Percutaneous Versus Open Pedicle Screw Fixation for Pyogenic Spondylodiscitis of the Thoracic and Lumbar Spine

Systematic Review and Meta-Analysis

Juan P. Cabrera, MD,† Gastón Camino-Willhuber, MD,‡ Sathish Muthu, MD,§ Alfredo Guiroy, MD,|| Marcelo Valacco, MD,¶ and Enrico Pola, MD#*

Study Design: A systematic review and meta-analysis.

Objective: This meta-analysis aimed to compare percutaneous (PPS) versus open pedicle screw (OPS) fixation for treatment of thoracic and lumbar spondylodiscitis.

Summary of Background Data: Pyogenic spondylodiscitis of the thoracic and lumbar spine can produce instability, deformity, and/or neurological compromise. When medical treatment is unsuccessful, surgical treatment is indicated, with the conventional open approach the usual standard of care. However, percutaneous techniques can be advantageous in medically vulnerable patients.

Materials and Methods: A literature search was performed using the PubMed, Web of Science, and Scopus databases, looking for comparative articles on pyogenic spondylodiscitis requiring surgical stabilization with pedicle screws. This systematic review is reported according to PRISMA guidelines.

Results: From 215 articles initially identified, 7 retrospective studies were analyzed, encapsulating an overall sample of 722 patients: 405 male (56.1%) and 317 female (43.9%). The treatment modality was PPS fixation in 342 patients (47.4%) and OPS fixation in 380 (52.6%). For PPS, operating time was 29.75 minutes ($P<0.0001$), blood loss 390.18 mL ($P<0.00001$), postoperative pain 1.54 points ($P<0.00001$), and length of stay 4.49 days ($P=0.001$) less than with OPS fixation, and wound infection 7.2% ($P=0.003$) less frequent. No difference in screw misplacement ($P=0.94$) or loosening ($P=0.33$) rates was observed.

Conclusion: Employing PPS fixation to treat pyogenic spondylodiscitis of the thoracic and lumbar spine is associated with significantly reduced operating time, blood loss, postoperative pain, length of stay, and rates of wound infection than OPS fixation, with no difference between the 2 treatments in rates of screw misplacement or screw loosening.

Key Words: discitis, pedicle screws, treatment outcome, minimally invasive surgical procedures, spinal fusion

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Pyogenic spondylodiscitis of the thoracic and lumbar spine is a spontaneous infectious disease of the intervertebral disk and adjacent vertebral bodies that typically affects individuals rendered medically vulnerable because of advanced age and/or comorbidities. Its estimated incidence is 0.4–5.8 cases/100.000 per year.[1] Treatment goals are to eradicate the infection, prevent or treat sepsis, and decrease mortality.[2] Even with appropriate medical management, mechanical complications due to bone destruction and subsequent spinal instability can occur, with or without neurological compromise.[3]

When medical treatment fails, and instability and/or deformity has developed, surgical treatment is indicated. Different surgical strategies are available, which include anterior,[4] lateral,[5] and posterior approaches[6] that can be performed through conventional open surgery or, alternatively, using minimally invasive percutaneous fixation in patients with high functional demand and single-level disease.[7] The open approach allows proper debridement, decompression, instrumentation, and abscess evacuation when necessary. Nonetheless, traditional open surgery can increase morbidity, due to prolonged surgical time,

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From the *Department of Neurosurgery, Hospital Clínico Regional de Concepción; †Faculty of Medicine, University of Concepción, Concepción, Chile; ‡Department of Orthopaedic and Traumatology, Institute of Orthopedics "Carlos E. Ottolenghi" Hospital Italiano de Buenos Aires, Buenos Aires, Argentina; §Department of Orthopaedics, Government Medical College & Hospital, Dindigul, Tamil Nadu, India; ||Spine Unit, Orthopedic Department, Hospital Español de Mendoza, Mendoza; ¶Department of Orthopedic and Traumatology, Hospital Churruca Visca, Buenos Aires, Argentina; and #Division of Spine Surgery, Department of Orthopaedics and Traumatology, Policlinico di Napoli University Hospital, Università della Campania "Luigi Vanvitelli", Naples, Italy.
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The authors declare no conflict of interest.
Reprints: Juan P. Cabrera, MD, Department of Neurosurgery, Hospital Clínico Regional de Concepción, San Martín 1436, Concepción 4030000, Chile (e-mail: jucabrera@udec.cl).

increased blood loss, and extended hospital lengths of stay. Minimally invasive approaches using percutaneous pedicle screws (PPS) have gained interest among surgeons treating other spinal conditions, exhibiting well-known advantages over open techniques.[8,9] However, their role treating pyogenic spondylodiscitis is less well understood.

Even though a classification system has recently been developed to guide surgical treatment of pyogenic spondylodiscitis according to severity,[7] no robust evidence has been published comparing minimally invasive and open posterior approach surgeries treating it. The main objective of the present analysis was to compare outcomes of percutaneous versus open pedicle screw (OPS) fixation in pyogenic spondylodiscitis of the thoracic and lumbar spine.

MATERIALS AND METHODS

In April 2021, we conducted a systematic review of previously unpublished literature from PubMed, Web of Science, and Scopus to identify studies assessing outcomes of pyogenic spondylodiscitis of the thoracic and lumbar spine treated with either PPS or OPS fixation. The systematic review was reported in accordance with Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines.[10]

The following *PICO* acronym was used:

P (Population): adult patients with pyogenic spondylodiscitis of the thoracic and lumbar spine requiring spinal stabilization.

I (Intervention): PPS fixation.

C (Comparison): OPS fixation.

O (Outcome): operating time, blood loss, postoperative pain, length of stay, wound infection, screw misplacement, and screw loosening.

T (Time): January 2010 to March 2021.

Search Strategy, Inclusion, and Exclusion Criteria

The initial search was performed and the screening process for all articles using titles and abstracts, with selected articles further analyzed for eligibility by having 2 reviewers independently assess the full-text. None of the authors had any conflict of interest related to this systematic review. Figure 1 depicts the search strategy flow chart.

The following advanced search terms were used: ((“spondylodiscitis”[All Fields] OR “pyogenic spondylodiscitis”[All Fields] OR “infectious spondylodiscitis”[All Fields] OR “discitis”[All Fields]) OR (“spondylitis”[All Fields] NOT (“ankylosing”[All Fields] OR “tuberculosis”[All Fields]))) AND (“fixation”[All Fields] OR “instrumentation”[All Fields] OR “stabilization”[All Fields] OR “pedicle screw”[All Fields]). Records were filtered from 2010 to the current date, restricted to English papers, and excluded animal and cadaver studies.

To be eligible for inclusion, a study had to compare PPS and OPS fixation for the treatment of pyogenic spondylodiscitis of the thoracic and lumbar spine, with or without debridement of the disk space, evacuation of an abscess, or debridement. Patients receiving any additional approach for debridement or interbody fusion were included only if the outcomes were reported separately from those for the posterior approach.

Excluded from analysis were studies involving patients undergoing laparoscopic or endoscopic treatment without instrumentation, patients receiving anterior column support via a nonposterior approach, tuberculosis or postoperative spondylodiscitis, and studies for which the specific outcomes of interest were unavailable.

Evidence Quality and Risk of Bias Assessment

Risk of bias was assessed for all the studies considered for inclusion in analysis to identify which studies should and should not be analyzed further, using the Cochrane ROBINS-I tool[11] for nonrandomized studies.

Data Extraction

From each study included in meta-analysis, the following unadjusted data were obtained, if available, for both comparison groups: age, sex, American Society of Anesthesiologists (ASA) health status, the surgical procedure performed, any additional surgery beyond pedicle screws, and outcomes.

Data Synthesis and Statistical Analysis

Data analysis and synthesis were performed using Review Manager (RevMan) [Computer program] Version 5.4.1, The Cochrane Collaboration, 2020. For continuous variables, the mean difference with 95% confidence intervals (CI) was calculated; for dichotomous outcomes, an odds ratio (OR) with 95% CI was calculated using the Mantel-Haenszel method. Statistical heterogeneity among studies was evaluated using the I^2 test, with the fixed-effect model then used if $I^2 <50\%$ and $P > 0.05$ and the random-effect model when $I^2 > 50\%$ and $P < 0.05$. A 2-tailed *P*-value <0.05 was considered significant. Sensitivity analysis was performed whenever heterogeneity among outcomes was identified. A funnel plot was used to evaluate for publication bias.

Evidence Table

The Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach[12] was used to assess the quality of the body of evidence synthesized during meta-analysis. On the basis of the risk of bias assessed using the ROBINS-I tool and the evidence generated by meta-analysis, a GRADE table was created using the online tool GRADEpro GDT [Software] (2015) McMaster University (developed by Evidence Prime Inc.) to summarize the outcomes and rate the overall quality of evidence. Using the GRADE approach, outcomes were graded as of “high,” “moderate,” “low,” or “very low” level of certainty, considering the parameters risk of bias, consistency of results, directness of evidence, precision of results, publication bias, effect size, confounder bias, and dose-response gradient. A plain language summary of the evidence is also provided.

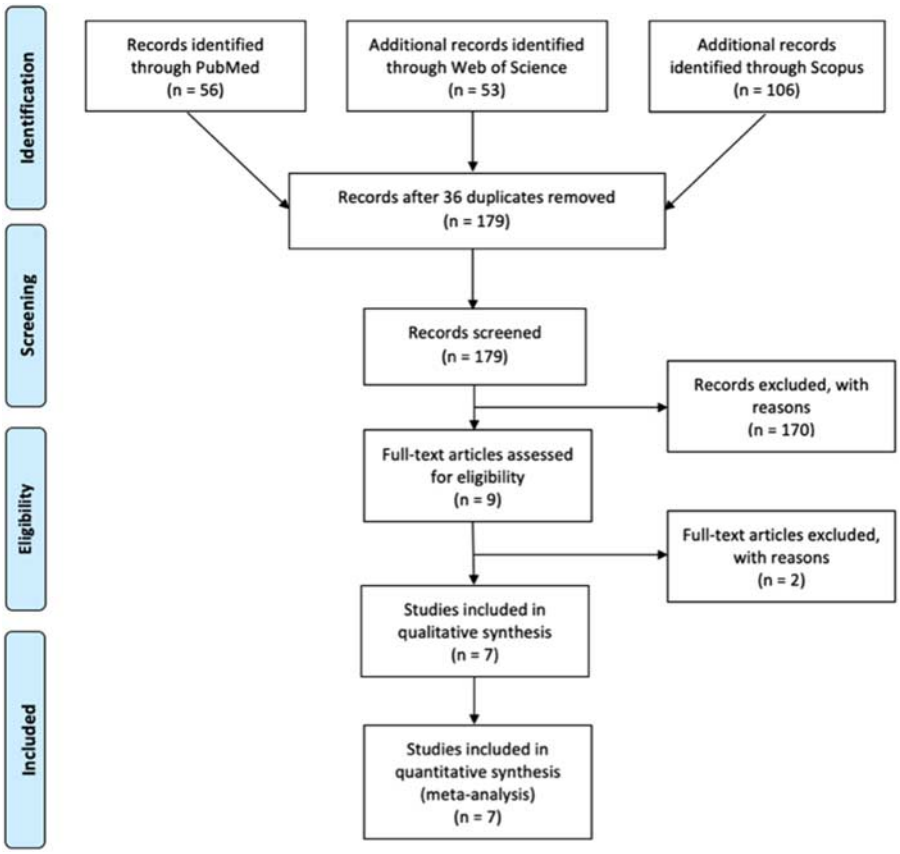

FIGURE 1. PRISMA flow diagram for identification and selection of studies. full color online

RESULTS

A total of 215 articles were identified during the initial search of the 3 databases. After 36 duplicated articles were removed, 179 articles were analyzed, among which 170 ultimately were excluded. This left 9 full-text articles for eligibility analysis by reviewers, with 7 ultimately selected for full analysis[13–19] (Fig. 1).

The 7 articles included in this systematic review are summarized in Table 1. All the studies were nonrandomized, retrospective studies and were consequently assessed for level of the perceived risk of bias using the ROBINS-I assessment tool.[11] Using this tool, 6 studies[13–16,18,19] were considered of moderate-risk and 1[17] of low risk of bias (Fig. 2).

Patient Demographics

Patient sex was reported for all 7 studies, age in 6 studies,[13,14,16–19] and ASA status in 4.[14,16–18] Overall, the sample included 722 patients: 405 male (56.1%) and 317 female (43.9%). The treatment modality was PPS fixation in 342 patients (47.4%) and OPS fixation in 380 (52.6%). Further details on study characteristics are provided in Table 1.

Segmental Anatomic Region

Six of 7 studies mentioned the region affected.[13,15–19] Chen et al[18] only included lumbar cases (N = 82), whereas Alaid et al[15] included thoracolumbar cases (N = 206). Regarding the articles that described segmental location, no differences were observed between open and percutaneous surgery. In Viezens et al study,[16] 49 cases had thoracic affection (24 in the open group and 25 in the percutaneous group), 7 in the thoracolumbar segment (2 in the open group and 5 in the percutaneous group), and 88 in the lumbar segment (43 in the open group and 45 in the percutaneous group). Lin et al[13] described 20 cases treated percutaneously (18 lumbar and 2 thoracic) and 27 treated openly (7 thoracic and 20 lumbar). In Keric et al study,[14] 2/3 of the cases were in the lumbar spine, whereas 1/3 affected the thoracic region. Finally, Janssen et al[19] described 78 cases treated with open surgery (13 thoracic, 61 lumbar, and 4 thoracolumbar transition) and 47 treated percutaneously (13 thoracic, 26 lumbar, and 8 thoracolumbar transition).

Outcomes

Operating Time

Operating time was analyzed in all 7 studies[13–19] in this systematic review. All authors reported shorter mean operating times with the percutaneous than with the open technique. On pooled analysis, a significant difference favored PPS over OPS: mean difference (MD) −29.75 minutes, 95% CI (−43.75, −15.76) ($P < 0.0001$). Significant heterogeneity was observed between the 7 studies ($I^2 = 51\%$, $P = 0.05$). Hence, a random-effects model was used (Fig. 3).

TABLE 1. General Characteristics of the 7 Studies Included in this Systematic Review

References, Country	Study Design	Number of Patients (Sex M/F)*	Mean Age (y) (PPS/OPS)*	ASA I and II (%) (PPS/OPS)*	Treatment (PPS/OPS)	Additional Surgical Treatment
Lin et al,[13] Taiwan	Retrospective	45 (25/20)	59.6/64.7	NR	20/25	PPS and OPS: first stage of anterolateral interbody fusion with autologous bone graft and debridement
Keric et al,[14] Germany	Retrospective	90 (49/41)	72.3 ± 11.1 (38–87)/ 68 ± 11.2 (31–84)†	2.9 ± 0.6/3.1 ± 0.6‡	66/24	PPS: robot-assisted, decompression, evacuation (45/66) OPS: evacuation, debridement (20/24)
Tschugg et al,[17] Austria	Retrospective	67 (24/43)	63.9 ± 12/ 64.4 ± 12	10 (52.7)/17 (35.5)	19/48	PPS: MIS-TLIF OPS: TLIF
Viezens et al,[16] Germany	Retrospective	148 (85/63)	64.1 ± 13.7/ 65.8 ± 12.1	2.8 ± 0.7/2.8 ± 0.6‡	75/73	PPS and OPS: Decompression, debridement, biopsy, second-stage anterior interbody fusion with autologous bone graft
Alaid et al,[15] Germany	Retrospective	206 (112/94)	< 70 y 90 ≥ 70 y 113	NR	98/108	PPS: robot-assisted, decompression (22/93) OPS: decompression (51/103) (missing n = 10)
Chen et al,[18] Taiwan	Retrospective	41 (24/17)	66.4 (44–79)/ 59.2 (37–86)	13 (76.5)/17 (70.8)	17/24	PPS: debridement, MIS-TLIF OPS: debridement, TLIF
Janssen et al,[19] Germany	Retrospective	125 (86/39)	69.9 ± 12.9 (34–89)/ 69.3 ± 12.6 (36–89)	NR	47/78	Second-stage anterior debridement, interbody fusion, or vertebral body replacement PPS: 32/47; 18 decompression OPS: 28/78
Total (patients)	—	722 (405/317)	—	—	342/380	—

*$P > 0.05$ between treatment groups.
†Median ± SD (range).
‡Mean ± SD.
ASA indicates American Society of Anesthesiologists; F, female; M, male; MIS, minimally invasive; NR, not reported; OPS, open pedicle screw; PPS, percutaneous pedicle screw; TLIF, transforaminal lumbar interbody fusion.

Blood Loss

Blood loss was directly measured in four studies.[13,17–19] All the authors reported significantly reduced blood loss using the percutaneous technique. In addition, in 3 studies,[16,18,19] intraoperative red blood cell transfusion rates were significantly lower in the percutaneous group. Pooled analysis again significantly favored PPS over OPS: MD −390.18 mL, 95% CI (−531.03, −249.33) ($P < 0.00001$). Significant heterogeneity was observed ($I^2 = 82\%$, $P = 0.0007$), so a random-effects model was employed (Fig. 3).

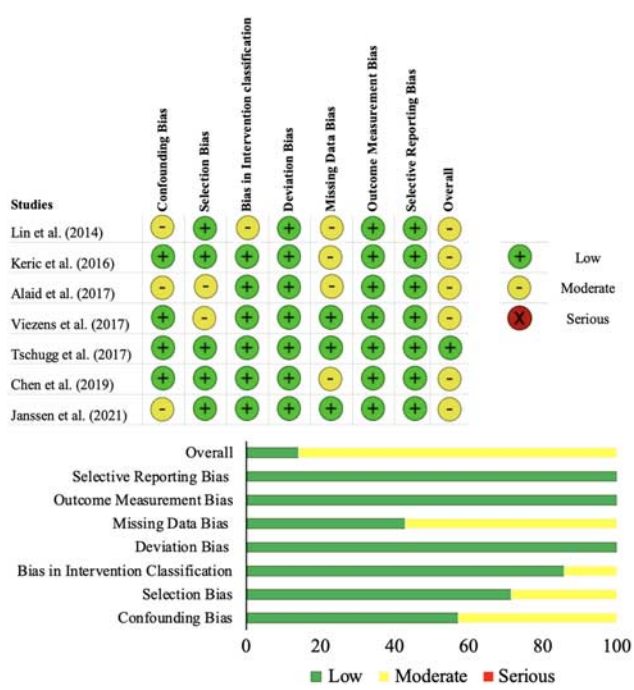

FIGURE 2. Perceived risk of bias across the seven studies included in meta-analysis using the ROBINS-I tool. full color online

Postoperative Pain

Pain during the postoperative phase was reported for 3studies[13,14,18] demonstrating better pain control in the percutaneous group. Pooled analysis again significantly favored PPS: MD −1.54, 95% CI (−1.93, −1.15) ($P < 0.00001$). Because of nonsignificant heterogeneity ($I^2 = 25\%$, $P = 0.26$), a fixed-effects model was employed (Fig. 4).

Length of Stay

Length of stay was analyzed in 4 studies[14,16,17,19]; all documenting fewer days in the hospital among PPS patients, with pooled analysis once again significantly favoring PPS: MD −4.49 days, 95% CI (−7.25, −1.74) ($P = 0.001$). Due to nonsignificant heterogeneity ($I^2 = 0\%$, $P = 0.78$), a fixed-effects model was utilized (Fig. 4).

Wound Infection

Wound infection rates associated with the posterior approach were reported for 6 studies.[13–17,19] Among these, the rate of wound infection was less with PPS in 5 studies[13–17], while 1 study[19] identified rates that were similar. Pooled

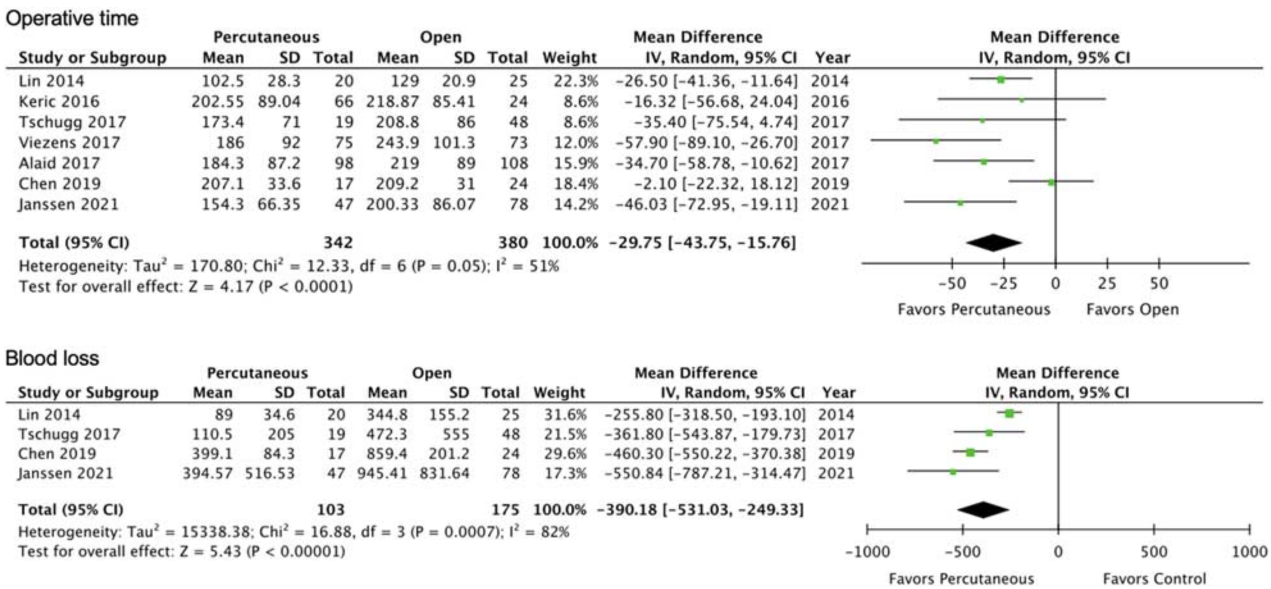

FIGURE 3. Forest plot of operating time and blood loss comparing percutaneous versus open pedicle screw fixation. CI indicates confidence interval. full color online

analysis again revealed a significant benefit of PPS over OPS: OR 0.46, 95% CI (0.27, 0.77) ($P=0.003$). Nonsignificant heterogeneity ($I^2=0\%$, $P=0.78$) again led to use of a fixed-effects model (Fig. 5).

Screw Misplacement

The rate of screw misplacement was reported for 4 studies,[13,14,16,17] among which 2 identified a lower rate with PPS[14,16] and the 2 others a lower rate with OPS.[13,17] The difference between studies on pooled analysis was nonsignificant: OR 0.91, 95% CI (0.08–10.38) ($P=0.94$). Because significant heterogeneity was noted ($I^2=69\%$, $P=0.02$), a random-effects model was used (Fig. 5).

Screw Loosening

Screw loosening or construct failure linked to the posterior approach was reported for 4 studies,[13–16] 3 identifying a lower rate of loosening with PPS and 1[16] with OPS. On pooled analysis, the difference between the 2 treatment approaches was nonsignificant: OR 0.68, 95% CI (0.31–1.49) ($P=0.33$). Because of nonsignificant heterogeneity ($I^2=0\%$, $P=0.56$), a fixed-effects model was utilized (Fig. 5).

Sensitivity Analysis

The overall effect, encompassing all the outcomes undergoing pooled analysis, was not altered substantially with the inclusion or exclusion of any individual study; nor

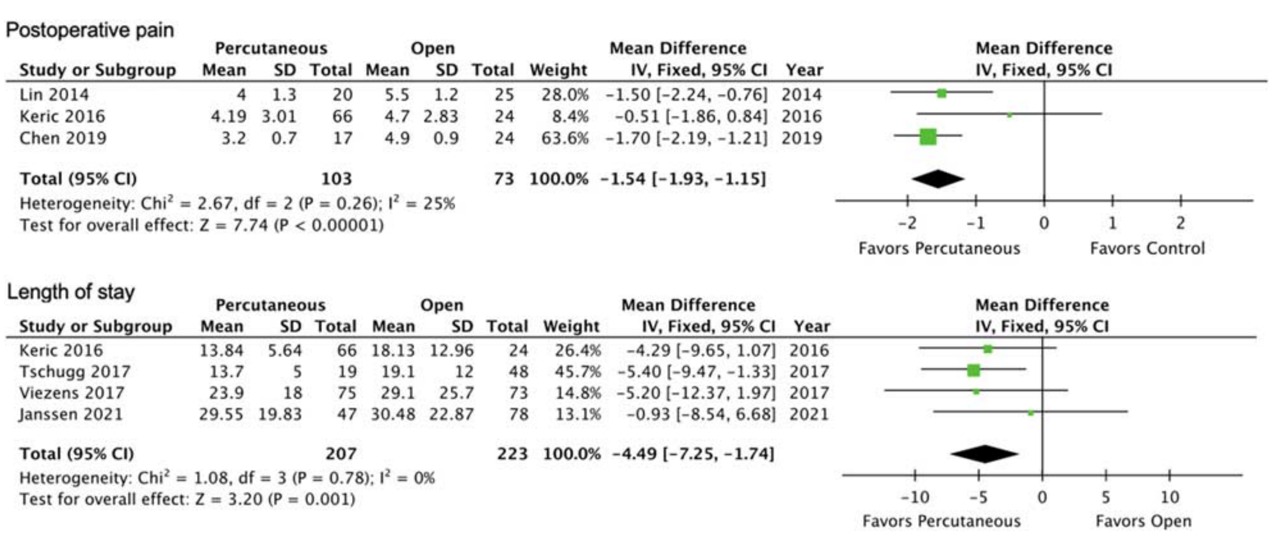

FIGURE 4. Forest plot of postoperative pain and length of stay comparing percutaneous versus open pedicle screw fixation. CI indicates confidence interval. full color online

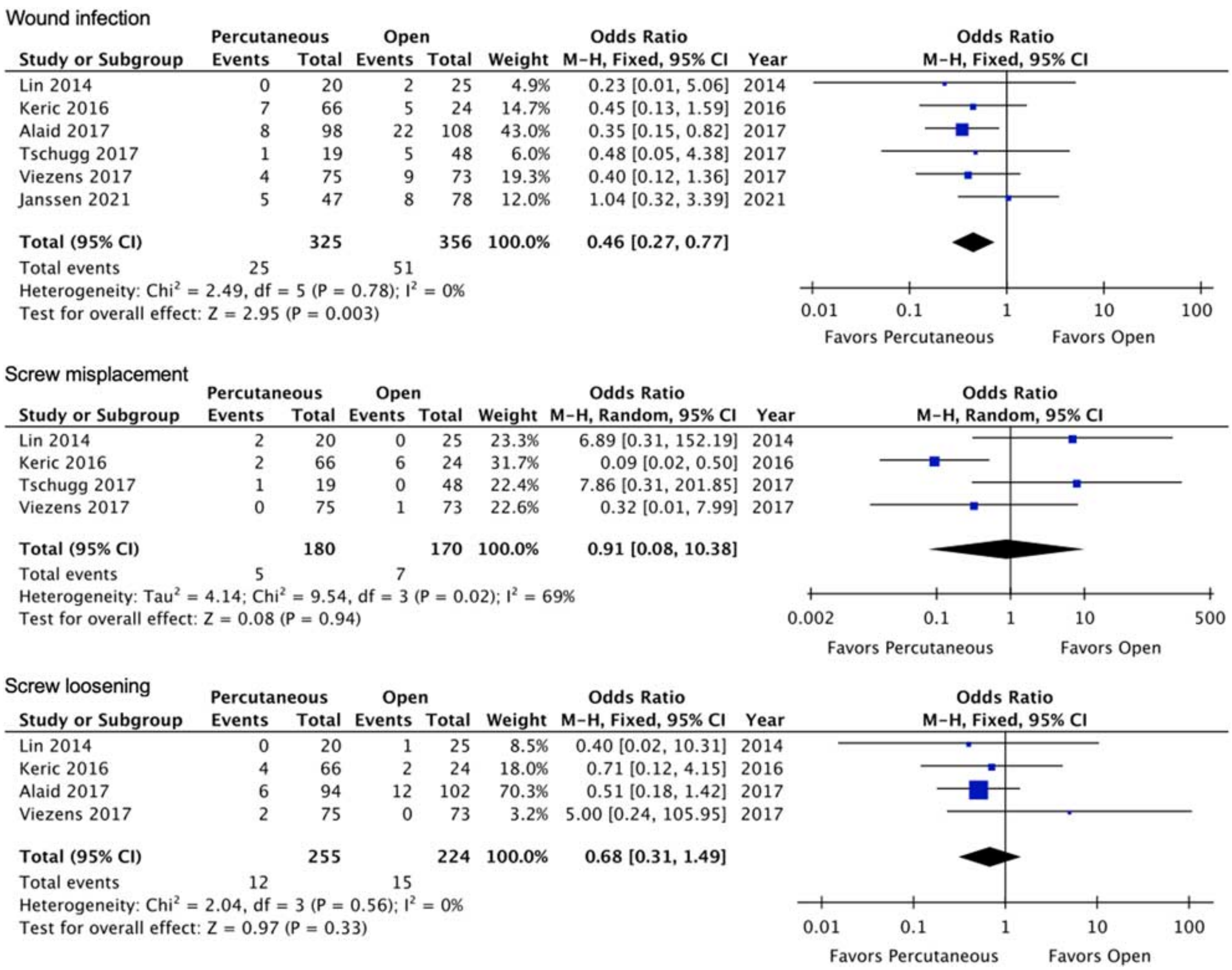

FIGURE 5. Forest plot of wound infection, screw misplacement, and screw loosening comparing percutaneous versus open technique. CI indicates confidence interval. full color online

did it ever change whether a fixed or random-effect model was indicated. No publication bias assessment by funnel plot was possible due to the small number of studies included in the meta-analysis.

Evidence Table

The level of evidence, using the GRADE approach, was considered of high certainly for the outcome wound infection; moderate for blood loss, postoperative pain, and length of stay; low for the outcomes operating time and screw misplacement; and very low for screw loosening. The outcomes operating time, blood loss, and screw loosening exhibited inconsistency in the measured effect across the studies in which each of these variables was analyzed (Table 2).

DISCUSSION

Pyogenic spondylodiscitis has increased in frequency in recent decades, partially due to higher life expectancies and the greater availability of high-quality imaging studies to detect it.[20] The most frequent route of infection is hematogenous, via which various structures within the vertebral segment unit can become involved.[21] In addition, despite adequate medical treatment and depending on the degree of bony and disk-ligament destruction, spinal instability can develop that requires spine fixation to prevent or treat kyphotic deformity, pain, disability, and neurological compromise.[22] A recent classification system, which exhibits substantial interobserver and intraobserver agreement, has been proposed to understand and standardize treatment.[23] The key objective of this clinical-radiologic classification system is to guide treatment based upon the severity of spondylodiscitis, with open surgery recommended for more severe disease.[1]

Minimally invasive pedicle screw fixation has gained acceptance as a means to stabilize degenerative,[24] deformity-induced,[25,26] osteoporotic,[27] traumatic,[28,29] and tumor-induced spinal instability[30] of the thoracic and lumbar spine. However, the potential role of percutaneous pedicle instrumentation treating infectious disease has received significantly less attention in the literature, especially for pyogenic spondylodiscitis. This might be due to

TABLE 2. Percutaneous Compared With Open Pedicle Screw Fixation for Pyogenic Spondylodiscitis

Patient or Population: Pyogenic Spondylodiscitis

Setting: Thoracolumbar Spine

Intervention: Percutaneous Pedicle Screw Fixation

Comparison: Open Pedicle Screw Fixation

Outcome Number of Participants (Studies)	Relative Effect (95% CI)	Anticipated Absolute Effects (95% CI)			Certainty	Summary
		With Open Method	With Percutaneous Method	Difference		
Operating time No. participants: 722 (7 retrospective studies)	—	The mean operating time was 204.15 min (SD = 71.38)	The mean operating time was 172.8 min (SD = 66.78)	WMD 29.75 min lower (43.75 lower to 15.76 lower)	⊕⊕◯◯ Low*†	The evidence suggests percutaneous pedicle screw insertion may result in a reduction in operating time
Blood loss No. participants: 278 (4 retrospective studies)	—	The mean blood loss was 655.47 mL (SD = 435.76)	The mean blood loss was 248.29 mL (SD = 210.10)	WMD 390.18 mL lower (531.03 lower to 249.33 lower)	⊕⊕⊕◯ Moderate*†	Percutaneous pedicle screw insertion likely results in a reduction in blood loss
Postoperative pain No. participants: 176 (3 retrospective studies)	—	The mean postoperative pain was 5.03 (SD = 1.64)	The mean postoperative pain was 3.79 (SD = 1.67)	WMD 1.54 lower (1.93 lower to 1.15 lower)	⊕⊕⊕◯ Moderate*	Percutaneous pedicle screw insertion likely results in a reduction in postoperative pain
Length of stay No. participants: 430 (4 retrospective studies)	—	The mean length of stay was 24.2 d (SD = 12.11)	The mean length of stay was 20.24 d (SD = 18.38)	WMD 4.49 d lower (7.25 lower to 1.74 lower)	⊕⊕⊕◯ Moderate*	Percutaneous pedicle screw insertion likely results in a reduction in length of stay
Wound infection No. participants: 681 (6 retrospective studies)	OR 0.46 (0.27–0.77)	14.3%	7.1% (4.3–11.4)	7.2% fewer (10 fewer to 2.9 fewer)	⊕⊕⊕⊕ High*	Percutaneous pedicle screw insertion results in a reduction in wound infection
Screw misplacement No. participants: 350 (4 retrospective studies)	OR 0.91 (0.08–10.38)	4.1%	3.8% (0.3–30.8)	0.4% fewer (3.8 fewer to 26.7 more)	⊕⊕◯◯ Low*	Percutaneous pedicle screw insertion does not reduce screw misplacement
Screw loosening No. participants: 479 (4 retrospective studies)	OR 0.68 (0.31–1.49)	6.7%	4.7% (2.2–9.7)	2.0% fewer (4.5 fewer to 3 more)	⊕◯◯◯ Very low*†	The evidence is very uncertain about the effect of percutaneous pedicle screw insertion on screw loosening

*Refer to ROBINS-I plot.
†Inconsistency in the measured effect across the included studies.
CI indicates confidence interval; OR, odds ratio; WMD, weighted mean difference.

the belief that inserting implants during an active infection might increase the rate of recurrence or colonize the implant. Current literature supports the safety of instrumented fusion in the setting of primary spinal infections, exhibiting rates of continued infection similar to those observed in patients who undergo totally non-instrumented decompression.[31]

Bridging fixation using PPS has been previously demonstrated to be effective at relieving pain, and at preventing both deformity and neurological compromise, as a better alternative than orthosis in noncomplicated pyogenic spondylodiscitis.[32] One well-known advantage of minimally invasive over conventional open techniques is substantially less injury to paraspinal tissues, leading to reduced blood loss, pain, disability, and hospital length of stay, thereby facilitating a patient's recovery.[33] A systematic comparison of these 2 modalities comparing their respective treatment effects using the best evidence available was necessary to aid spine surgeons in their decision-making when managing pyogenic spondylodiscitis of the thoracolumbar spine.

As recommended,[1] open surgery is primarily reserved for sicker patients and more severe cases of bone destruction with kyphotic deformity.[17] The principal management of pyogenic spondylodiscitis management is antibiotic therapy.[34] The wider muscle detachment that occurs during open surgery, thereby creating a greater space surrounding the infected disk space—an avascular structure—combined with the adjacent vertebrae could interfere with the hematological delivery of antibiotics. Therefore, an additional anterior/lateral approach for kyphosis reduction and reconstruction, like that reported by Lin et al,[13] Viezens et al,[16] and Janssen et al,[19] should be considered, followed by a posterior percutaneous approach to preserve the blood supply while benefitting from reduced blood loss, operating time, hospital stays, and postoperative pain, as demonstrated by the pooled analysis conducted during the current systematic review. This said, 360 degrees decompression and reconstruction using single-stage open posterior surgery is possible for severely collapsed pyogenic spondylodiscitis.[35]

A spinal epidural abscess associated with neurological compromise or uncontrolled infection may need debridement, and this usually involves a laminectomy. In the study by Alaid et al,[15] 10 of 30 (33%) patients who underwent wound revision were reported to have an epidural abscess, while only 35 of 175 (20.0%) patients who did not require wound revision had one. Notwithstanding this difference, epidural abscess is usually approachable through an additional, minimal, midline incision during percutaneous fixation, as reported by Keric et al[14] (in 45/66 patients) and by Viezens et al.[16] They also can be accessed using a Wiltse approach,[36] in both instances achieving evacuation and bilateral decompression, if needed, with no additional incision, as reported by Tschugg et al[17] and Chen et al.[18]

Notably, with low certainty of the evidence, the rates of screw misplacement were not significantly different in the present meta-analysis. Screw misplacement is a recognized event in spine surgery, but is always a point of concern for surgeons, its incidence under-reported despite its potential impact on patient outcomes.[37] On the one hand, the gold-standard open surgery offers access to all the anatomic landmarks needed during surgery, allowing surgeons to palpate the pedicle walls and, thereby, avoid mal-positioning. On the other hand, minimally invasive surgery obliges the surgeon to utilize radiologic assistance—for example, fluoroscopy, navigation, robotic—and assessing the cannulated pedicle screws during positioning reduces the rates of lateral malposition and medial perforation to those observed with open techniques.[38]

With the level of evidence considered very uncertain in this systematic review, the rate of screw loosening did not appear to be different in patients undergoing percutaneous and open fixation. However, in pyogenic non-postoperative spondylodiscitis, this issue must be regarded with special caution. The radiologic and clinical criteria used for to assess screw loosening is highly variable in the literature.[39] One possible causative factor is the infectious environment of the surrounding bony structures, leading to the previously described "septic loosening" phenomenon.[40] Loosened screws frequently require revision surgery when symptoms or construct failure occurs. Recently, carbon-fiber–reinforced PEEK instrumentation has been compared with titanium screws treating spondylodiscitis, with carbon-fiber instrumentation demonstrating a significantly higher rate of screw loosening (35% vs. 14%, $P=0.004$).[41]

The present systematic review has limitations that must be emphasized to appropriately interpret the results. First, the analysis was performed extracting data for 7 retrospective nonrandomized comparative studies with mainly a moderate perceived risk of bias. Overall, the demographic characteristics of the patients in each study were similar; however, the risk of some selection bias cannot be denied. Second, variability in medical and surgical treatment, like different spinal fusion and debridement techniques, are likely in the studies we included in our analysis, which also could influence the outcomes we observed. Moreover, treatment selection bias based on case severity is inherent in nonrandomized studies, as open surgery is more likely to be indicated in patients with severe deformity. The presence of epidural abscesses could also bias the patient selection; in this regard, significantly higher prevalence of epidural abscesses is mentioned in 3 studies in the open group,[13,14,16] whereas 1 study found no differences in both groups.[15] Preoperative neurological compromise, a potential bias affecting the selection, is mentioned in 1 study with similar prevalence in the open and minimally invasive group.[15] Finally, no comparison between thoracic and lumbar location was described in the included articles.

To decrease bias in some outcomes included in our study—like operating time, blood loss, postoperative pain, length of stay, and wound infection rate—we restricted our analysis to the isolated posterior approach. Third, screw misplacement was compared using 1 study in which robot-assistance was used, whereas surgeons employed fluoroscopy-guided or free-hand techniques in all the other studies. Finally, moderate statistical heterogeneity was observed for the outcome "operating time," while substantial statistical heterogeneity was identified for the outcomes "blood loss" and "screw misplacement."

CONCLUSIONS

Treating pyogenic spondylodiscitis of the thoracic and lumbar spine with PPS fixation is associated with significantly reduced operating time, blood loss, postoperative pain, length of hospital stay, and wound infections relative to using an OPS technique. However, no difference was observed between these 2 surgical approaches in the rates of screw misplacement and screw loosening. Further, well-designed, prospective, comparative studies are needed to confirm these results.

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