there was a significant reduction by 10.5° (SMD = 1.873 [95% CI, 1.572, 2.173]). At the final follow-up, compared to postoperative data, there was an increase in the pooled mean by 3.7°, which was statistically significant (SMD = −0.582 [95% CI, −0.810, −0.354]) (Fig. 4).

AVBCR was not estimated for the anterior fusion group due to insufficient data for creating a forest plot. In the combined surgery group, the pooled mean for AVBCR at admission was 55.2% (95% CI, 46.3–64.0). For the PSF group, the pooled mean

Table 2 – Pooled indicators for patients groups.

Parameters	Anterior fusion	Combined fusion	PSF		
			All patients	MIS	Open
Radiological indicators					
Cobb angle at admission, °	18.2	11.7	17.1	–	–
Cobb angle post-surgery, °	4.9	1.3	6.6	–	–
Cobb angle at final follow-up, °	7.1	4.9	10.3	–	–
AVBCR, %	n/a	55.2	37.8	–	–
Spinal canal stenosis, %	41.5	35.9	46.3	–	–
Cobb angle dynamics					
Cobb angle decreasing at discharge, °	−13.3	−10.4	−10.5	–	–
Cobb angle increasing after discharge, °	+2.2	+3.6	+3.9	–	–
Overall Cobb angle dynamics, °	−11.1	−6.8	−6.6	–	–
Intraoperative indicators and hospital stay					
Operation time, minutes	204.2	161.8	–	96.5	120.1
Blood loss, ml	512.9	721.1	–	83.8	233.7
Length of stay, days	n/a	15.4	–	6.6	12.3
Complications					
Superficial wound infection rate, %	3.0	2.8	2.2	–	–
Deep wound infection rate, %	3.0	3.0	2.0	–	–
Implant-related complications, %	4.4	5.4	5.6	–	–
Long-term results					
Fusion rate, %	92.9	90.6	–	–	–
Pseudoarthrosis rate, %	7.1	8.1	–	–	–
Non-union rate, %	–	3.1	–	–	–
Fracture healing, %	–	–	93.7	–	–
VAS	2.8	n/a	1.8	–	–
ODI	17.2	15.4	13.4	–	–

AVBCR, anterior vertebral body compression rate; n/a, not available; MIS, minimally invasive (percutaneous) surgery; ODI, Oswestry disability index; PSF, pedicle screw fixation; VAS, visual analogue scale of pain.

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Ray et al., 2013	-0.330	0.288	0.083	-0.894	0.234	-1.148	0.251
Briem et al., 2014 combined	-1.209	0.486	0.237	-2.162	-0.256	-2.486	0.013
Kreinest et al., 2017	-0.156	0.207	0.043	-0.561	0.249	-0.755	0.450
Scholz et al., 2017 Intervention	0.023	0.535	0.286	-1.024	1.071	0.044	0.965
Lindtner et al., 2018 Bi ACR	0.729	0.350	0.123	0.042	1.415	2.080	0.038
Lindtner et al., 2018 Mono ACR	0.807	0.352	0.124	0.117	1.496	2.294	0.022
	0.008	0.263	0.069	-0.507	0.523	0.030	0.976

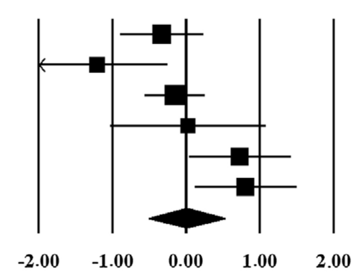

Fig. 3 – Forest plot showing the SMD for the change in Cobb angle from postoperative to final follow-up in patients after combined approach. $I^2 = 71.7\%$; Q-test, $p = 0.003$; Begg's test, $p = 0.851$.

for AVBCR was 37.8% (95% CI, 33.7–41.9). Because corpectomy was performed in most patients in the anterior and combined fusion groups, this parameter was not estimated post-surgery.

The pooled mean for the percentage of spinal canal stenosis, due to the absence of postoperative data, was calculated only at admission and ranged from 42% to 46% for all three groups (Tables 2, A3–A5).

Meta-analysis of intraoperative indicators and hospitalization duration

The pooled mean operative time for the anterior and combined groups was 204.2 min (95% CI, 148.7−259.7) and 161.8 min (95% CI, 134.2−189.4), respectively. For the open and percutaneous PSF groups, the operative time was lower (Table 2), at 120.1 min (95% CI, 108.3–131.9) and 96.5 min (95% CI, 82.4–110.6), respectively.

The pooled mean blood loss was 512.9 ml (95% CI, 4.8–1030.6) for anterior approaches and 721.1 ml (95% CI, 14.9–1457.2) for combined approaches. For the open and percutaneous PSF groups, blood loss was also lower (Table 2), at 233.7 ml (95% CI, 171.5–295.9) and 83.8 ml (95% CI, 71.7–95.9), respectively.

The pooled mean hospitalization duration for patients after combined approach was 15.4 days (95% CI, 13.3−17.5), respectively. Insufficient data was available to calculate this parameter for the anterior group patients. For patients after open PSF, the pooled hospitalization duration was similar, at

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Hwang et al., 2009 non-fusion	-1.288	0.249	0.062	-1.776	-0.801	-5.177	0.000
Lakshmanan et al., 2009	-1.193	0.301	0.091	-1.783	-0 603	-3.964	0.000
Lee et al., 2009 group 1-2	-0.415	0.280	0.079	-0.964	0.134	-1.480	0.139
Liao et al., 2009	-0.995	0.401	0.161	-1.780	-0.210	-2.483	0.013
Ni et al., 2010	-0.601	0.241	0.058	-1.074	-0.129	-2.496	0.013
Li et al., 2012 SSPI	-0.065	0.258	0.067	-0.572	0.441	-0.254	0.800
Zhang et al., 2013	-0.327	0.285	0.081	-0.885	0.231	-1.147	0.251
Chou et al., 2014 non-fusion	-2.055	0.373	0.139	-2.785	-1.325	-5.514	0.000
Vanek et., 2014 MIS	-0.429	0.337	0.114	-1.090	0.232	-1.273	0.203
Lin et al., 2016 Group A	-0.939	0.333	0.111	-1.592	-0.286	-2.819	0.005
Lin et al., 2016 Group B	-0.346	0.256	0.065	-0.848	0.155	-1.353	0.176
Lin et al., 2016 Group C	-0.904	0.332	0.110	-1.554	-0.253	-2.722	0.006
Fan et al., 2017 PPSF	-0.086	0.178	0.032	-0.435	0.264	-0.481	0.631
Zhao et al., 2018	-0.043	0.229	0.053	-0.493	0.406	-0.189	0.850
Oh and Seo., 2019	-0.284	0.259	0.067	-0.793	0.224	-1.095	0.274
Yang et al., 2019 MIS	-1.637	0.272	0.074	-2 171	-1.103	-6.011	0.000
Yang et al., 2019 OPPF	-1.210	0.256	0.066	-1.713	-0.708	-4.720	0.000
Alkosha et al., 2020 TLICS 3 PSF	0.000	0.408	0.167	-0.800	0.800	0.000	1.000
Alkosha et al., 2020 TLICS 4 PSF	0.000	0.333	0.111	-0.653	0.653	0.000	1.000
Alkosha et al., 2020 TLICS 5 PSF	-0.500	0.415	0.172	-1.313	0.313	-1.206	0.228
Collinet et al., 2020	-0.149	0.263	0.069	-0.664	0.367	-0.566	0.572
Cheng et al., 2023	-0.093	0.408	0.167	-0.894	0.708	-0.228	0.820
Perna et al., 2023 Group A	-0.130	0.157	0.025	-0.439	0.178	-0.828	0.407
	-0.582	0.116	0.014	-0.810	-0.354	-5.005	0.000

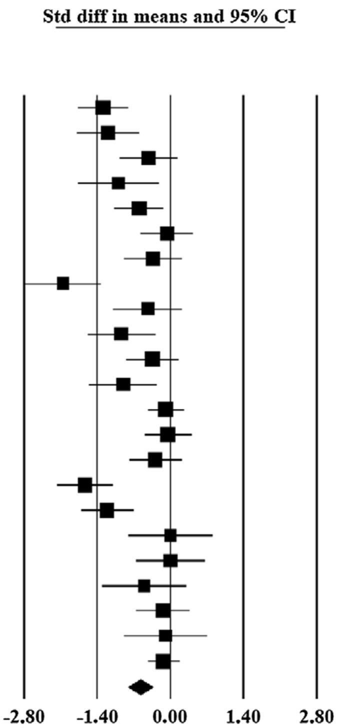

Fig. 4 – Forest plot showing the SMD for the change in Cobb angle from postoperative to final follow-up in patients after PSF. $I^2 = 75.2\%$; Q-test, $p < 0.001$; Begg's test, $p = 0.162$.

12.3 days (95% CI, 11.2–13.4). A clear advantage (Table 2) was observed for patients after percutaneous PSF, with a duration of 6.6 days (95% CI, 4.7–8.5).

Meta-analysis of complications and long-term outcomes

Surgery-related complications in the anterior approach group were infrequent and observed in only a few patients. The pooled prevalence of superficial and deep wound infections, as well as implant-related complications, was 3.0% (95% CI, 0.8–11.4), 3.0% (95% CI, 0.8–11.4), and 4.4% (95% CI, 1.3–14.1), respectively.

In the combined surgery group, all wound complications were associated with the posterior approach. In this group, the pooled prevalence of superficial and deep wound infections was 2.8% (95% CI, 1.2–6.7) and 3.0% (95% CI, 1.3–7.1), respectively (Table A4). The pooled prevalence of implant-associated complications (pedicle screw and vertebral body prosthesis migration) in this group was 6.5% (95% CI, 2.7–14.5). In the PSF group, the pooled prevalence for complication rates was similar (Tables 2 and A5), at 2.2% (95% CI, 1.5–3.1), 2.0% (95% CI, 1.4–3.1), and 5.6% (95% CI, 4.3–7.3), respectively.

No cases of postoperative neurological deterioration were identified in any of the patient groups.

In the anterior and combined approach groups, the pooled prevalence for the fusion rate was similar, at 92.9% (95% CI, 82.4−97.3) and 90.6% (95% CI, 80.2−95.9), respectively (Tables 2, A3, and A4). The fracture healing rate with PSF without fusion was also high, at 93.7% (95% CI, 89.5–96.3).

In the anterior approach group, the pooled mean for the VAS score was 2.8 (95% CI, 1.9–3.6) (Table A3). In the combined approach group, there was insufficient data to create a forest plot. The pooled means for the ODI in the anterior and combined approach groups were 17.2 (95% CI, 10.4−23.9) and 15.4 (95% CI, 12.2−18.6), respectively. For patients after PSF in the long-term post-trauma period, these scores were lower (Table 2), at 1.8 (95% CI, 1.2–2.3) and 13.4 (95% CI, 10.4–16.3), respectively.

Discussion

A significant motivation for conducting this study was the lack of a systematic review specifically addressing neurologically intact TLBF. Almost all previously published meta-analyses have a major drawback—they mix patients with and without spinal cord injuries. In our view, this mixing of patient groups is not always appropriate for several reasons. First, fractures involving spinal cord injuries are often associated with a higher degree of bony destruction and fragment displacement into the spinal canal. Second, in these injuries, most patients require decompression, which significantly increases the surgical trauma and further destabilizes the spinal motion segment. Third, long-term clinical outcomes for patients with an initial ASIA grade A and E can differ substantially, even with excellent postoperative results.

At the same time, as shown in a series of studies, decompression may not be necessary in cases of neurologically intact TLBF. The resorption of fragments can occur with conservative treatment,[65] as well as after short-segment PSF without intervention into the spinal canal.[66] This fact could be a significant counterargument when considering anterior fusion techniques in these patients.

During this systematic review, we encountered a significant lack of comparative studies, which affected the methodology of the meta-analysis. In previously published comparative meta-analyses, the number of included studies varied from 3 to 16. Groups of patients with only neurologically intact fractures reduced this number to 2, which does not allow for a fully adequate comparison. Therefore, we chose an alternative comparison method, which allowed us to include 49 articles. Initially, we formed several patient groups based on the approach used (short-segment PSF without fusion, anterior, and combined fusion). Then, using a single-arm meta-analysis method, we determined the pooled indicators of short- and long-term outcomes for each group. After that, we compared the obtained data using simple comparison.

For example, comparisons of intraoperative blood loss, operative time, and hospitalization duration demonstrated clear advantages of posterior methods and fully support the findings of previous studies.[8–17] Most patients who underwent the anterior approach had a corpectomy, which increased the invasiveness of the procedure, lengthened the surgery, and resulted in additional blood loss. Consequently, patients who underwent percutaneous PSF demonstrated clear advantages of this method in reducing blood loss, operative time, and hospital stay duration.

One of the objectives of this systematic review was to evaluate radiological outcomes at all stages of treatment. Previously published meta-analyses have shown conflicting results. Some studies indicated the advantages of combined interventions in intraoperative correction of kyphotic deformity[11] or in maintaining the achieved correction.[10] In one meta-analysis,[9] the author demonstrated the advantages of the PSF method. In the remaining studies,[12–16] no significant difference was found between anterior and posterior approaches in kyphosis correction and the maintenance of the achieved result.

In the present study analysis of the pooled means of radiological indicators yielded the following results: the pooled mean Cobb angle at admission was higher in patients who underwent the anterior approach and PSF, consistent with recent data from the network meta-analysis by Duan et al.[17] The anterior approach demonstrated a greater capacity for reducing kyphotic deformity (13.3°), despite the limited use of distractive implants. This could be attributed to the facilitation provided by corpectomy, patient positioning on the side, and the possibility of direct visual control during repositioning. Furthermore, all pure anterior procedures were performed through a routine open approach. It is possible that minimally invasive techniques might yield different results for this patient group.

The degree of kyphosis correction loss post-surgery was nonsignificant in the combined surgery group, indicating the effectiveness of the PSF and anterior fusion combination in maintaining the load-bearing capacity of the anterior spinal column.

Regarding AVBCR, we could not estimate the pooled mean for this parameter in the anterior fusion group because none of the authors reported it in their patients. For the PSF group, the 95% confidence interval was limited to 42%. For the combined fusion group, AVBCR was higher (up to 64% within the 95% confidence interval); however, this result may be significantly limited by the fact that only two articles provided the mean value with SD. Thus, we cannot reliably state that the combined fusion method was used in patients with a higher degree of vertebral body compression.

Complications were analyzed in five meta-analyses. In one study,[8] the complication rate was significantly lower in the PSF group, while in another, it was lower after anterior approaches.[9] In the other three studies,[10,15,17] no significant difference in complication rates was found. None of the studies analyzed complications by group, mixing infectious and implant-associated complications, making precise interpretation of the results difficult.

In the present meta-analysis, the pooled prevalence of superficial and deep infections, as well as implant-related complications, showed no differences between the groups. In the anterior fusion group, the authors of one study[62] did not specify the exact type of implant-related complication that led to reoperation using a posterior approach a few days after the initial surgery. In the combined fusion group, implant-related complications were mainly related to PSF, as well as to cortical breaches by the titanium prosthesis.

Long-term outcomes were assessed in seven meta-analyses. The authors compared pain severity using the VAS[10,11,15,17] and time to return to work.[9,12,13,16] None of the studies found a significant difference between anterior and posterior approaches. In our meta-analysis, we were able to calculate pooled prevalence for fusion rates and the Oswestry Disability Index as well. Better results were obtained for the group of patients with short-segment PSF. Specifically, after PSF, the ODI score was up to 25% better than after anterior approaches.

Thus, a simple comparison of pooled measures demonstrated an advantage of the routine open anterior approach in reducing kyphotic deformity. and the combined approach group demonstrated a nonsignificant loss of kyphosis correction post-surgery. Given the significantly higher intraoperative trauma, with a substantial prolongation of anesthesia time and increased blood loss for anterior and combined procedures, and the comparable or even better ODI scores at the final follow-up for the PSF group, we believe that the benefits of kyphosis correction may be negated.

We assume that the high effectiveness of standard PSF is because, in patients with A3 and A4 type fractures according to the AOSpine classification, the posterior tension band remains intact after the injury in most cases. Moreover, this tension band is not disrupted by laminectomy, as it often is in patients with spinal cord compression. This, in our opinion, explains the relatively high fracture healing rate in patients with neurologically intact TLBF following standard rigid external or internal immobilization. In this context, in some patients with relatively low vertebral compression and kyphosis, performing an anterior corpectomy may not offer greater advantages or lead to better clinical outcomes.

Limitations of the study

A limitation of this meta-analysis is the consolidation by most authors of the included studies of all burst fractures into a single category, which includes A3 and A4 fractures according to the AOSpine classification, as well as types A, B, and C injuries according to the Denis classification. Distinguishing TLBF into more specific subtypes would have facilitated a more detailed analysis of the outcomes.

We also selected a 20-year time frame for the inclusion of publications. Given the follow-up periods, the earliest group of included patients underwent surgery starting in 1992. Considering that percutaneous fixation and modern instrumentation for anterior approaches only became widely adopted in the 1990s, we decided not to include earlier articles in the meta-analysis.

Another limitation is the relatively low number of patients in the anterior and combined fusion groups. A larger sample size could provide more precise pooled estimates. However, in the absence of publication bias and outliers, the pooled parameters are unlikely to differ significantly, even with a larger patient cohort.

A significant limitation of this meta-analysis is the absence of included studies with a high level of evidence and the methodology of simple comparison of pooled means. While this methodology does not allow conclusions to be drawn with a high level of evidence, the relatively high precision of the pooled indicators provides surgeons with a clearer understanding of the effectiveness and safety of the techniques studied.

Conclusions

For patients with neurologically intact thoracolumbar burst fractures, with a kyphotic angle of less than 19.1° and an anterior vertebral body compression rate of less than 41.9%, short-segment pedicle screw fixation without fusion may be preferable option due to reduced intraoperative blood loss, shorter operation duration, shorter hospital stay, and better ODI scores at final follow-up. Routine anterior fusion has demonstrated high potential for kyphosis correction. The loss of the Cobb angle from surgery to final follow-up was non-significant only in patients who underwent combined surgery. When determining the surgical approach, surgeons should carefully weigh the advantages of anterior and combined fusion against the significantly higher surgical trauma compared to standard PSF. Further prospective randomized trials are needed to provide high-quality evidence for selecting the optimal treatment method in patients with neurologically intact thoracolumbar burst fractures.

Funding

No special funding was received in support of this study. No benefits in any form have been or will be received from a commercial party related directly or indirectly to this manuscript.

Appendix A.

Table A1 – Characteristics of patient groups at hospital stage.

Study	Number of patients	Approach	Cobb angle at admission, °	AVBCR at admission, %	Canal stenosis at admission, %	OpT, minutes	BL, ml	Cobb angle after surgery, °	LoS, days
Wood et al., 2003 ANT[64]	6	Anterior	8.1 ± 14.8		46.8 ± 15.9			6.8 ± 13	
Briem et al., 2004 combined[55]	10	Combined	11.3 ± 2.8					5.9 ± 3.0	
Wood et al., 2005 anterior[5]	20	Anterior	10.5 ± 10.6		39.5 ± 15.7	232.9 ± 35.9	783.5 ± 370.4	4.8 ± 9	7.2 ± 1.2
Wild et al., 2007[21] MIS group	10	MIS PSF				87.4 ± 17.6	194.4 ± 72.6		
Wild et al., 2007[21] Open group	11	Open PSF				80.9 ± 18.3	380 ± 198.9		
Hwang et al., 2009[22] non-fusion group	39	Open PSF	20.8 ± 6.4		39.2 ± 19.3	117 ± 33	315 ± 57	8.2 ± 4.8	11.6 ± 3.8
Lakshmanan et al., 2009[23]	26	Open PSF	19.6 ± 8.3					6.3 ± 8.9	
Lee et al., 2009[24] group 1–2	26	Open PSF	19.0 ± 7.3	35.7 ± 11.9				12.5 ± 8.0	
Liao et al., 2009[25]	14	Open PSF	22.6 ± 5.9	50.4 ± 14	51.4 ± 13.3	159.1 ± 30.2	221.4 ± 150.3	3.1 ± 3.2	12.9 ± 3.3
Ni et al., 2010[26]	36	MIS PSF	18.7 ± 7.1	42.2 ± 5.8		78	75	3.6 ± 6.5	5
Blondel et al., 2011[27] group 1	22	MIS PSF	13.0					3.2	
Blondel et al., 2011[27] group 2	7	MIS PSF	12.1					2.6	
Eleraky et al., 2011 Group 1[2]	16	Anterior	20.5 ± 5.1					6.0 ± 1.8	
Eleraky et al., 2011 Group 2[2]	16	Anterior	21.5 ± 5.2					4.0 ± 1.5	
Jiang et al., 2012[28] Percutaneous group	31	MIS PSF	8.3 ± 5.2	33.38 ± 12.43		79.7 ± 12.7	79 ± 40.4	−1.7 ± 4.0	9.7 ± 0.9
Kim et al., 2012[29]	9	Open PSF		45.6 ± 6.8	55.0 ± 12.0	91	90		
Li et al., 2012[30] SSPI group	30	Open PSF	16.5 ± 9.1			101 ± 28	203 ± 88	7.1 ± 6.9	
Schmid et al., 2012 group B[57]	14	Combined			31.7 ± 20	213 ± 41	1110 ± 790		14.4 ± 6.4
Ray et al., 2013[58]	25	Combined	16.2 ± 6.7	50.7 ± 12.7	42.2 ± 11.8			5.3 ± 4.4	
Wang et al., 2013[31]	26	MIS PSF	15.0						
Wu et al., 2013 anterior[1]	24	Anterior	21.2 ± 5.7			176.3 ± 20.7	255.1 ± 38.4	4.8 ± 1.6	
Zhang et al., 2013[32]	25	Open PSF	17.1 ± 7.1	38.0 ± 10.5	25.0 ± 5.8	84.2 ± 13.9	245.2 ± 74.1	4.2 ± 3.0	
Chou et al., 2014[33] non-fusion group	22	Open PSF	16.4 ± 6.6					1.5 ± 5.3	
Proietti et al., 2014 [34]	60	MIS PSF							
Takami et al., 2014[35]	21	MIS PSF	8.5			95.7 ± 21.9	40.7 ± 33.5	−4.2	
Vanek et al., 2014[36] MIS group	18	MIS PSF	9.3 ± 10.1			53 ± 10	56 ± 17	0.3 ± 9.7	
Zhao et al., 2015[37] PFFV group	32	Open PSF	19.8 ± 7.3	37.31 ± 10.83		115.7 ± 12.8	229.1 ± 28.3	7.1 ± 3.3	
Zhao et al., 2015[37] TSSF group	35	Open PSF	20.5 ± 6.1	39.43 ± 10.12		93.1 ± 10.9	218.9 ± 20.4	8.0 ± 3.6	
Fu et al., 2016[38] OPSF-4 group	14	Open PSF	9.2 ± 5.9	31.2 ± 11.3		89.2 ± 18.9	251.4 ± 132.8		
Fu et al., 2016[38] OPSF-6 group	41	Open PSF	12.1 ± 6.3	33.9 ± 13.6		100.7 ± 21.3	236.1 ± 123.8		
Fu et al., 2016[38] PPSF-4 group	16	MIS PSF	14.3 ± 6.9	32.7 ± 10.8		88.8 ± 16.4	97.5 ± 27.9		
Fu et al., 2016[38] PPSF-6 group	13	MIS PSF	9.9 ± 4.0	31.0 ± 10.9		98.8 ± 18.5	110 ± 10.7		
Hitchon et al., 2016[59]	11	Anterior							
Lin et al., 2016[39] Group A	20	Open PSF	22.3 ± 6.6	53.4 ± 12.5	52.7 ± 12.5	142 ± 57.2	101.7 ± 72.5	5.6 ± 4.8	11.5 ± 3.8
Lin et al., 2016[39] Group B	31	Open PSF	20.9 ± 9.2	49.1 ± 11.2	48.1 ± 16.5	227.2 ± 43.6	600 ± 403.1	3.7 ± 7.8	13.7 ± 3.9
Lin et al., 2016[39] Group C	20	Open PSF	21.7 ± 6.7	49.7 ± 14.8	53.5 ± 14	161.7 ± 28.5	247.5 ± 164.2	2.4 ± 5.1	13.7 ± 2.3
Fan et al., 2017[40] PPSF group	63	MIS PSF	20.1 ± 8.3			72.5 ± 7.7	54 ± 17.2	6.4 ± 7.1	
Kreinest et al., 2017[4]	47	Combined	14 ± 7					7.2 ± 6.0	
Mayer et al., 2017[3] PA-F	14	Combined	12.6 ± 6.8						
Mayer et al., 2017[3] POST-I group	22	Open PSF	11.1 ± 6.5						
Scholz et al., 2017 Intervention[60]	7	Combined	11 ± 9.5					3.6 ± 8.5	
Lindtner et al., 2018 Bi ACR[61]	19	Combined	8.6 ± 9.4					−6.5 ± 5.1	21.5 ± 20.5
Lindtner et al., 2018 Mono ACR[61]	18	Combined	6.7 ± 11.6					−7.9 ± 6.6	17.3 ± 10.6
Zhao et al., 2018[41]	38	MIS PSF	18.7 ± 8.6	62.0 ± 6		90.7 ± 21.9	89.2 ± 31.9	5.8 ± 6.8	4.8 ± 1

– Table A1 (*Continued*)

Study	Number of patients	Approach	Cobb angle at admission, °	AVBCR at admission, %	Canal stenosis at admission, %	OpT, minutes	BL, ml	Cobb angle after surgery, °	LoS, days
Gumussuyu et al., 2019 Combined[62]	14	Combined		59.7 ± 17.4	32.8 ± 22.1		358.5 ± 169.5		10.6 ± 5.5
Oh and Seo., 2019[42]	30	MIS PSF	9.1 ± 11.9	28.1 ± 11.2				0.8 ± 14.7	
Trungu et al., 2019[43] ISG group	73	MIS PSF	5.6			56		1.8	3
Trungu et al., 2019[43] nISG group	71	MIS PSF	4.3			40		0.7	3
Yang et al., 2019[44] group A	30	Open PSF	24.0 ± 7.1	37.65 ± 8.28		96.6 ± 8.8	125.0 ± 19.9		9.35 ± 1.5
Yang et al., 2019[44] group B	30	MIS PSF	26.2 ± 6.2	32.8 ± 8.4		51.6 ± 7.1	63.8 ± 13.5		5.15 ± 0.8
Yang et al., 2019[45] MIS group	36	MIS PSF	15.7 ± 7.4	36.4 ± 14.3		134.3 ± 35	90.7 ± 77	6.0 ± 2.5	10.8 ± 2.5
Yang et al., 2019[45] OPPF group	36	Open PSF	16.5 ± 6.5	37.5 ± 12.9		120.6 ± 30.3	350 ± 20.4	5.4 ± 2.6	12.8 ± 2.8
Alkosha et al., 2020[46] ALL						123 ± 24	142 ± 37		2.7 ± 0.5
Alkosha et al., 2020[46] TLICS 3	12	MIS PSF	22 ± 3					17.0 ± 2.0	
Alkosha et al., 2020[46] TLICS 4	18	MIS PSF	21 ± 3					17.0 ± 2.0	
Alkosha et al., 2020[46] TLICS 5	12	MIS PSF	25 ± 2					18.0 ± 2.0	
Collinet et al., 2020[47]	29	MIS PSF	8.5 ± 4.0	23.0 ± 10.0				5.4 ± 4.8	
Kocis et al., 2020[48] OPSF group	23	Open PSF	12.1			52	328.7	−3.8	
Kocis et al., 2020[48] PPSF group	23	MIS PSF	10.9			49.7	29	−4.5	
Shao et al., 2020[49]	22	MIS PSF	16.3	40.5 ± 7.8		65	60	3.7	7
Zou et al., 2020[50] PPS group	29	MIS PSF		62.1 ± 5.1		77 ± 7.6	55.1 ± 13.3		4.4 ± 0.6
Jordan et al., 2021 ICBG[63]	21	Combined				142.4 ± 21.7			16.1 ± 4.3
Jordan et al., 2021 PTFI[63]	23	Combined				133.8 ± 23.2			15.1 ± 7.5
Cheng et al., 2023[51]	12	MIS PSF	14.4 ± 6.7	27.6 ± 9.4		147.2 ± 45.6	67.8 ± 34.2	6.5 ± 4.3	
Hoffman et al., 2023[52] CG group	44	Open PSF							
Hoffman et al., 2023[52] IG group	33	Open PSF							
Perna et al., 2023[53] Group A	81	MIS PSF	11.7 ± 5.6			78 ± 15	121.3 ± 34	8.1 ± 4.4	3.4 ± 2.1
Zhu et al., 2023[54] MIS-F group	39	MIS PSF		32.2 ± 9.8		150.4 ± 13.1	48.3 ± 6.7		9.2 ± 0.9
Zhu et al., 2023[54] MIS-O group	43	MIS PSF		29.2 ± 11.5		126.2 ± 22	46.5 ± 6.1		9 ± 1.4
Zhu et al., 2023[54] Open-C group	48	Open PSF		31.9 ± 10.3		131.3 ± 20.6	105.2 ± 12.6		11.2 ± 1.2

AVBCR, anterior vertebral body compression rate; BL, blood loss; LoS, length of stay; MIS PSF, percutaneous pedicle screw fixation; OpT, operation time; PSF, pedicle screw fixation.

Table A2 – Complications and follow-up results of studied patient groups.

Study	Complications rate, %				Cobb angle at FU,°	Fusion results at FU, %				VAS	ODI
	Posterior SWI	Posterior DWI	Anterior WI	Implant-related		Fusion	Stable fibrous fusion	Non-union	Fracture healing		
Wood et al., 2003 ANT[64]					14.7 ± 20.4					2.4 ± 2.8	22.7 ± 19.3
Briem et al., 2004 combined[55]					8.2 ± 2.8						
Wood et al., 2005 anterior[5]			0	0	10.5 ± 12.6	95	5			2.8 ± 2	20.7 ± 13.3
Wild et al., 2007[21] MIS group	0	0		0					100		
Wild et al., 2007[21] Open group	0	0		0					100		
Hwang et al., 2009[22] non-fusion group				28.2	15.2 ± 6.0					3.4 ± 0.9	
Lakshmanan et al., 2009[23]					15.7 ± 6.7						
Lee et al., 2009[24] group 1–2	0	0		3.9	15.6 ± 6.9						
Liao et al., 2009[25]	0	0			7.1 ± 4.7						
Ni et al., 2010[26]	3.9	0		3.9	7.6 ± 6.8						
Blondel et al., 2011[27] group 1	0	0		0	5.2						
Blondel et al., 2011[27] group 2	0	0		0	3.6						
Eleraky et al., 2011 Group 1[2]			0	0	8.5 ± 2.3	87.5	12.5				
Eleraky et al., 2011 Group 2[2]			0	0	6.5 ± 2.4	100					
Jiang et al., 2012[28] Percutaneous group	0	0		0						3.6 ± 0.3	13.5 ± 6.1
Kim et al., 2012[29]	0	0		0						2.2	
Li et al., 2012[30] SSPI group	0	0		3.3	7.5 ± 5.2					1.1 ± 0.6	
Schmid et al., 2012 group B[57]											14.3 ± 11.7
Ray et al., 2013[58]	4		0	4	7.5 ± 7.4	87.5	12.5				
Wang et al., 2013[31]	0	0		0	2.1				100		
Wu et al., 2013 anterior[1]					4.7 ± 1.1						13 ± 2.4
Zhang et al., 2013[32]	0	0		0	5.3 ± 3.7					2.0 ± 0.7	34 ± 4
Chou et al., 2014[33] non-fusion group	0	0		13.6	13.8 ± 6.6				100	2.1 ± 0.9	
Proietti et al., 2014[34] ALL	1.7	1.7		1.7							
Proietti et al., 2014[34] group A										1.8	12
Proietti et al., 2014[34] group B										4.3	38
Takami et al., 2014[35]	0	0		4.8	−0.6				100		
Vanek et al., 2014[36] MIS group	0	0		0	4.4 ± 9.4						
Zhao et al., 2015[37] PFFV group	0	0		0							
Zhao et al., 2015[37] TSSF group	2.9	0		5.7							
Fu et al., 2016[38] OPSF-4 group	0	0		0					100		
Fu et al., 2016[38] OPSF-6 group	0	0		0					100		
Fu et al., 2016[38] PPSF-4 group	0	0		0					100		
Fu et al., 2016[38] PPSF-6 group	0	0		7.7					100		
Hitchon et al., 2016[59]	0	0	0	9.1		100					
Lin et al., 2016[39] Group A	0	0		0	10.3 ± 5.2						
Lin et al., 2016[39] Group B	0	0		3.2	6.4 ± 7.8						
Lin et al., 2016[39] Group C	0	0		10	7.1 ± 5.3						
Fan et al., 2017[40] PPSF group	1.6	0		0	7.0 ± 6.9					0.7 ± 0.6	3.2 ± 1.7
Kreinest et al., 2017[4]			0	0							
Mayer et al., 2017[3] PA-F			0	0	9.6 ± 5.5	71.4	28.6				20 ± 20

NEUROCIRUGIA. 2025;36(2):112–128

– **Table A2 (*Continued*)**

Study	Complications rate, %				Cobb angle at FU,°	Fusion results at FU, %				VAS	ODI
	Posterior SWI	Posterior DWI	Anterior WI	Implant-related		Fusion	Stable fibrous fusion	Non-union	Fracture healing		
Mayer et al., 2017[3] POST-I group	0	0		0	14.7 ± 10.6				90.9		16.3 ± 17.1
Scholz et al., 2017 Intervention[60]			0	0	8.3 ± 9.5	100					13.3 ± 10.6
Lindtner et al., 2018 Bi ACR[61]	0	0	0	0	−3.6 ± 6.6	100					10.1 ± 9.5
Lindtner et al., 2018 Mono ACR[61]	0	0	0	27.8	−2.8 ± 7.1	100					19 ± 18.2
Zhao et al., 2018[41]	2.6	0		0	6.1 ± 7.0						5.9 ± 2.7
Gumussuyu et al., 2019 Combined[62]	0	7.1	0	0							17.7 ± 11.5
Oh and Seo., 2019[42]	0	0		6.7	4.6 ± 11.9					1.2 ± 1.2	9.5 ± 6.1
Trungu et al., 2019[43] ISG group	0	0		1.4	2.9					2.2	16.8
Trungu et al., 2019[43] nISG group	1.4	0		1.4	0.8					2.4	15.6
Yang et al., 2019[44] group A	0	0		0	11.0 ± 3.0					1.3 ± 0.7	
Yang et al., 2019[44] group B	0	0		0	12.8 ± 4.2					0.9 ± 0.7	
Yang et al., 2019[45] MIS group	0	0		0	10.7 ± 3.2					2.2 ± 0.6	4.5 ± 2.6
Yang et al., 2019[45] OPPF group	0	0		0	9.2 ± 3.6					2.5 ± 0.9	4.7 ± 3.3
Alkosha et al., 2020[46] ALL									85.7		
Alkosha et al., 2020[46] TLICS 3	0	0		0	17.0 ± 3.0						15 ± 2
Alkosha et al., 2020 [46] TLICS 4	0	0		0	17.0 ± 3.0						15 ± 2
Alkosha et al., 2020[46] TLICS 5	0	0		0	19.0 ± 2.0						18 ± 2
Collinet et al., 2020[47]				0	6.2 ± 5.9				100	2.3	11.8
Kocis et al., 2020[48] OPSF group	0	0		0	0.1						
Kocis et al., 2020[48] PPSF group	0	0		0	0.2						
Shao et al., 2020[49]	4.5	0		4.5	5.5				100	15 ± 0.7	12.2 ± 4.3
Zou et al., 2020[50] PPS group	0	0		0						0.4 ± 0.4	5.3 ± 1.8
Jordan et al., 2021 ICBG[63]	0	0	0	4.8		90.5	4.8	4.7			
Jordan et al., 2021 PTFI[63]	0	0	0	0							
Cheng et al., 2023[51]	0	8.3		8.3	6.9 ± 4.3				100	0.8 ± 0.7	
Hoffman et al., 2023[52] CG group											21.4 ± 23.7
Hoffman et al., 2023[52] IG group											17.7 ± 11.8
Perna et al., 2023[53] Group A	1.2	0	9.9		8.7 ± 4.8					4.5 ± 1.8	27.3 ± 10.1
Zhu et al., 2023[54] MIS-F group			0							1.2 ± 0.5	11.5 ± 2.3
Zhu et al., 2023[54] MIS-O group			0							1.2 ± 0.8	12 ± 2.1
Zhu et al., 2023[54] Open-C group			0							1.4 ± 0.7	12.2 ± 2.6

DWI, deep wound infection; FU, follow-up; ODI, Oswestry disability index; SWI, superficial wound infection; VAS, visual analogue scale of pain; WI, wound infection.

Table A3 – Results of meta-analysis for patients of anterior fusion group.

Parameter	Pooled mean or prevalence	95%CI	I^2 test, %	Q-test, p	Begg's test, p
Operation time, minutes	204.2	148.7–259.7	97.4	0	–
Blood loss, ml	512.9	4.8–1030.6	97.5	0	n/a
Cobb angle at admission, °	18.2	14.6–21.8	82.2	0	0.327
Cobb angle post-surgery, °	4.9	4.0–5.8	67.0	0.016	0.117
Cobb angle at final follow-up, °	7.1	4.9–9.4	91.4	0	0.624
AVBCR, %	n/a				
Spinal canal stenosis, %	41.5	35.1–47.2	0	0.323	n/a
Superficial wound infection rate, %	3.0	0.8–11.4	0	0.994	0.089
Deep wound infection rate, %	3.0	0.8–11.4	0	0.994	0.089
Implant-related complications, %	4.4	1.3–14.1	0	0.822	0.734
Fusion rate, %	92.9	82.4–97.3	0	0.709	0.497
Pseudoarthrosis rate, %	7.1	2.7–17.6	0	0.709	0.497
Non-union rate, %	n/a				
VAS	2.8	1.9–3.6	0	0.745	n/a
ODI	17.2	10.4–23.9	74.9	0.019	0.602

AVBCR, anterior vertebral body compression rate; CI, confidence interval; n/a, not available; ODI, Oswestry disability index; VAS, visual analogue scale of pain.

Table A4 – Results of meta-analysis for patients of combined fusion group.

Parameter	Pooled mean or prevalence	95%CI	I^2 test, %	Q-test, p	Begg's test, p
Operation time, minutes	161.8	134.2–189.4	95.5	0	0.602
Blood loss, ml	721.1	14.9–1457.2	96.4	0	n/a
Length of stay, days	15.4	13.3–17.5	89.6	0	0.453
Cobb angle at admission, °	11.7	9.7–13.5	85.7	0	0.453
Cobb angle post-surgery, °	1.3	-4.2–6.7	98.9	0	0.573
Cobb angle at final follow-up, °	4.9	0.8–8.9	97.9	0.018	0.177
AVBCR, %	55.2	46.3–64.0	88.5	0	n/a
Spinal canal stenosis, %	35.9	28.7–43.1	81.8	0.004	0.602
Superficial wound infection rate, %	2.8	1.2–6.7	0	0.998	0.281
Deep wound infection rate, %	3.0	1.3–7.1	0	0.985	0.370
Implant-related complications, %	5.4	2.1–13.1	40.7	0.100	0.754
Fusion rate, %	90.6	80.2–95.9	34.7	0.095	0.177
Pseudoarthrosis rate, %	8.1	3.2–18.7	39.8	0.098	0.293
Non-union rate, %	3.1	1.4–9.5	0	0.979	0.099
VAS	n/a				
ODI	15.4	12.2–18.6	81.8	0	0.091

AVBCR, anterior vertebral body compression rate; CI, confidence interval; n/a, not available; ODI, Oswestry disability index; VAS, visual analogue scale of pain.

Table A5 – Results of meta-analysis for patients of pedicle screw fixation group.

Parameter	Pooled mean or prevalence	95%CI	I^2 test, %	Q-test, p	Begg's test, p
Operation time (percutaneous PSF), minutes	96.5	82.4–110.6	99.4	0	0.065
Operation time (open PSF). minutes	120.1	108.3–131.9	97.8	0	0.083
Blood loss (percutaneous PSF). ml	83.8	71.7–95.9	98.8	0	0.125
Blood loss (open PSF). ml	233.7	171.5–295.9	99.8	0	0.882
Length of stay (percutaneous PSF). days	6.6	4.7–8.5	99.8	0	0.531
Length of stay (open PSF). days	12.3	11.2–13.4	91.8	0	0.404
Cobb angle at admission, °	17.1	15.1–19.1	96.3	0	0.377
Cobb angle post-surgery, °	6.6	4.4 – 8.7	98.2	0	0.791
Cobb angle at final follow-up, °	10.3	8.6–12.0	95.8	0	0.724
AVBCR, %	37.8	33.7–41.9	97.1	0	0.661
Spinal canal stenosis, %	46.3	34.6–58.0	97.2	0	0.453
Superficial wound infection rate, %	2.2	1.5–3.1	0	1.000	0.991
Deep wound infection rate, %	2.0	1.4–3.1	0	1.000	0.103
Implant-related complications, %	5.6	4.3–7.3	0	0.956	0.481
Fracture healing, %	93.7	89.5–96.3	0	0.564	0.087

– Table A5 (Continued)

Parameter	Pooled mean or prevalence	95%CI	I^2 test, %	Q-test, p	Begg's test, p
VAS	1.8	1.2–2.3	99.3	0	0.063
ODI	13.4	10.4–16.3	99.4	0	0.294

CI, confidence interval; ODI, Oswestry disability index; VAS, visual analogue scale of pain.

Declaration of competing interest

The authors declare that they have no conflict of interest.

REFERENCES

1. Wu H, Wang CX, Gu CY, Zhang ZY, Tong S, Yan HD, et al. Comparison of three different surgical approaches for treatment of thoracolumbar burst fracture. Chin J Traumatol. 2013;16(1):31–5.
2. Eleraky MA, Duong HT, Esp E, Kim KD. Expandable versus nonexpandable cages for thoracolumbar burst fracture. World Neurosurg. 2011;75(1):149–54, http://dx.doi.org/10.1016/j.wneu.2010.09.018.
3. Mayer M, Ortmaier R, Koller H, Koller J, Hitzl W, Auffarth A, et al. Impact of sagittal balance on clinical outcomes in surgically treated T12 and L1 burst fractures: analysis of long-term outcomes after posterior-only and combined posteroanterior treatment. Biomed Res Int. 2017;2017:1568258, http://dx.doi.org/10.1155/2017/1568258.
4. Kreinest M, Schmahl D, Grützner PA, Matschke S. Radiological results and clinical patient outcome after implantation of a hydraulic expandable vertebral body replacement following traumatic vertebral fractures in the thoracic and lumbar spine: a 3-year follow-up. Spine (Phila Pa 1976). 2017;42(8):E482–9, http://dx.doi.org/10.1097/BRS.0000000000001862.
5. Wood KB, Bohn D, Mehbod A. Anterior versus posterior treatment of stable thoracolumbar burst fractures without neurologic deficit: a prospective, randomized study. J Spinal Disord Tech. 2005;18 Suppl:S15–23, http://dx.doi.org/10.1097/01.bsd.0000132287.65702.8a.
6. Anderson PA, Raksin PB, Arnold PM, Chi JH, Dailey AT, Dhall SS, et al. Congress of neurological surgeons systematic review and evidence-based guidelines on the evaluation and treatment of patients with thoracolumbar spine trauma: surgical approaches. Neurosurgery. 2019;84(1):E56–8, http://dx.doi.org/10.1093/neuros/nyy363.
7. Sharif S, Shaikh Y, Yaman O, Zileli M. Surgical techniques for thoracolumbar spine fractures: WFNS Spine Committee Recommendations. Neurospine. 2021;18(4):667–80, http://dx.doi.org/10.14245/ns.2142206.253.
8. Hinojosa-Gonzalez DE, Estrada-Mendizabal RJ, Bueno-Gutierrez LC, Roblesgil-Medrano A, Tellez-Garcia E, Galindo-Garza CA, et al. A network meta-analysis on the surgical management of thoracolumbar burst fractures: anterior, posterior, and combined. Spine Surg Relat Res. 2023;7(3):211–8, http://dx.doi.org/10.22603/ssrr.2022-0196.
9. Wang T, Wang Z, Ji P, Zhang J, Zhang C, Zhang L. The efficacy and safety of anterior versus posterior approach for the treatment of thoracolumbar burst fractures: a systematic review and meta-analysis. Ann Transl Med. 2022;10(6):309, http://dx.doi.org/10.21037/atm-22-903.
10. Smits AJ, Polack M, Deunk J, Bloemers FW. Combined anteroposterior fixation using a titanium cage versus solely posterior fixation for traumatic thoracolumbar fractures: a systematic review and meta-analysis. J Craniovertebr Junction Spine. 2017;8(3):168–78, http://dx.doi.org/10.4103/jcvjs.JCVJS_8_17.
11. Oprel P, Tuinebreijer WE, Patka P, den Hartog D. Combined anterior-posterior surgery versus posterior surgery for thoracolumbar burst fractures: a systematic review of the literature. Open Orthop J. 2010;4:93–100, http://dx.doi.org/10.2174/1874325001004010093.
12. Zhu Q, Shi F, Cai W, Bai J, Fan J, Yang H. Comparison of anterior versus posterior approach in the treatment of thoracolumbar fractures: a systematic review. Int Surg. 2015;100(6):1124–33, http://dx.doi.org/10.9738/INTSURG-D-14-00135.1.
13. Tan T, Donohoe TJ, Huang MS, Rutges J, Marion T, Mathew J, et al. Does combined anterior–posterior approach improve outcomes compared with posterioronly approach in traumatic thoracolumbar burst fractures? Aa systematic review. Asian Spine J. 2020;14(3):388–98, http://dx.doi.org/10.31616/asj.2019.0203.
14. Roblesgil-Medrano A, Tellez-Garcia E, Bueno-Gutierrez LC, Villarreal-Espinosa JB, Galindo-Garza CA, Rodriguez-Barreda JR, et al. Thoracolumbar burst fractures: a systematic review and meta-analysis on the anterior and posterior approaches. Spine Surg Relat Res. 2021;6(2):99–108, http://dx.doi.org/10.22603/ssrr.2021-0122.
15. Hughes H, Carthy AM, Sheridan GA, Donnell JM, Doyle F, Butler J. Thoracolumbar burst fractures: a systematic review and meta-analysis comparing posterior-only instrumentation versus combined anterior–posterior instrumentation. Spine (Phila Pa 1976). 2021;46(15):E840–9, http://dx.doi.org/10.1097/BRS.0000000000003934.
16. Xu GJ, Li ZJ, Ma JX, Zhang T, Fu X, Ma XL. Anterior versus posterior approach for treatment of thoracolumbar burst fractures: a meta-analysis. Eur Spine J. 2013;22(10):2176–83, http://dx.doi.org/10.1007/s00586-013-2987-y.
17. Duan Y, Feng D, Chen J, Wu Y, Li T, Jiang L, et al. Anterior, posterior and anterior–posterior approaches for the treatment of thoracolumbar burst fractures: a network meta-analysis of randomized controlled trials. J Invest Surg. 2024;37(1):2301794, http://dx.doi.org/10.1080/08941939.2024.2301794.
18. Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009;6(7):e1000097.
19. Keynan O, Fisher CG, Vaccaro A, Fehlings MG, Oner FC, Dietz J, et al. Radiographic measurement parameters in thoracolumbar fractures: a systematic review and consensus statement of the spine trauma study group. Spine (Phila Pa 1976). 2006;31(5):E156–65, http://dx.doi.org/10.1097/01.brs.0000201261.94907.0d.
20. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ. 2003;327(7414):557–60, http://dx.doi.org/10.1136/bmj.327.7414.557. PMID: 12958120; PMCID: PMC192859.
21. Shi L, Lin L. The trim-and-fill method for publication bias: practical guidelines and recommendations based on a large database of meta-analyses. Medicine (Baltimore). 2019;98(23):e15987, http://dx.doi.org/10.1097/MD.0000000000015987.

22. Wild MH, Glees M, Plieschnegger C, Wenda K. Five-year follow-up examination after purely minimally invasive posterior stabilization of thoracolumbar fractures: a comparison of minimally invasive percutaneously and conventionally open treated patients. Arch Orthop Trauma Surg. 2007;127(5):335–43, http://dx.doi.org/10.1007/s00402-006-0264-9.
23. Hwang JH, Modi HN, Yang JH, Kim SJ, Lee SH. Short segment pedicle screw fixation for unstable T11-L2 fractures: with or without fusion? A three-year follow-up study. Acta Orthop Belg. 2009;75(6):822–7.
24. Lakshmanan P, Jones A, Mehta J, Ahuja S, Davies PR, Howes JP. Recurrence of kyphosis and its functional implications after surgical stabilization of dorsolumbar unstable burst fractures. Spine J. 2009;9(12):1003–9, http://dx.doi.org/10.1016/j.spinee.2009.08.457.
25. Lee SH, Pandher D, Yoon K, Lee S, Oh KJ. The effect of postoperative immobilization on short-segment fixation without bone grafting for unstable fractures of thoracolumbar spine. Indian J Orthop. 2009;43(2):197–204, http://dx.doi.org/10.4103/0019-5413.41870.
26. Liao JC, Fan KF, Chen WJ, Chen LH. Posterior instrumentation with transpedicular calcium sulphate graft for thoracolumbar burst fracture. Int Orthop. 2009;33(6):1669–75, http://dx.doi.org/10.1007/s00264-008-0677-x.
27. Ni WF, Huang YX, Chi YL, Xu HZ, Lin Y, Wang XY, et al. Percutaneous pedicle screw fixation for neurologic intact thoracolumbar burst fractures. J Spinal Disord Tech. 2010;23(8):530–7, http://dx.doi.org/10.1097/BSD.0b013e3181c72d4c.
28. Blondel B, Fuentes S, Pech-Gourg G, Adetchessi T, Tropiano P, Dufour H. Percutaneous management of thoracolumbar burst fractures: evolution of techniques and strategy. Orthop Traumatol Surg Res. 2011;97(5):527–32, http://dx.doi.org/10.1016/j.otsr.2011.03.020.
29. Jiang XZ, Tian W, Liu B, Li Q, Zhang GL, Hu L, et al. Comparison of a paraspinal approach with a percutaneous approach in the treatment of thoracolumbar burst fractures with posterior ligamentous complex injury: a prospective randomized controlled trial. J Int Med Res. 2012;40(4):1343–56, http://dx.doi.org/10.1177/147323001204000413.
30. Kim HY, Kim HS, Kim SW, Ju CI, Lee SM, Park HJ. Short segment screw fixation without fusion for unstable thoracolumbar and lumbar burst fracture : a prospective study on selective consecutive patients. J Korean Neurosurg Soc. 2012;51(4):203–7, http://dx.doi.org/10.3340/jkns.2012.51.4.203.
31. Li X, Ma Y, Dong J, Zhou XG, Li J. Retrospective analysis of treatment of thoracolumbar burst fracture using mono-segment pedicle instrumentation compared with short-segment pedicle instrumentation. Eur Spine J. 2012;21(10):2034–42, http://dx.doi.org/10.1007/s00586-012-2214-2.
32. Wang J, Zhou Y, Zhang ZF, Li CQ, Zheng WJ, Liu J. Radiological study on disc degeneration of thoracolumbar burst fractures treated by percutaneous pedicle screw fixation. Eur Spine J. 2013;22(3):489–94, http://dx.doi.org/10.1007/s00586-012-2462-1.
33. Zhang L, Zou J, Gan M, Shi J, Li J, Yang H. Treatment of thoracolumbar burst fractures: short-segment pedicle instrumentation versus kyphoplasty. Acta Orthop Belg. 2013;79(6):718–25.
34. Chou PH, Ma HL, Wang ST, Liu CL, Chang MC, Yu WK. Fusion may not be a necessary procedure for surgically treated burst fractures of the thoracolumbar and lumbar spines: a follow-up of at least ten years. J Bone Joint Surg Am. 2014;96(20):1724–31, http://dx.doi.org/10.2106/JBJS.M.01486.
35. Proietti L, Scaramuzzo L, Schirò GR, Sessa S, D'Aurizio G, Tamburrelli FC. Posterior percutaneous reduction and fixation of thoraco-lumbar burst fractures. Orthop Traumatol Surg Res. 2014;100(5):455–60, http://dx.doi.org/10.1016/j.otsr.2014.06.003.
36. Takami M, Yamada H, Nohda K, Yoshida M. A minimally invasive surgery combining temporary percutaneous pedicle screw fixation without fusion and vertebroplasty with transpedicular intracorporeal hydroxyapatite blocks grafting for fresh thoracolumbar burst fractures: prospective study. Eur J Orthop Surg Traumatol. 2014;24 Suppl 1:S159–65, http://dx.doi.org/10.1007/s00590-013-1266-2.
37. Vanek P, Bradac O, Konopkova R, de Lacy P, Lacman J, Benes V. Treatment of thoracolumbar trauma by short-segment percutaneous transpedicular screw instrumentation: prospective comparative study with a minimum 2-year follow-up. J Neurosurg Spine. 2014;20(2):150–6, http://dx.doi.org/10.3171/2013.11.SPINE13479.
38. Zhao QM, Gu XF, Yang HL, Liu ZT. Surgical outcome of posterior fixation, including fractured vertebra, for thoracolumbar fractures. Neurosciences (Riyadh). 2015;20(4):362–7, http://dx.doi.org/10.17712/nsj.2015.4.20150318.
39. Fu Z, Zhang X, Shi Y, Dong Q. Comparison of surgical outcomes between short-segment open and percutaneous pedicle screw fixation techniques for thoracolumbar fractures. Med Sci Monit. 2016;22:3177–85, http://dx.doi.org/10.12659/msm.896882.
40. Lin YC, Fan KF, Liao JC. Two additional augmenting screws with posterior short-segment instrumentation without fusion for unstable thoracolumbar burst fracture — comparisons with transpedicular grafting techniques. Biomed J. 2016;39(6):407–13, http://dx.doi.org/10.1016/j.bj.2016.11.005.
41. Fan Y, Zhang J, He X, Huang Y, Wu Q, Hao D. A comparison of the mini-open Wiltse approach with pedicle screw fixation and the percutaneous pedicle screw fixation for neurologically intact thoracolumbar fractures. Med Sci Monit. 2017;23:5515–21, http://dx.doi.org/10.12659/msm.905271.
42. Zhao Q, Hao D, Wang B. A novel, percutaneous, self-expanding, forceful reduction screw system for the treatment of thoracolumbar fracture with severe vertebral height loss. J Orthop Surg Res. 2018;13(1):174, http://dx.doi.org/10.1186/s13018-018-0880-4.
43. Oh HS, Seo HY. Percutaneous pedicle screw fixation in thoracolumbar fractures: comparison of results according to implant removal time. Clin Orthop Surg. 2019;11(3):291–6, http://dx.doi.org/10.4055/cios.2019.11.3.291.
44. Trungu S, Forcato S, Bruzzaniti P, Fraschetti F, Miscusi M, Cimatti M, et al. Minimally invasive surgery for the treatment of traumatic monosegmental thoracolumbar burst fractures: clinical and radiologic outcomes of 144 patients with a 6-year follow-up comparing two groups with or without intermediate screw. Clin Spine Surg. 2019;32(4):E171–6, http://dx.doi.org/10.1097/BSD.0000000000000791.
45. Yang M, Zhao Q, Hao D, Chang Z, Liu S, Yin X. Comparison of clinical results between novel percutaneous pedicle screw and traditional open pedicle screw fixation for thoracolumbar fractures without neurological deficit. Int Orthop. 2019;43(7):1749–54, http://dx.doi.org/10.1007/s00264-018-4012-x.
46. Yang P, Chen K, Zhang K, Sun J, Yang H, Mao H, et al. Percutaneous short-segment pedicle instrumentation assisted with O-arm navigation in the treatment of thoracolumbar burst fractures. J Orthop Translat. 2019;21:1–7, http://dx.doi.org/10.1016/j.jot.2019.11.002.
47. Alkosha HM, Omar SA, Albayar A, Awad BI. Candidates for percutaneous screw fixation without fusion in thoracolumbar fractures: a retrospective matched cohort study. Global Spine

J. 2020;10(8):982–91, http://dx.doi.org/10.1177/2192568219886320.
48. Collinet A, Charles YP, Ntilikina Y, Tuzin N, Steib JP. Analysis of intervertebral discs adjacent to thoracolumbar A3 fractures treated by percutaneous instrumentation and kyphoplasty. Orthop Traumatol Surg Res. 2020;106(6):1221–6, http://dx.doi.org/10.1016/j.otsr.2020.05.006.
49. Kocis J, Kelbl M, Kocis T, Návrat T. Percutaneous versus open pedicle screw fixation for treatment of type A thoracolumbar fractures. Eur J Trauma Emerg Surg. 2020;46(1):147–52, http://dx.doi.org/10.1007/s00068-018-0998-4.
50. Shao RX, Zhou H, Peng L, Pan H, Yue J, Hu QF. Clinical efficacy and outcome of intelligently inflatable reduction in conjunction with percutaneous pedicle screw fixation for treating thoracolumbar burst fractures. J Int Med Res. 2020;48(3), http://dx.doi.org/10.1177/0300060520903658, 300060520903658.
51. Zou P, Yang JS, Wang XF, Wei JM, Liu P, Chen H. Comparison of clinical and radiologic outcome between mini-open Wiltse approach and fluoroscopic-guided percutaneous pedicle screw placement: a randomized controlled trial. World Neurosurg. 2020;144:e368–75, http://dx.doi.org/10.1016/j.wneu.2020.08.145.
52. Cheng C, Li G, Luo Y, Lin Z. Treatment of thoracolumbar fractures by closed reduction via a percutaneous solid pedicle screw. Acta Ortop Bras. 2023;31(spe1):e259041, http://dx.doi.org/10.1590/1413-785220233101e259041.
53. Hoffmann MF, Kuhlmann K, Schildhauer TA, Wenning KE. Improvement of vertebral body fracture reduction utilizing a posterior reduction tool: a single-center experience. J Orthop Surg Res. 2023;18(1):321, http://dx.doi.org/10.1186/s13018-023-03793-7.
54. Perna A, Franchini A, Gorgoglione FL, Barletta F, Moretti B, Piazzolla A, et al. Short-segment percutaneous fusion versus open posterior fusion with screw in the fractured vertebra for thoracolumbar junction burst vertebral fracture treatment. J Neurosci Rural Pract. 2023;15(1):34–41, http://dx.doi.org/10.25259/JNRP_370_2023.
55. Zhu X, Shao Y, Lu Y, Sun J, Chen J. Comparison of pedicle screw fixation by four different posterior approaches for the treatment of type A thoracolumbar fractures without neurologic injury. Front Surg. 2023;9:1036255, http://dx.doi.org/10.3389/fsurg.2022.1036255.
56. Briem D, Lehmann W, Ruecker AH, Windolf J, Rueger JM, Linhart W. Factors influencing the quality of life after burst fractures of the thoracolumbar transition. Arch Orthop Trauma Surg. 2004;124(7):461–8, http://dx.doi.org/10.1007/s00402-004-0710-5.
57. Schmid R, Lindtner RA, Lill M, Blauth M, Krappinger D, Kammerlander C. Combined posteroanterior fusion versus transforaminal lumbar interbody fusion (TLIF) in thoracolumbar burst fractures. Injury. 2012;43(4):475–9, http://dx.doi.org/10.1016/j.injury.2011.12.011.
58. Ray WZ, Krisht KM, Dailey AT, Schmidt MH. Clinical outcomes of unstable thoracolumbar junction burst fractures: combined posterior short-segment correction followed by thoracoscopic corpectomy and fusion. Acta Neurochir (Wien). 2013;155(7):1179–86, http://dx.doi.org/10.1007/s00701-013-1737-6.
59. Scholz M, Kandziora F, Tschauder T, Kremer M, Pingel A. Prospective randomized controlled comparison of posterior vs. posterior–anterior stabilization of thoracolumbar incomplete cranial burst fractures in neurological intact patients: the RASPUTHINE pilot study. Eur Spine J. 2018;27(12):3016–24, http://dx.doi.org/10.1007/s00586-017-5356-4.
60. Lindtner RA, Mueller M, Schmid R, Spicher A, Zegg M, Kammerlander C, et al. Monosegmental anterior column reconstruction using an expandable vertebral body replacement device in combined posterior–anterior stabilization of thoracolumbar burst fractures. Arch Orthop Trauma Surg. 2018;138(7):939–51, http://dx.doi.org/10.1007/s00402-018-2926-9.
61. Gumussuyu G, Islam NC, Kose O, Gungor M, Ozcan H. Comparison of two segment combined instrumentation and fusion versus three segment posterior instrumentation in thoracolumbar burst fractures: a randomized clinical trial with 10 years of follow up. Turk Neurosurg. 2019;29(4):555–63, http://dx.doi.org/10.5137/1019-5149.JTN.25025-18.3.
62. Jordan MC, Jansen H, Meffert RH, Heintel TM. Comparing porous tantalum fusion implants and iliac crest bone grafts for spondylodesis of thoracolumbar burst fractures: prospective cohort study. Sci Rep. 2021;11(1):17409, http://dx.doi.org/10.1038/s41598-021-96400-w.
63. Hitchon PW, Abode-Iyamah K, Dahdaleh NS, Shaffrey C, Noeller J, He W, et al. Nonoperative management in neurologically intact thoracolumbar burst fractures: clinical and radiographic outcomes. Spine (Phila Pa 1976). 2016;41(6):483–9, http://dx.doi.org/10.1097/BRS.0000000000001253.
64. Wood K, Buttermann G, Mehbod A, Garvey T, Jhanjee R, Sechriest V. Operative compared with nonoperative treatment of a thoracolumbar burst fracture without neurological deficit. A prospective, randomized study. J Bone Joint Surg Am. 2003;85(5):773–81, http://dx.doi.org/10.2106/00004623-200305000-00001. Erratum in: J Bone Joint Surg Am. 2004 Jun;86-A(6):1283.
65. Grin AA, Karanadze VA, Kordonskiy AYu, Talypov AE, Lvov IS, Abdrafiev RI. Efficacy and safety of conservative treatment in patients with neurologically intact thoracolumbar burst fractures: a meta-analysis. Russ J Spine Surg (Khirurgiya Pozvonochnika). 2024;21(2):27–38, http://dx.doi.org/10.14531/ss2024.2.27-38.
66. Grin A, Karanadze V, Lvov I, Kordonskiy A, Talypov A, Smirnov V, et al. Effective method of pedicle screw fixation in patients with neurologically intact thoracolumbar burst fractures: a systematic review of studies published over the last 20 years. Neurocirugia (Astur: Engl Ed). 2024;35(6):299–310, http://dx.doi.org/10.1016/j.neucie.2024.07.009. S2529-8496(24)00048-0.