EFFICACY AND SAFETY OF SHORT SEGMENT PEDICLE SCREW FIXATION IN PATIENTS WITH NEUROLOGICALLY INTACT BURST FRACTURES OF THE LOWER THORACIC AND LUMBAR SPINE: A META-ANALYSIS OF STUDIES PUBLISHED OVER THE LAST 20 YEARS

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Objective. To conduct a systematic review and meta-analysis of studies on the surgical treatment of patients with uncomplicated burst fractures of the lower thoracic and lumbar spine and to determine the effectiveness and safety of short transpedicular fixation (TPF) in this patient group.

Material and Methods. The study included articles with the following criteria: publication date from January 1, 2004, to December 31, 2023; patient sample descriptions involving uncomplicated burst fractures from T10 to L5; TPF involving one segment adjacent to the fractured vertebra in both cranial and caudal directions without spinal fusion; descriptions of treatment outcomes or complications; and an average follow-up period of at least 12 months. Meta-analysis was conducted using the Comprehensive Meta-Analysis software, version 2.2.064. Depending on the level of heterogeneity (I^2 test), either a fixed-effects or random-effects model was applied. Begg's or Egger's test was used to assess publication bias, and any bias present was corrected using the trim-and-fill method.

Results. The application of TPF resulted in a significant reduction in the overall Cobb angle by 5.9 degrees in the percutaneous group and by 7.6 degrees when using a midline approach. Regarding AVBCR (anterior vertebral body compression ratio), a reduction of 24.0 % and 24.8 % was observed in both groups, respectively. The overall complication rates were as follows: superficial infection, 2.2 %; deep infection, 2.0 %; and implant-associated complications, 5.6 %. No patient developed a neurological deficit. The levels of work adaptation W1 and W2 on the Denis scale were achieved in 70.9 % of patients. The overall quality of life, as measured by the Oswestry Disability Index, averaged 13.4 %.

Conclusions. Short transpedicular fixation without additional spinal fusion or laminectomy appears to be an effective and safe method for treating burst fractures of the lower thoracic and lumbar spine without neurological deficits. This method allows for regression of kyphotic deformity in the long-term post-injury period by at least 5.9 degrees and restoration of anterior vertebral height by 24 %. The approach demonstrated relatively low overall postoperative complication rates. More than 90 % of patients were able to return to full-time work, either in their previous position or with reduced physical demands.

Key Words: transpedicular fixation; uncomplicated burst fractures; lower thoracic and lumbar spine; meta-analysis.

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Compression comminuted fractures of the lower thoracic and lumbar spine (lTLS) are among the most common types of spine and spinal cord injury. The incidence of these injuries can reach up to 13 cases per 100,000 population annually, and the majority of them are not accompanied by the neurological deficit [1]. The most conventional treatment option is surgery. The most effective technique is short-segment pedicle screw fixation (PSF) of the segments adjacent to the fractured vertebra without decompression and additional spinal fusion [2]. Currently, a large number of systematic reviews and meta-analyses on fractures of lTLS have been published in the literature. All of them are comparative publications discussing the necessity of creating a bone block during PSF [2–4], removal of implants during PSF [5, 6], the extent of PSF [7, 8], the use of intermediate pedicle screws in a broken vertebra [9, 10], as well as comparing minimally invasive PSF with open surgery through the posterior median approach [11–13]. These studies have a substantial deficiency – the authors include data on complicated fractures that can significantly affect the outcome. Given this plentiful number of systematic papers, we did not find any single-group meta-analysis in the literature showing overall value of radiologic features of injuries, complications, and clinical outcomes in patients with burst fractures of the lTLS without neurological deficit.

The present paper represents the final part of a previously started systematic study [14], covering 69 articles and focusing on the surgical treatment of uncomplicated burst fractures of the lTLS. The optimal treatment for these injuries was found to be short-segment PSF of the segments adjacent to the fractured vertebra without decompression and additional spinal fusion. The current study focuses on identifying specific efficacy and safety of the short-segment PSF using statistical procedures of single-group meta-analysis.

The objective is to conduct a systematic review and meta-analysis of studies on the surgical treatment of patients with uncomplicated burst fractures of the lower thoracic and lumbar spine and to determine the effectiveness and safety of short-segment pedicle screw fixation (PSF) in this patient group.

Material and Methods

Selection of articles

The study was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [15]. The study was registered in the PROSPERO (No. CRD42024531104).

The following keywords were the query used in the Pubmed database search: 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].

Inclusion criteria for articles in a systematic review:

1) publication date: from January 1, 2004 to December 31, 2023;

2) availability of a full-text article in English or Russian;

3) A3 or A4 fracture type according to the AO Spine classification, or A, B, or C burst fracture types according to the Denis classification, or the author's specific reference to the presence of a burst fracture in patients without classification;

4) absence of injury to the spinal cord or its roots at the time of admission to the hospital;

5) PSF with involvement of one segment adjacent to the fractured vertebra, each in the caudal and cranial directions;

6) PSF without spinal fusion;

7) patients over 18;

8) description in the study of treatment outcomes or developed complications;

9) mean follow-up for a patient sample of at least 12 months.

All articles not meeting these criteria were excluded from the study. The algorithm of article search and selection is shown in Fig. 1.

Data collection

Data from each article were recorded in the appropriate table cell. Basic information included sample size, mean age of patients, gender distribution, diagnosis, and mechanism of injury. The main block of data included the technique of PSF (percutaneous or midline approach), radiologic signs on admission, after surgery and during the final examination, the mean time till the final examination, complications associated with surgery, implant-associated complications in the late period of injury (breakage or migration of implant elements), pain severity according to Denis scale (Table 1) and VAS, quality of life at the time of the final examination according to the Denis scale (Table 2), as well as according to the Oswestry scale. The degree of kyphotic deformity of the segment (the Cobb angle), anterior vertebral body compression percentage (AVBCP) relative to intact segments, the grade of spinal stenosis according to the mid-sagittal canal diameter [16], and fracture union were recorded when studying radiologic signs.

Statistical analysis

Meta-analysis was performed in Comprehensive Meta-analysis software, version 2.2.064 (Biostat, Englewood, NJ, USA). Heterogeneity was evaluated using the I2 test. If the I2 parameter was less than 50 %, heterogeneity was considered low, 50–75 % – moderate, and more than 75% – high [17]. If there was no evidence of statistical heterogeneity between studies (Cochrane Q-test: $p > 0.10$), a fixed-effect model was used. In other cases, a random-effects model (DerSimonian and Laird) was applied. Publication bias was accepted if $p < 0.05$ by Begg's test. If the data contained a large number of outliers and Begg's test was less informative ($p = 0$), an additional evaluation of funnel plot symmetry and Egger's test were performed. If there was no publication bias, the result was shown as a forest plot. If publication bias was present, it was eliminated using the trim-and-fill method (trimming and filling in 'missing' studies) [18].

Standardised mean difference (SMD) was used for comparison of radiologic signs at different stages of the study. The result was shown as 95% CI. If the whole interval was strictly greater or less than 0, the difference was considered statistically significant.

Results

Selection of articles and general profile of patients

An initial search on the Pubmed database revealed 1,255 articles. After applying a filter for age and language, the remaining abstracts were reviewed. The initial search resulted in the selection of 189 studies for review of full-text versions. Of them, 35 met the necessary criteria and were included in the present study (Fig. 1). A total of 1,552 patients' treatment data were presented in the papers. Some authors divided the sample into two or more groups depending on the specific features of surgery. A total of 35 articles reported the treatment outcomes of 57 groups of patients. The majority of patients were men (62.6 %). The median mean age in the studies was 44.8 years. The main causes of injury to lTLS were falls from height (42.1 %) and traffic accidents (43.6 %). The features of each study are available in supplementary files (Appendix 1, 2) on the journal's website (https://www. spinesurgery.ru).

A previous systematic review (PROSPERO No. CRD42024531093) [14] found that the technique of short-segment PSF performance (percutaneous or midline approach) had a considerable effect on such parameters as the Cobb angle correction rate and AVBCP restoration. For this reason, radiologic signs were analysed separately for the percutaneous pedicle screw fixation (pPSF) and posterior midline PSF (pmPSF) groups. Other parameters were estimated for the whole sample of articles simultaneously.

Meta-analysis of radiologic signs

We have analysed the changes over time of the overall values of Cobb angle and AVBCR for pPSF and pmPSF at the time of admission to the hospital, after surgery, and at the final examination (Tables 3, 4).

For pPSF, surgical treatment resulted in a significant reduction in Cobb angle by 8.6° (SMD 1.5 [95 % CI: 1.2–1.9], I^2 = 81.6 %; Q-test: p = 0; Begg's test: p = 0.113) and AVBCR by 26.4 % (SMD 3.6 [95 % CI: 2.5–4.7], I^2 = 95.8 %; Q-test: p = 0; Begg's test: p = 0.065). From the time of surgery to the patient's final examination, the kyphotic deformity had increased significantly by 2.7° (SMD -0.3 [95 % CI: -0.6; -0.1], I^2 = 65.4 %; Q-test: p = 0.001; Begg's test: p = 0.099) and ABCR by 2.8 % (SMD -0.4 [95 % CI: -0.6; -0.3], I^2 = 0.0 %; Q-test: p = 0.984; Begg's test: p = 0.677).

For pmPSF in the early postoperative period, a remarkable reduction in kyphotic deformity by 12.5° was registered (I^2 = 77.8 %; Q-test: p = 0; Begg's test: p = 0.001; adjusted SMD 1.9 [95 % CI: 1.5–2.4]) and restoration of fractured vertebral body height by 31.1 % (SMD 3.2 [95 % CI: 2.8-3.6], I^2 = 59.4 %; Q-test: p = 0.008; Begg's test: p = 0.245). After surgery and at the time of final examination, a significant increase in kyphosis by 4.9° (SMD -0.9 [95 % CI: -1.2; -0.5], I^2 = 72.1 %; Q-test: p = 0; Begg's test: p = 0.392) and AVBCR index by 6.8% (I^2 = 0; Q-test: p = 0.508; Begg's test: p = 0.013; adjusted SMD -0.6 [95 % CI, -0.8; -0.4]) were verified.

The overall value of spinal canal stenosis grade after elimination of publication bias (trim-and-fill) was 43.1%

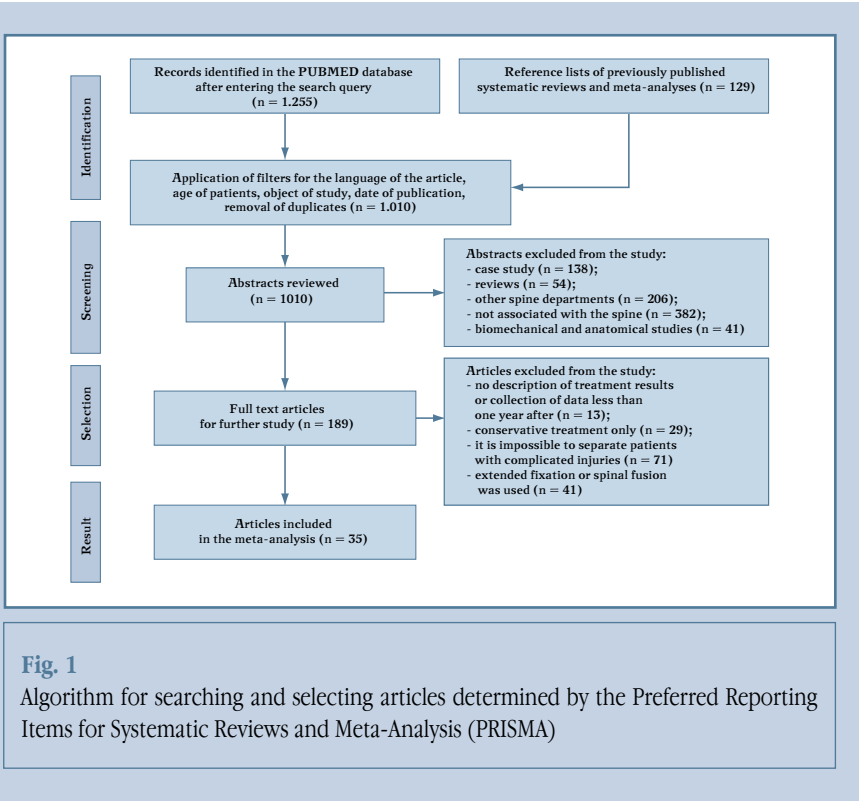

Fig. 1
Algorithm for searching and selecting articles determined by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA)

Table 1
Pain severity scale according to Denis et al. (1984)

Grade	Criteria
P1	No pain
P2	Minimal pain, no need for medication
P3	Moderate pain, occasional medication, no interruption of work or activities of daily life
P4	Moderate to severe pain, requires frequent use of analgesics, causes frequent absences from work or significantly facilitates the work performed
P5	Constant severe pain, chronic medication

Table 2
Occupational adaptation scale according to Denis et al. (1984)

Grade	Criteria
W1	Physically demanding activity is possible
W2	Able to return to previous employment (sedentary) or return to physically demanding activity with slight modification
W3	Unable to return to previous employment, working full-time at a new job with easier working conditions
W4	Unable to return to previous employment, working at a new job with easier working conditions, working part-time or frequently missing work due to pain
W5	Unable to work

(95 % CI: 33.8–52.5). It is impossible to estimate the overall value of spinal canal compression grade at the time of the final examination because of the lack of data in published articles.

A meta-analysis of postoperative complications

The overall value of incidence of superficial (subaponeurotic) postoperative wound infection reached 2.2% (95 % CI: 1.5–3.1); $I^2 = 0$; Q-test: p = 1.00; Begg's test: p = 0; Egger's test: p = 0.991. The overall incidence of wound infection requiring revision surgery was 2.0 % (95 % CI: 1.4–3.1); $I^2 = 0$; Q-test: p = 1.00; Begg's test: p = 0; Egger's test: p = 0; Egger's test: p = 0.103.

The overall incidence of implant-associated complications was 5.6 % (95 % CI: 4.3–7.3; Fig. 2). In order to identify the possible efficacy of implant removal in reducing the incidence of this complication, we categorized patients into temporary and permanent PSF groups. In temporary PSF (6 to 12 months), the overall incidence of fixation failure at the final examination was 4.6% (95 % CI: 3.0–6.9; $I^2 = 0$; Q-test: p = 0.956; Begg's test: p = 0.481). If implants were not removed during the entire follow-up period, the overall incidence of implant-associated complications after elimination of publication bias (trim-and-fill) was 5.8 % (95 % CI: 3.2–10.4; $I^2 = 60.4$; Q-test: p = 0.001; Begg's test: p = 0.05).

None of the patients in the selected articles suffered from any neurological deficit. There was only one patient [50] who developed a clinically relevant adjacent-level syndrome that required surgery. Due to such a small number of cases, we did not calculate the overall value of the above complications.

Meta-analysis of long-term outcomes

The overall incidence of fracture union according to control CT scan in injury long-term was 93.7 % (95 % CI: 89.5–96.3; Fig. 3).

The overall VAS pain score (Fig. 4) was 1.8 (95 % CI: 1.2–2.3). The majority (81.5 %) of patients in the long-term period of injury did not experience pain in the injury site, or the pain syndrome was so mild that it did not require analgesics (Table 5).

The overall quality of life score according to the Oswestry scale (Fig. 5) reached 13.4 % (95 % CI: 10.4–16.3). In the majority (90.3 %) of cases, the patients returned to full-time work over time, either under the same conditions or with mitigated duties (Table 5).

Discussion

The issue of treatment of patients with burst fractures of the lTLS, despite the enormous number of published retrospective and prospective studies, systematic reviews, and meta-analyses, is still a relevant issue. The choice of treatment

Table 3

Changes over time of the overall value of Cobb angle after surgical treatment

Parameter	Overall value (95 % CI)	I^2	Q-тест, p	Begg's test, p
At admission, degrees				
pPSF	15.9 (12.6–19.2)	97.8	0	0.322
pmPSF	18.2 (16.2–20.2)	90.0	0	0.711
After surgery, degrees				
pPSF	7.3 (3.7–11.0)	98.9	0	0.246
pmPSF	5.7 (4.5–7.0)	86.8	0	0.903
At the final examination, degrees				
pPSF	10.0 (7.3–12.7)	97.1	0	0.159
pmPSF	10.6 (8.7–12.5)	91.9	0	0.542
Total changes over time from admission to the final examination, degrees				
pPSF	-5.9	–	–	–
pmPSF	-7.6	–	–	–

pPSF – percutaneous pedicle screw fixation;
pmPSF – posterior midline pedicle screw fixation.

Table 4

Changes over time of the overall value of AVBCR angle after surgical treatment

Parameter	Overall value (95% CI)	I^2	Q-тест, p	Begg's test, p	Value after trim-and-fill
At admission, %					
pPSF	34.8 (27.5–42.0)	98.4	0	0.542	–
pmPSF	40.5 (37.1–43.9)	89.1	0	0.208	–
After surgery, %					
pPSF	8.4 (5.9–10.8)	93.1	0	0.325	–
pmPSF	9.4 (6.5–12.4)	92.0	0	0.025	8.9 (6.2–11.7)
At the final examination, %					
pPSF	10.8 (7.8–13.7)	96.2	0	0.325	–
pmPSF	15.7 (11.1–20.3)	96.3	0	0.211	–
Total changes over time from admission to the final examination, %					
pPSF	-24.0	–	–	–	–
pmPSF	-24.8	–	–	–	–

pPSF – percutaneous pedicle screw fixation;
pmPSF – posterior midline pedicle screw fixation.

option by the surgeon and the patient's subsequent informed consent for the treatment are usually guided by available randomized clinical trials (RCTs) and published guidelines. If there are no relevant RCTs in the literature, the choice of treatment option is guided by knowledge of the incidence of complications, successful fracture union, and the outcomes of subsequent social and occupational adaptation of patients. The most accurate data for such a prediction can be achieved by a single-group meta-analysis that results in specific indicators with confidence intervals formed by the processing of all available studies on the subject. It is necessary to point out that these data are more accurate than the standard mean or median values from the systematic review. It considers the study weight in forming the outcome depending on the sample size, as well as, in some cases, standard deviation data. Currently, we have not found any meta-analysis in the literature describing the efficacy and safety of any surgical treatment option for compression and comminuted fractures of the lTLS using overall value.

A systematic review [14] found that the optimal surgical treatment for burst fractures of lTLS without neurological deficit is standard short-segment PSF without the use of additional spinal fusion. It is necessary to point out that these patients did not show a considerable effect of additional screws in the fractured vertebrae during short-segment PSF on both intraoperative parameters and long-term treatment outcomes [14]. Following the above, patients with and without intermediate PSF were included in this meta-analysis. Consequently, we limited the present study to the group of patients with the aforementioned treatment option to reduce the probability of developing publication bias and to form a more homogeneous sample of papers.

The analysis of radiologic signs showed that percutaneous PSF was performed in patients with less severe kyphosis and AVBCR on admission (15.9° and 34.8 %, respectively) compared to a sample where the standard midline approach was used (18.2° and 40.5 %, respectively). However, both techniques demonstrated excellent orthopaedic outcomes in the long-term follow-up. The ovearll value of kyphotic deformity was corrected by at least 5.9° by the time of the final examination, and the degree of vertebral body compression was reduced by 24.0 %. This result clearly illustrates the advantage of PSF in maintaining the effect of fracture correction achieved during repositioning maneuvers compared to the results of conservative treatment [55], in which the overall value of kyphosis and AVBCR progressed by 3.0° and 3.7%, respectively, under conditions of insufficiently rigid immobilization of the fracture.

The analysis of complications showed a rather high safety of the standard short-segment PSF. In the presented sample of articles, there were no cases of revision surgery associated with the development of neurological deficit or progression of kyphotic deformity during the entire follow-up period. Nonetheless, the 2.0 % chance of deep infection is remarkable and should be considered both by a surgeon when determining treatment strategies and by a patient when signing the informed consent for surgery. It should also be stated that the overall value of implant-associated complications incidence was relatively low (5.6 %), despite the absence of interbody bone block. We associate this with a number of reasons.

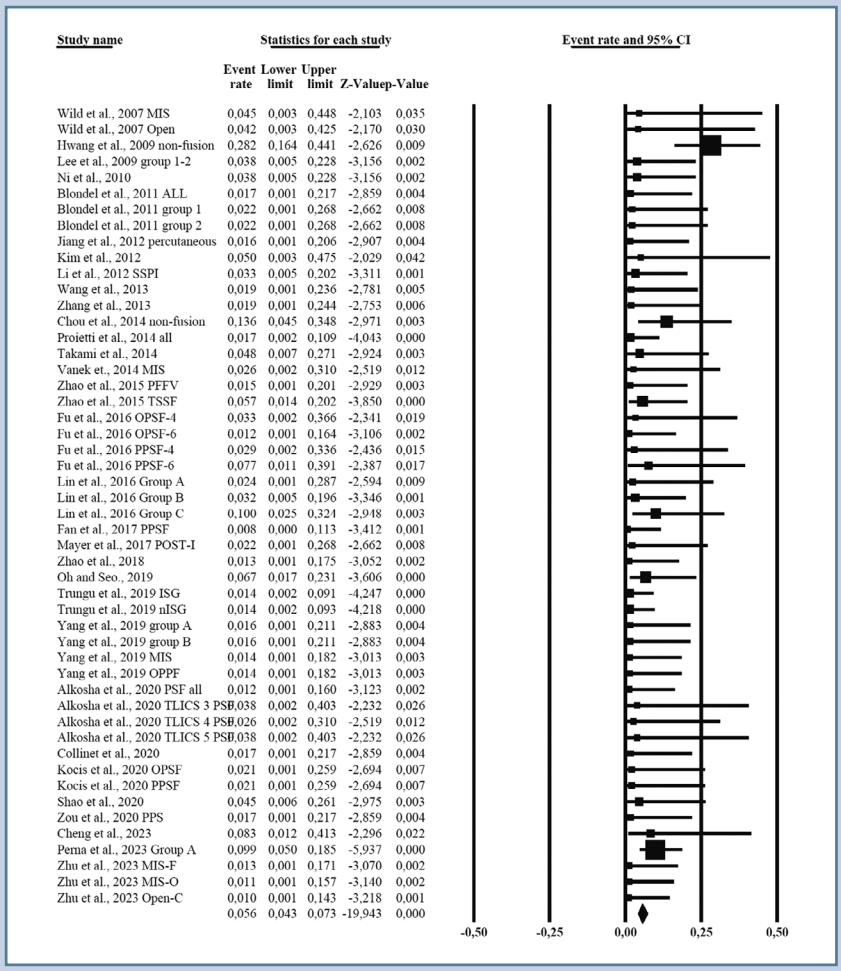

Fig. 2
Overall value of implant-associated complications: $I^2 = 23.3$ %; Q-test: p = 0.075; Begg's test: p = 0.089

First, no patient underwent laminectomy, even in cases of 50 % or more compression of the spinal canal contents, and therefore the posterior column remained almost completely intact. Furthermore, in conditions of rigid immobilization, degenerative changes in the facet joints are found, resulting in their partial or complete ankylosis over time [56] that, in turn, also contributes to the stability of the injured segment.

Most authors stated the possibility of preventing instrumentation breakage and screw migration as the reason for removing the PSF system. The calculation of the overall value of implant-associated complications incidence depending on the duration of PSF showed almost similar rates, with a difference of 1.2 % for temporary fixation compared to permanent PSF. Nevertheless, because of the limitations of a one-group meta-analysis, it was impossible to make a statistically significant comparison between the two groups.

The selected PSF technique also showed high efficacy concerning the long-term treatment outcomes. The rate of fracture union was high, exceeding 96 % within the confidence interval. It should be noted that those remaining patients in whom the authors found failure of union along the fracture line had no clinical signs of instability, and there was no progression of kyphosis or signs of instrumentation failure. The authors preferred not to remove the PSF in these patients; there were no clinical consequences of fracture non-union.

The analysis of clinical outcomes also showed a high efficiency of the technique. Only 5.3 % of patients required regular intake of analgesics. More than 80.0 % of them did not need analgesics because of absence or mild severity of pain. Quality of life evaluation showed minimal impairment according to the Oswestry scale. More than 90.0 % of patients are characterized by almost complete social and occupational adaptation in the long-term of injury.

Limitations of the study. The limitations of this review are that the majority of authors of the analysed studies combined fractures of types A3 and A4 according to AO Spine, as well as injuries of types A, B, and C according to Denis scale into one group. Separating burst fractures of lTLS into subtypes would allow for a more accurate calculation of overall value. Only a small number of authors have used the Denis scale in assessing long-term outcomes that, in our opinion, most objectively shows the impact of the pain on the patient's life and the quality of his following occupational rehabilitation. A more frequent use of this scale would produce a more accurate overall value.

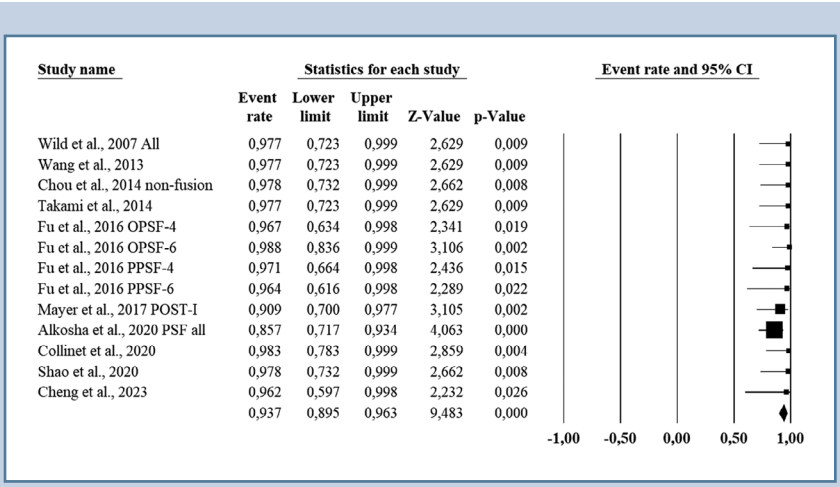

Fig. 3
Overall value of fracture union after treatment: $I^2 = 0.0$ %; Q-test: p = 0.564; Begg's test: p = 0.087

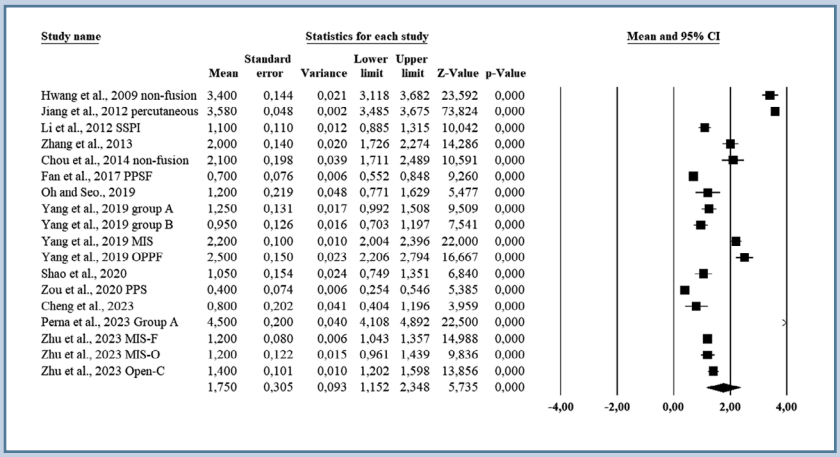

Fig. 4
Overall value of pain syndrome severity according to VAS

Nevertheless, despite the limitations of the study, we believe that the available data are enough for an objective understanding by both surgeon and patient of the expected efficacy of the analysed treatment option, the incidence of some complications, and the possibility of predicting further social and occupational adaptation.

Conclusion

Short-segment PSF without additional spinal fusion or laminectomy appears

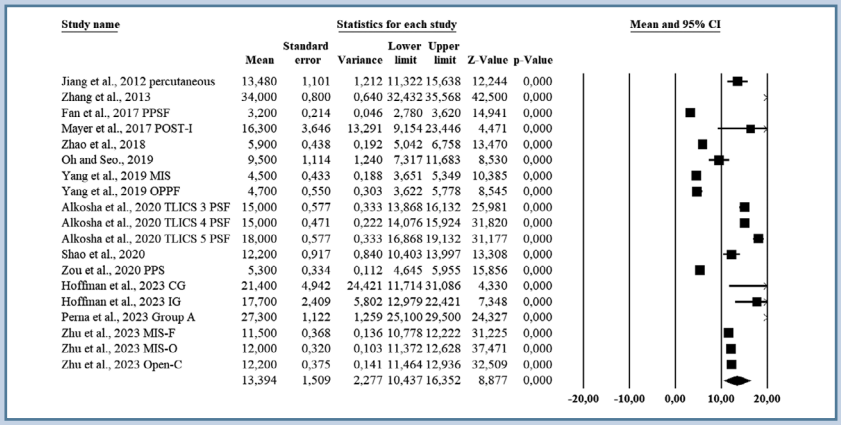

Fig. 5
Overall value of quality of life at the final examination according to Oswestry scale: $I^2 = 99.4$ %; Q-test: p = 0; Begg's test: p = 0.294

Table 5
Results of a meta-analysis of the pain severity and occupational adaptation according to Denis in the long-term period of injury

Parameter	Overall value, % (95 % ДИ)	Heterogeneity		Begg's test	Overall value after trim-and-fill, % (95 % CI)
		I^2, %	Q-тест, p		
Severity of pain syndrome					
P1 and P2	81.5 (74.8–86.7)	0	0.466	0.293	–
P3	15.5 (9.6–22.2)	18.7	0.287	0.098	–
P4 and P5	5.3 (2.6–10.5)	0	0.762	0.099	–
Results of occupational adaptation					
W1 and W2	70.9 (62.6–78.0)	31.5	0.188	0.024	67.2 (59.1–74.5)
W3	23.1 (15.9–32.4)	33.7	0.197	0.142	–
W4 and W5	11.7 (6.8–19.5)	3.8	0.416	0.091	–

to be an effective and safe technique for treating burst fractures of the lTLS without neurological deficit. This technique allows for regression of kyphotic deformity in the long-term post-injury period by at least 5.9 degrees and restoration of anterior vertebral height by 24 %. The overall incidence of infection in the area of instrumentation is 2.0 % and of implant-associated complications is 5.6 %. In the long-term of injury, the overall value of pain severity according to VAS is 1.8 points. The overall value of Oswestry scale in these patients is 13.4 % that is equivalent to minimal disruption to life activities. More than 90 % of patients returned to full-time employment as a result of the treatment, either in their previous position or with mitigated duties.

The study had no sponsors. The authors declare that they have no conflict of interest.
The study was approved by the local ethics committees of the institutions.
All authors contributed significantly to the research and preparation of the article, read and approved the final version before publication.

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