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REVIEW ARTICLE

Comparative clinical efficacy and safety of cortical bone trajectory screw fixation and traditional pedicle screw fixation in posterior lumbar fusion: a systematic review and meta-analysis

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Abstract

Purpose To compare the clinical efficacy and safety between cortical bone trajectory (CBT) and pedicle screw (PS) in posterior lumbar fusion surgery.

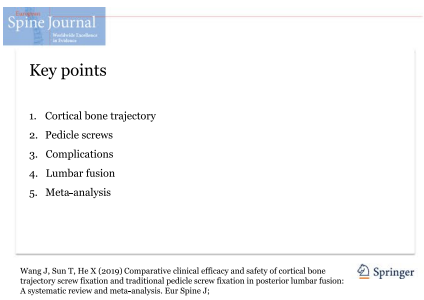
Methods Five electronic databases were used to identify relevant studies comparing the clinical efficacy and safety between CBT and PS. The main outcomes were postoperative fusion rates and complication (especially in superior facet joint violations, symptomatic ASD, wound infection, dural tear, screw malposition and hematoma). The secondary results included operation time, intraoperative blood loss, length of hospital stay, incision length, ODI, VAS, JOA score, JOA recovery rate, patients' satisfaction and health-related quality of life.

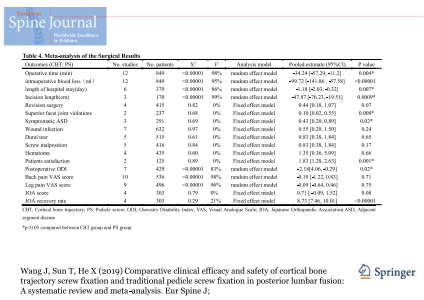
Results The outcomes showed that there was no significant difference in terms of fusion rate ($p = 0.55$), back and leg VAS score ($p > 0.05$), JOA score ($p = 0.08$) and incidence of reoperation ($p = 0.07$). However, CBT was superior to PS with Oswestry Disability Index (ODI) ($p = 0.02$), JOA recovery rate ($p < 0.00001$) and patients' satisfaction ($p = 0.001$). In addition, CBT was superior to PS with significantly lower incidence of superior facet joint violation and symptomatic ASD. However, there was no significant difference regarding wound infection ($p > 0.05$) and screw malposition ($p > 0.05$). CBT group required significant shorter operation time, less blood loss, shorter incision length and shorter length of hospital stay in comparison with PS group ($p < 0.05$).

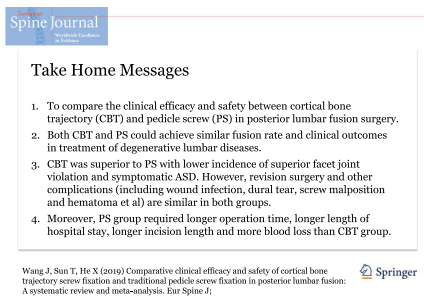
Conclusions Both CBT and PS achieve similar, fusion rate and revision surgery rate. Furthermore, CBT is superior to PS with lower incidence of complications, shorter operation time, less blood loss, shorter incision length and shorter length of hospital stay.

Graphical abstract

These slides can be retrieved under Electronic Supplementary Material.







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Keywords Cortical bone trajectory · Pedicle screws · Complications · Lumbar fusion · Meta-analysis

Introduction

Pedicle screw (PS) fixation is the current major technique for posterior spinal fusion. It has been widely used in the treatment of various lumbar pathologies, such as lumbar stenosis, spondylolisthesis and lumbar instability due to its good biomechanical stability [1–4]. But several drawbacks of PS, including the risk of superior facet joint violation, extensive muscle injury and lack of purchase in osteoporotic patients, have also been pointed out [5–8]. More recently, there has been a rise in the use of cortical bone trajectory (CBT), first reported by Santoniet et al. [9], in which screws followed a medial-to-lateral path in the transverse plane and a caudal-to-cephalad path in the sagittal plane through the pedicle. CBT improved pullout strength by maximizing thread contact of the screw with the cortical bone of the vertebrae. CTB placement is the more favorable procedure compared with PS placement, because of less lateral muscle dissection, a shorter incision length and a more medially located entry point.

Multiple biomechanical studies have shown that the CBT technique provided higher pullout strength, higher insertional torque and similar stability of the screw-rod construct compared to the traditional pedicle screw fixation [10–14]. Several clinical studies have demonstrated that CTB provided similar clinical outcomes, less multifidus muscle damage and lower surgical complication as compared to PS [15–19]. Other studies, however, hold the opposite outcomes [20–22]. So far, both CBT and PS are used in posterior lumbar fusion and it remains uncertain for which is the better operative technique. We therefore performed a systematic review and meta-analysis to evaluate the clinical efficacy and safety between CBT and PS in posterior lumbar fusion surgery.

Materials and methods

Search strategy and study selection

A comprehensive literature search was performed via following databases: PubMed, EMBASE, Cochrane library, Web of science and Ovid databases. The retrieval time is from January 2009 to June 2018 without language restriction. We located studies with the following search terms: cortical bone trajectory, CBT, cortical screw, CS, pedicle screw, PS and lumbar.

Inclusion criteria

The following inclusion criteria were used: (1) a randomized controlled trials (RCTs) or prospective and retrospective studies which compared CBT screw fixation with PS fixation in posterior lumbar fusion; (2) provided sufficient information regarding clinical efficacy and the safety of CBT and PS; (3) outcome measurements included at least one of the following indicators: operation time, intraoperative blood loss, length of hospital stay, incision length, fusion rates, complications, back and leg pain visual analog score (VAS), Oswestry Disability Index (ODI) and Japanese Orthopaedic Association (JOA).

Exclusion criteria

(1) Duplicate publications, (2) insufficient outcomes regarding clinical efficacy and the safety of CBT and PS, (3) systematic reviews, meta-analysis, case reports, editorials, letters, cadaveric studies, vitro studies and animal experiments were excluded.

Data extraction

The data were extracted independently by two reviewers from the inclusive studies. Any dispute was resolved by discussion or by involving a third reviewer. The following information was extracted from each study: (1) study design (first author, country, publication time and type of study); (2) study population (number of included patients, age and sex); (3) surgical procedures; (4) clinical efficacy (fusion rates and ODI, VAS, JOA score, patients' satisfaction and HRQOL); (5)clinical safety (complications rates, revision surgery, operation time, intraoperative blood loss, length of hospital stay and incision length). Complications included intraoperative complications (facet joint violation, dural tear, screw malposition,) and postoperative complications (screw loosening, cage migration, screw pullout, cage subsidence, adjacent segment disease, hematoma, superficial wound infection and deep wound infection).

Data analysis

All the meta-analyses were performed with the Review Manager Software (RevMan Version 5.3 Cochrane Collaboration). The continuous data were calculated by mean difference (MD) with 95% confidence intervals (CI), and dichotomous variables were determined by using risk ratio

(RR) with 95% confidence intervals (CI). The X^2 test (p values) and I^2 statistic test were used to calculate the statistical heterogeneity. When the test for heterogeneity was $p < 0.1$ or $I^2 > 50\%$, the data were considered very heterogeneous and random effects model was used; if the $p > 0.1$ or $I^2 \leq 50\%$, the heterogeneity between studies was not significant, a fixed effect model was used. $p < 0.05$ indicated that the difference was statistically significant.

Risk of bias individual studies

A systematic assessment of bias in the RCTs was performed using the Cochrane collaboration tool [23]. The risk of bias of the cohort studies was assessed using the Newcastle–Ottawa scale [24]. Risk of bias of the included studies was independently assessed by two reviewers. Disagreements will be resolved by discussion or by consulting a third author.

Results

Search results

A total of 421 articles from PubMed, EMBASE, Cochrane library, Web of science and Ovid database were initially identified. 154 articles were found in PubMed, 73 articles were from Web of Science, 11 articles were found in Cochrane library, 142 articles were from EMBASE, and 41 articles from Ovid were found. 216 references were excluded because of duplication. By screening the titles and abstracts, 185 studies were directly excluded. The

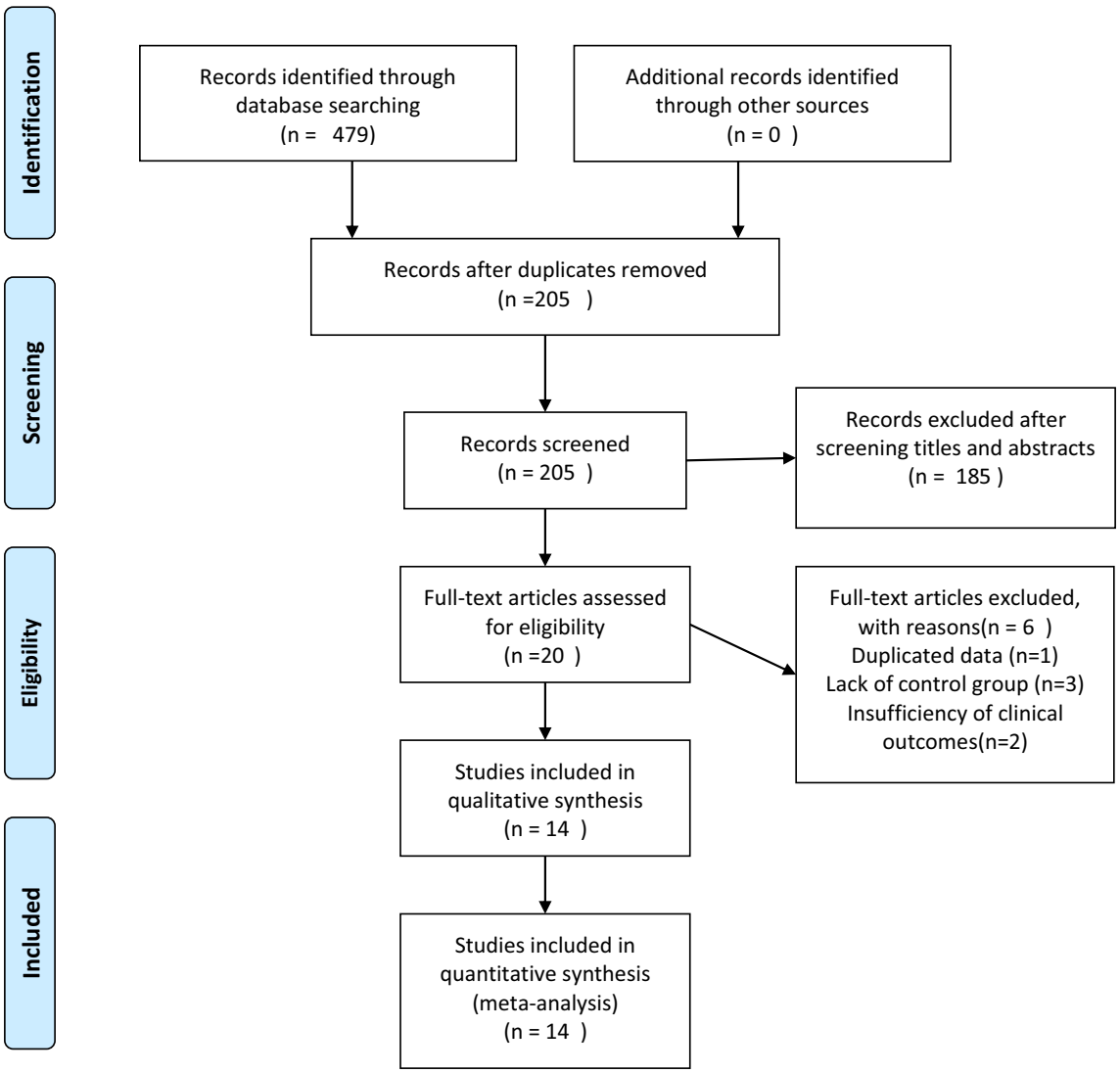

Fig. 1 Study selection flow diagram

remaining 20 studies underwent a comprehensive full-text analysis. Finally, 14 studies met the inclusion criteria and were included in this meta-analysis [15–18, 20–22, 25–30]. The flow diagram of the search strategy is summarized in Fig. 1.

Study characteristics

The eligible studies included 2 randomized control trials and 12 cohort studies published in 2015–2018. A total of 954 patients were involved in the 14 studies. The CBT group was 466 patients, and the PS group was 488 patients. The characteristics of included studies are presented in Table 1. In two RCTS, risk of bias in blinding of participants and personnel was considered as high risk owing to no blinding to the surgeons and the other bias was low risk (Table 2). All 12 cohort studies were assessed by Newcastle–Ottawa scale (NOS). Of the studies, four studies scored 7 points, six studies scored 8 points, and two studies scored 9 points (Table 3). A score ≥ 7 indicated a good quality study; thus, the studies were of a relatively high quality.

Clinical efficacy

Fusion rates

Fourteen studies [15–18, 20–22, 25, 26–31] including 954 patients (466 patients in the CBT group and 488 in the PS group) that reported fusion rates at the last follow-up. These studies reported fusion rates based on the dynamic radiographs and CT images between 12- and 40-month follow-up. The pooled fusion rates were 92.6% (452/488 levels) in the CBT group and 92.7% (471/508 levels) in the PS group. There was no significant heterogeneity between the two groups ($p = 0.94$, $I^2 = 0\%$); fixed effects model was used for meta-analysis. The results showed that there was no statistically significant difference in fusion rates between the two groups [RR = 0.99, 95% CI (0.95, 1.02), $p = 0.55$; Fig. 2].

Postoperative ODI

Seven studies [16–18, 25, 26, 29, 31] compared mean ODI between CBT and PS. There was significant heterogeneity between the two groups ($P < 0.00001$, $I^2 = 83\%$). The pooled estimated revealed that PS group had more obvious

Table 1 Included studies characteristics

Author	Year	Country	Design	Case		Ages (year)		Sex (*M*/*F*)		Follow-up (month)	Operation
				CBT	PS	CBT	PS	CBT	PS	CBT/PS	
Chin et al.	2017	USA	Cohort	30	30	48 ± 3	62 ± 3	18/12	15/15	24/24	NM
Hung et al.	2016	China	Cohort	16	16	60.37 ± 11.07	64.12 ± 5.79	5/11	6/10	18/18	PLIF
Lee et al.	2015	Korea	RCT	38	39	51.3 ± 12.4	51.9 ± 11.7	33/5	34/5	12/12	PLIF
Marengo et al.	2018	Italy	Cohort	20	20	45 ± 9.63	54 ± 12.01	12/8	9/11	12/12	PLIF
Sakaura et al.	2016	Japan	Cohort	95	82	68.7 ± 9.5	67 ± 8.7	46/49	36/46	35/40	PLIF
Sakaura et al.	2018	Japan	Cohort	22	20	70.7 ± 7.3	68.3 ± 9.6	4/18	6/14	39/35	PLIF
Takenaka et al.	2017	Japan	Cohort	42	77	65.7 ± 8.1	65.7 ± 11.4	18/24	31/46	17/35	PLIF
Xi et al.	2016	China	Cohort	12	20	63.4 ± 6.1	63.4 ± 6.1	NM	NM	11/11	PLIF + TLIF
Orita et al.	2016	Japan	Cohort	20	20	63.5 ± 9.4	63.7 ± 14.3	11/9	12/8	13/18	TLIF
Lee et al.	2018	Korea	RCT	35	37	51.2 ± 11.9	51.7 ± 10.4	31/4	33/4	24/24	PLIF
Chen et al.	2016	USA	Cohort	18	15	53.39 ± 1.97	59.2 ± 3.12	11/7	2/13	15/15	NM
Peng et al.	2017	China	Cohort	51	46	62.8	61.9	23/28	21/25	24/24	PLIF
Lee et al.	2018	Korea	Cohort	22	31	62.7 ± 10.1	64.2 ± 9.3	9/13	12/19	12/12	PLIF + PLF
Malcolm et al.	2018	USA	Cohort	45	35	63 ± 9	57 ± 11	20/25	7/28	12/12	TLIF

CBT cortical bone trajectory, *PS* pedicle screw, *PLIF* posterior lumbar interbody fusion, *TLIF* transforaminal lumbar interbody fusions, *PLF* posterolateral lumbar fusion

Table 2 Risk of bias assessment for randomized controlled trials

Author	Sequence generation	Allocation concealment	Blinding	Incomplete outcome data	Selective reporting	Other bias
Lee et al. [26]	Low	Low	High	Low	Low	Low
Lee et al. [17]	Low	Low	High	Low	Low	Low

Table 3 Newcastle–Ottawa scale (NOS) assessment of cohort study

Author	Year	Level of evidence	Selection	Comparability	Outcomes	Quality judgment
Chin et al.	2016	III	4	1	3	8
Hung et al.	2016	IV	4	2	2	8
Peng et al.	2017	IV	4	1	2	7
Marengo et al.	2018	III	4	2	2	8
Sakaura et al.	2016	III	4	2	3	9
Sakaura et al.	2018	III	4	2	3	9
Takenaka et al.	2017	III	4	1	3	8
Xi et al.	2016	IV	4	1	2	7
Malcolm et al.	2018	III	4	2	2	8
Orita et al.	2016	III	4	1	2	7
Lee et al.	2018	III	4	2	2	8
Chen et al.	2016	IV	4	1	2	7

Selection: (1) representativeness of the exposed cohort, (2) selection of the nonexposed cohort, (3) ascertainment of exposure and (4) demonstration that outcome of interest was not present at the start of study

Comparability: comparability of cohorts on the basis of the design or analysis

Outcome: (1) assessment outcome, (2) was follow-up long enough for outcomes to occur, (3) adequacy of follow-up of cohorts (≥ 1 years)

NOS scores ≥ 7 indicate a high-quality study

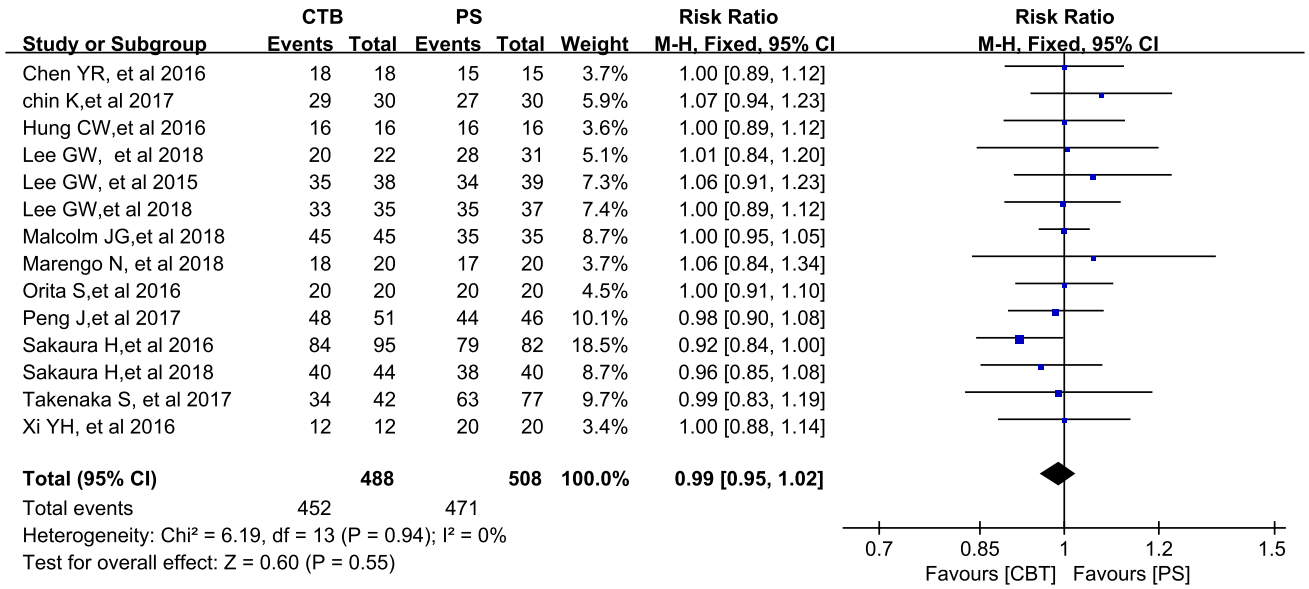

Fig. 2 Comparison of fusion rate

disabilities postoperatively when compared to the CBT group. [MD = − 2.18, 95% CI (− 4.06, − 0.29), $p = 0.02$;] (Table 4).

Postoperative back and leg pain VAS score

Ten studies [16–18, 22, 25, 26, 28–31] and nine studies [16, 17, 22, 25, 26, 28–31] reported mean back pain VAS score and leg pain VAS score within the CBT and PS groups, respectively. The outcomes indicated that VAS scores for low back pain of CBT group were better than PS group [MD = − 0.19, 95% CI (− 1.22, 0.83)]; however, this difference failed to reach statistical significance ($p = 0.71$). Mean leg pain intensity of PS group was slightly greater than that in the CTB group; there were no significant differences between the groups [MD = − 0.09, 95% CI (− 0.64, 0.46); $p = 0.75$] (Table 4).

Table 4 Meta-analysis of the surgical results

Outcomes (CBT: PS)	No. studies	No. patients	X^2	I^2 (%)	Analysis model	Pooled estimate (95% CI)	p value
Operative time (min)	12	849	< 0.00001	98	Random effect model	− 34.24 (− 57.29, − 11.2)	0.004*
Intraoperative blood loss (ml)	12	849	< 0.00001	95	Random effect model	− 99.72 (− 141.86, − 57.58)	< 0.00001*
Length of hospital stay (day)	6	379	< 0.00001	86	Random effect model	− 1.18 (− 2.03, − 0.32)	0.007*
Incision length (cm)	3	170	< 0.00001	99	Random effect model	− 47.87 (− 76.23, − 19.51)	0.0009*
Revision surgery	4	415	0.82	0	Fixed effect model	0.44 (0.18, 1.07)	0.07
Superior facet joint violations	2	237	0.68	0	Fixed effect model	0.10 (0.02, 0.55)	0.008*
Symptomatic ASD	3	291	0.69	0	Fixed effect model	0.43 (0.20, 0.89)	0.02*
Wound infection	7	632	0.97	0	Fixed effect model	0.55 (0.20, 1.50)	0.24
Dural tear	5	515	0.61	0	Fixed effect model	0.83 (0.38, 1.84)	0.65
Screw malposition	5	416	0.84	0	Fixed effect model	0.83 (0.38, 1.84)	0.17
Hematoma	4	435	0.60	0	Fixed effect model	1.35 (0.36, 5.09)	0.66
Patients satisfaction	2	125	0.89	0	Fixed effect model	1.83 (1.28, 2.63)	0.001*
Postoperative ODI	7	429	< 0.00001	83	Random effect model	− 2.18,(4.06, − 0.29)	0.02*
Back pain VAS score	10	536	< 0.00001	98	Random effect model	− 0.19 (− 1.22, 0.83)	0.71
Leg pain VAS score	9	496	< 0.00001	96	Random effect model	− 0.09 (− 0.64, 0.46)	0.75
JOA score	4	303	0.79	0	Fixed effect model	0.71 (− 0.09, 1.52)	0.08
JOA recovery rate	4	303	0.29	21	Fixed effect model	8.73 (7.46, 10.01)	< 0.00001*

ODI Oswestry Disability Index, *VAS* visual analog scale, *JOA* Japanese Orthopaedic Association, *ASD* adjacent segment disease

*$p < 0.05$ indicated that the difference was statistically significant

Postoperative JOA score and JOA recovery rate

Four studies [20, 21, 25, 30] compared mean JOA scores and JOA recovery rate between CBT and PS groups (Table 4). JOA scores and JOA recovery rate had no significant heterogeneity between two groups ($p = 0.79$, $I^2 = 0\%$ and $p = 0.29$, $I^2 = 21\%$). The pooled estimate from the studies revealed that CBT had better functional improvement by JOA [MD = 0.71, 95% CI (− 0.09, 1.52), $p = 0.08$] and JOA recovery rate [MD = 8.73, 95% CI (7.46, 10.01), $p < 0.00001$)] when compared to PS groups.

Patients' satisfaction

Among two studies [17, 31], there was significant difference in patients' satisfaction at 1 month after surgery between CBT group [38/57 (66.7%)] and PS group [25/68 (36.8%)] [OR = 3.52, 95% CI (1.67–7.43), $p = 0.001$] (Table 4). At the 6 month, 1-year and 2-year follow-up, there was no significant difference between the groups.

HRQOL

One cohort study [31] and one RCT [17] analyzed HRQOL outcomes using SF-12; the results suggest no difference in the Mental Component Summary score and Physical Component Summary score between CBT and PS ($p > 0.05$).

Clinical safety

Complication rate

Nine studies [15, 17, 18, 20, 21, 26, 27, 29, 30] with a total of 736 patients (360 patients in the CBT group and 376 in the PS groups) reported the data of complication rate. The analysis indicated that PS group had a significant higher complication rate than CBT group [RR = 0.46, 95% CI (0.33 to 0.64), $p < 0.00001$], and no heterogeneity was detected among the studies ($p = 0.66$, $I^2 = 0\%$) (Fig. 3). Moreover, the incidences of intraoperative complications [RR = 0.41, 95% CI (0.24–0.69), $p = 0.001$] and postoperative complications [RR = 0.53, 95% CI (0.34–0.82), $p = 0.004$] were higher in the PS group than those in the CBT group; there was no significant heterogeneity ($p = 0.44$, $I^2 = 0\%$) and ($p = 0.98$, $I^2 = 0\%$) (Figs. 4, 5). We further divided complications into six common parts, which included superior facet joint violations, symptomatic ASD, wound infection, dural tear, screw malposition and hematoma.

Two studies [18, 26] reported superior facet joint violations; significant difference was observed between the CBT and PS groups [0.85% (1/118) in CTB group and 11.76% (14/119) in the PS group], [RR = 0.1, 95% CI (0.02–0.55), $p = 0.008$)] (Table 4). Perfect homogeneity was present with $p = 0.68$ and $I^2 = 0\%$. Three studies [17, 20, 21] with 291 patients reported symptomatic ASD. The incidence of symptomatic ASD of PS group was significantly higher than that of CBT group [RR = 0.43, 95% CI (0.20–0.89), $p = 0.02$;

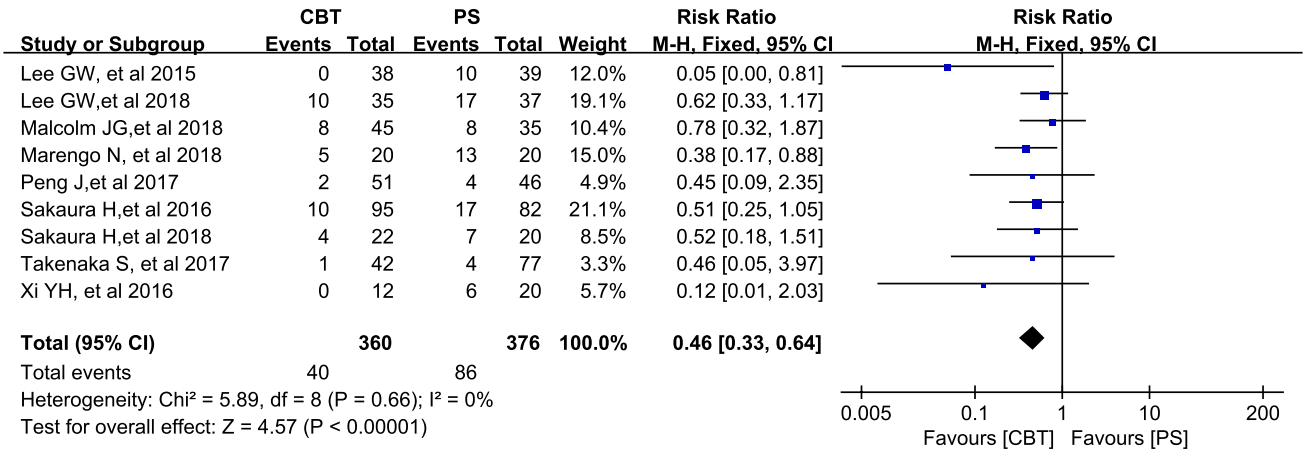

Fig. 3 Comparison of complications rate

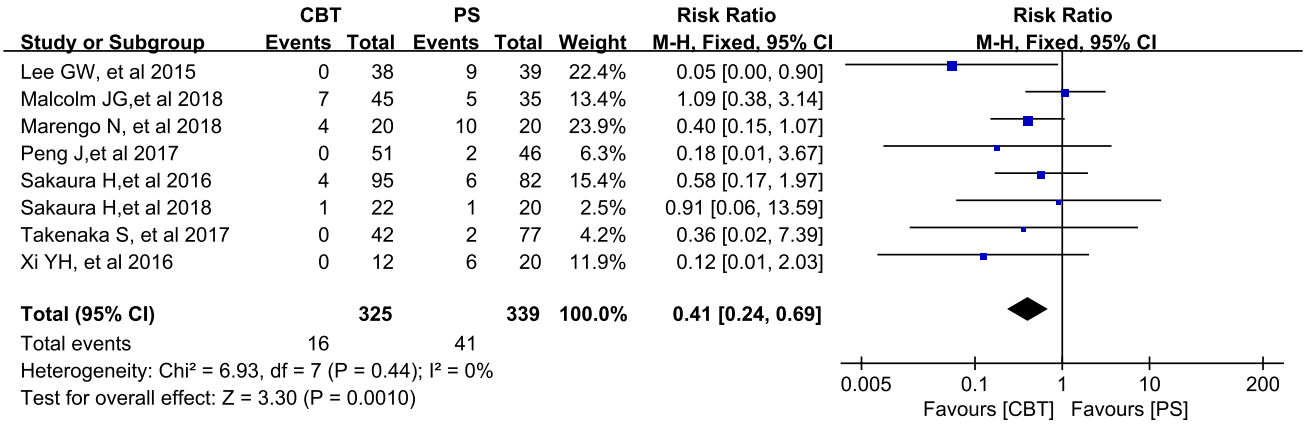

Fig. 4 Comparison of intraoperative complications rate

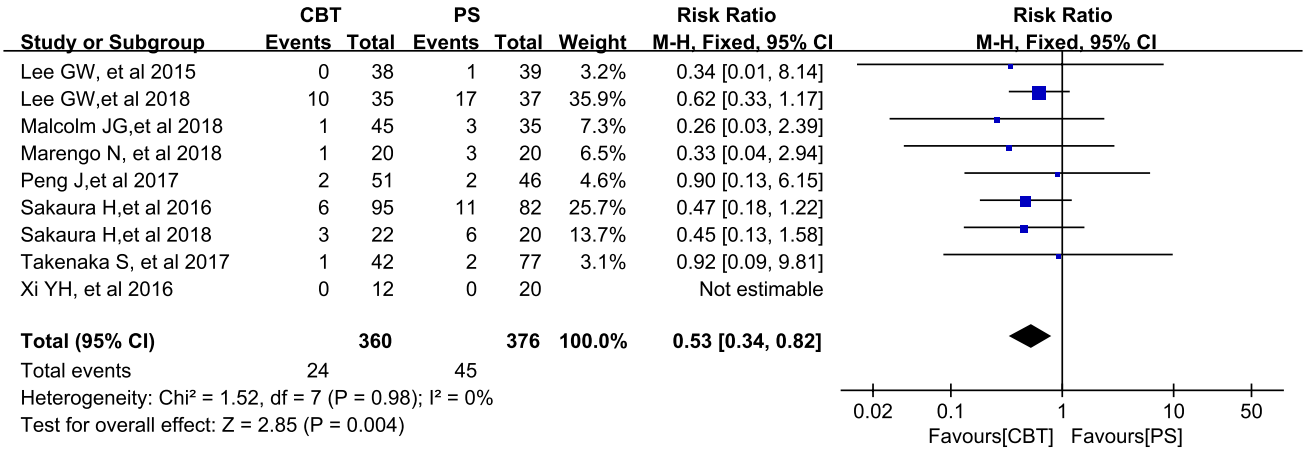

Fig. 5 Comparison of postoperative complications rate

$I^2 = 0\%$] (Table 4). Seven studies [15, 18, 20, 21, 26, 27, 29] reported postoperative wound infection [RR = 0.55 (95% CI (0.20–1.50), $p = 0.24$)]; this difference failed to reach statistical significance (Table 4). Regarding dural tear, five studies [15, 20, 21, 27, 29] revealed that CBT group and PS group had similar rates of dural tear without significant

heterogeneity [RR = 0.83, 95% CI (0.38–1.84), $p = 0.65$] and ($p = 0.61$, $I^2 = 0\%$) (Table 4). Five studies [18, 20, 21, 26, 27] reported the data of screw malposition with no statistical difference between both groups [RR = 0.53, 95% CI (0.21–1.33), $p = 0.17$] (Table 4). Four studies [15, 20, 21, 29] with a total of 435 patients reported the data of hematoma. There was no significant heterogeneity between two groups ($p = 0.60$; $I^2 = 0\%$); CBT group and PS group had similar incidence of hematoma [RR = 1.35, 95% CI (0.36–5.09), $p = 0.66$] (Table 4).

Other complications including cage subsidence and screw loosening were reported by Lee et al. [17]; they noted that signs of screw loosening were observed in 7 of 37 patients (19%) in PS group and 4 of 35 patients (11.4%) in CBT group B ($p = 0.51$), and cage subsidence was revealed in two patients in each group with no significant difference. Marengo et al. [18] found that there was one case of cage subsidence in the CBT group and two in the PS group without significant difference.

Revision surgery

Four studies [15, 20, 21, 27] including 415 patients (201 patients in the CBT group and 214 in the PS group) reported reoperations at the final follow-up. There was no significant heterogeneity between the two groups ($p = 0.82$; $I^2 = 0\%$). The results showed that reoperation rate of CBT group was lower than PS groups with no statistical difference [RR = 0.44, 95% CI (0.18, 1.07), $p = 0.07$] (Fig. 6).

Operation time, intraoperative blood loss, length of hospital stay and incision length

The operation time was available from 12 studies [15, 16, 18, 20, 21, 25, 26–31]. The results revealed that the operation time of CBT group was shorter than that of PS group (MD = − 34.24; 95% CI (− 57.29 to − 11.2); $p = 0.004$). Regarding intraoperative blood loss, 12 studies [15, 16, 18, 20, 21, 25, 26–31] revealed that PS group had a significantly higher blood loss than CBT [MD = − 99.72, 95% CI (− 141.86 to − 57.58), $p < 0.00001$; $I^2 = 95\%$]. Six studies [18, 25, 26, 27, 29, 31] reported the length of hospital stay, showing that length of hospital stay was significantly less in CBT than that in PS (MD = − 1.18; 95% CI (− 2.03 to − 0.32) $p = 0.007$). The incision length was available from three studies [18, 26, 31]. Length of incision was significantly shorter in CBT group than in PS group (MD = − 47.87, 95% CI (− 76.23 to 19.51); $p = 0.0009$) (Table 4).

Sensitivity analysis and publication bias

Sensitivity analysis by reanalyzing the data after sequential single elimination of each studies revealed no significant changes for operation time, intraoperative blood loss, length of hospital stay and incision length. After single elimination of each study, there was also no statistically significant difference in postoperative ODI, postoperative back and leg pain VAS score between the CBT and PS groups. The funnel plot of the studies that reported the fusion rate is shown in Fig. 7, indicating minimal publication bias.

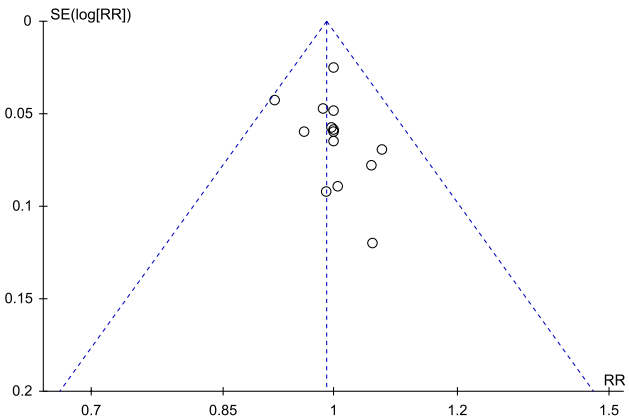

Fig. 7 Funnel plot of fusion rate

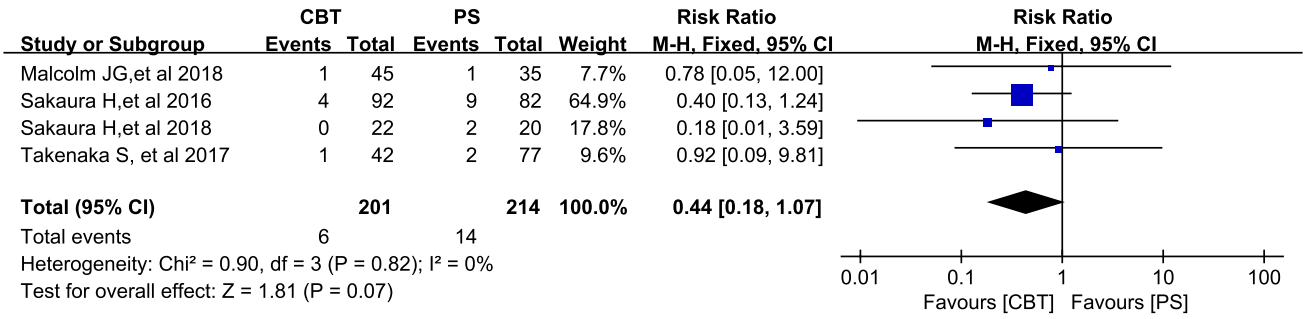

Fig. 6 Comparison of revision surgery rate

Discussion

Two RCT and twelve cohort studies from the literature search up to June 2018 were included. This meta-analysis included 954 patients comparing the safety and efficacy between CBT and PS and suggests that there are not significant difference in outcomes for postoperative back and leg pain VAS and postoperative JOA score. However, CBT was superior to PS with a significant lower postoperative ODI and higher JOA recovery rate. Moreover, CBT group had significantly better results in operation time, intraoperative blood loss, length of hospital stay and incision length compared with PS group. Furthermore, CBT group was associated with less revision surgery compared with PS group without significant statistical difference.

Fusion rates are considered one of the most important factors in the evaluation of the clinical efficacy between CBT and PS in posterior lumbar fusion surgery. This meta-analysis showed that there was no statistically significant difference in fusion rates between CBT group and PS group. The pooled fusion success rates were 92.6% (452/488 levels) in the CBT group and 92.7% (471/508 levels) in the PS group. Two prospectively randomized comparative study, conducted by Lee et al. [17, 26], found that the fusion rates were seen to be equivalent between CTB and PS in single-level PLIF at 1-year follow-up and the 2-year follow-up. The outcomes at 2-year follow-up are improved from 87.2 to 94.5% in PS group and from 92.1 to 94.3% in CTB group compared with the outcomes at 1-year follow-up. Some recent papers revealed that using CTB in lumbar fusion surgery may produce slightly lower fusion rates in comparison with PS. Sakaura et al. [20, 21] recently reported clinical and radiological outcomes after single-level and two-level PLIF with CBT screw fixation compared with those using traditional PS fixation. They noted that the fusion rates were lower in the CTB group than those in the PS group in both single-level and two-level PLIF, although the difference was not statistically significant. Sakaura et al. selected articular surface of the superior articular process as starting point. The differences of the entry point and the trajectory may be associated with structural stability, resulting in relatively lower fusion rates in the CTB group.

The complication rates are regarded as one of the most important factors to evaluate clinical safety between CBT group and PS group. The results of this meta-analysis showed that the PS group had significant higher complication rates compared with the CBT group. In the current study, comparing CBT with PS showed that there was no significant difference with respect to wound infection, dural tear, screw malposition and hematoma. The most important clinically findings were that PS was associated with significant higher incidences of superior facet joint violations and symptomatic ASD.

Superior facet joint violation was a common complication during pedicle screw placement. In this meta-analysis, the incidence of superior facet violations of PS group was significant higher than that of CBT group [0.85% (1/118) in CTB group and 11.76% (14/119) in the PS group], which was not consistent with the previous studies in which the incidence of the facet joint violation occurred in 3–35% in open pedicle screw fixation and 4–50% in percutaneous surgery [5, 6, 32, 33]. Facet joint with lumbar intervertebral disk constitutes the lumbar complex which is responsible for the spine movement, stability, torsion and load-bearing ability [34]. Facet joint violations can destroy the spine stability and further accelerate the development of adjacent segment disease [18, 26] Due to the entry point of the CTB being near the pars articularis, which is far from the superior facet joint, the risk of superior facet violation is much lower than that in traditional PS.

Adjacent segment degeneration (ASD) is one of the major complications after lumbar fusion surgery. Various possible risk factors of ASD have been reported, including facet joints degeneration or violation, multi-level fusion, segmental lordosis and excessive disk height distraction [35–39]. The rates of symptomatic ASD were 5.92% (9/152) in the CBT group and 14.39% (20/139) in the PS group, which showed that the incidence of symptomatic ASD after posterior lumbar fusion with PS is higher than that with CBT. The results indicated that CBT screw fixation could reduce the incidence of symptomatic ASD by limiting the dissection of the superior facet joints, reducing paraspinal muscles dissection which could maintain spine stability. Several studies indicated that treatment of symptomatic ASD after lumbar fusion surgery using cortical bone trajectory screw fixation technique results in satisfactory effects [40, 41]. In the recent retrospective study, Lee et al. [32] noted the minimally invasive surgery with CBT for ASD offers similar fusion rates, better clinical outcomes, faster recovery and better patients' satisfaction in comparison with PS group.

In this current study, there was a trend toward increased postoperative surgical infection rates in PS when compared to CBT (1.3% vs. 2.8%). However, this was no statistical significance. PS group are confronted with larger incisions, more extensive soft tissue dissection, longer operation time, larger blood loss and wider retraction, which could increase the rate of surgical site infections. Long operation time and large blood loss increased periods of tissue retraction and resulted in tissue ischemia and necrosis which increased the risk of wound infections [41]. Extensive muscle dissection and large incisions not only maximize soft tissue trauma, but also increase the dead space in the operative site [42, 43].

Other main complications included dural tear, screw malposition, hematoma, screw loosening and cage migration.

In this meta-analysis, the rates of dural tear were similar between 2 groups (10/255 vs. 11/260). Cerebrospinal fluid (CSF) leak caused persistent headache, deep wound infection and meningitis which in turn resulted in a longer postoperative hospitalization [44, 45]. Rare complications including screw pullout had been seldom observed in these studies. Therefore, both posterior lumbar fusion with CBT and with PS was relatively safe.

The results of this meta-analysis showed that CBT was superior to PS in terms of patient satisfaction, operation time, intraoperative blood loss, length of hospital stay and incision length. Many studies had demonstrated that there were strong association between longer operative time and perioperative complications [46–50]. Kim et al. [49] suggested that operative time was an independent risk factor for postoperative complications in single-level lumbar fusion. Phan et al. [50] noted that operation time was a risk factor for many postoperative complications, such as wound and pulmonary complications, venous thromboembolism and reoperation. Perioperative complications would significantly prolong the hospital stay, and consequently increase the hospitalization costs and reduce patient satisfaction.

Limitations

This meta-analysis has several limitations. First, the included studies have only two RCTS and the rest are cohort studies. Besides, small sample studies are more likely to overestimate the clinical effects. Second, studies were performed in different surgical centers by different types of surgery, surgical experience and lumbar pathology, which are possible sources of clinical heterogeneity. Last, in this meta-analysis, postoperative follow-up period of the studies was relatively short. (The mean follow-up period was less than 2 years.)

Conclusions

Overall, this meta-analysis demonstrates that both CBT and PS achieve similar fusion rate and clinical outcomes in the treatment of degenerative lumbar diseases. However, CBT is associated with better postoperative JOA recovery rate and ODI. Furthermore, CBT is superior to PS with lower incidence of superior facet joint violation and symptomatic ASD. However, revision surgery and other complications (including wound infection, dural tear, screw malposition and hematoma, etc.) are similar in both groups. Moreover, PS group require longer operation time, longer length of hospital stay, longer incision length and more blood loss than CBT group.

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Compliance with ethical standards

Conflicts of interest All authors declare that they have no conflict of interest.

References

1. Athanasakopoulos MMA, Triantafyllopoulos G, Koufos S, Pneumaticos SG (2013) Posterior spinal fusion using pedicle screws. Orthopedics 36:e951–e957. https://doi.org/10.3928/01477447-20130624-28
2. Cheng XZK, Sun X et al (2017) Clinical and radiographic outcomes of bilateral decompressionvia a unilateral approach with transforaminal lumbar interbody fusion for degenerative lumbarspondylolisthesis with stenosis. Spine J 17:1127–1133. https://doi.org/10.1016/j.spinee.2017.04.011
3. Lee NKK, Yi S et al (2017) Comparison of outcomes of anterior-, posterior- and transforaminal lumbar interbody.pdf. World Neurosurg 101:216–226. https://doi.org/10.1016/j.wneu.2017.01.114
4. Lidar ZBA, Lifshutz J, Maiman DJ (2005) Clinical and radiological relationship between posterior lumbar interbody fusion and posterolateral lumbar fusion. Surg Neurol 64:303–308. https://doi.org/10.1016/j.surneu.2005.03.025
5. Babu R, Park JG, Mehta AI, Shan T, Grossi PM, Brown CR, Richardson WJ, Isaacs RE, Bagley CA, Kuchibhatla M, Gottfried ON (2012) Comparison of superior-level facet joint violations during open and percutaneous pedicle screw placement. Neurosurgery 71:962–970. https://doi.org/10.1227/NEU.0b013e31826a88c8
6. Herren C, Reijnen M, Pishnamaz M, Lichte P, Andruszkow H, Nebelung S, Siewe J, Hildebrand F, Kobbe P (2018) Incidence and risk factors for facet joint violation in open versus minimally invasive procedures during pedicle screw placement in patients with trauma. World Neurosurg 112:e711–e718. https://doi.org/10.1016/j.wneu.2018.01.138
7. Liu J, Deng H, Long X, Chen X, Xu R, Liu Z (2016) A comparative study of perioperative complications between transforaminal versus posterior lumbar interbody fusion in degenerative lumbar spondylolisthesis. Eur Spine J 25:1575–1580. https://doi.org/10.1007/s00586-015-4086-8
8. Mehta VA, McGirt MJ, Garces Ambrossi GL, Parker SL, Sciubba DM, Bydon A, Wolinsky JP, Gokaslan ZL, Witham TF (2011) Trans-foraminal versus posterior lumbar interbody fusion: comparison of surgical morbidity. Neurol Res 33:38–42. https://doi.org/10.1179/016164110X12681290831289
9. Santoni BG, Hynes RA, McGilvray KC, Rodriguez-Canessa G, Lyons AS, Henson MA, Womack WJ, Puttlitz CM (2009) Cortical bone trajectory for lumbar pedicle screws. Spine J 9:366–373. https://doi.org/10.1016/j.spinee.2008.07.008
10. Matsukawa K, Yato Y, Imabayashi H, Hosogane N, Abe Y, Asazuma T, Chiba K (2016) Biomechanical evaluation of fixation strength among different sizes of pedicle screws using the cortical bone trajectory: what is the ideal screw size for optimal fixation? Acta Neurochir (Wien) 158:465–471. https://doi.org/10.1007/s00701-016-2705-8
11. Matsukawa K, Yato Y, Imabayashi H, Hosogane N, Asazuma T, Chiba K (2016) Biomechanical evaluation of lumbar pedicle screws in spondylolytic vertebrae: comparison of

fixation strength between the traditional trajectory and a cortical bone trajectory. J Neurosurg Spine 24:910–915. https://doi.org/10.3171/2015.11.SPINE15926
12. Sansur CA, Caffes NM, Ibrahimi DM, Pratt NL, Lewis EM, Murgatroyd AA, Cunningham BW (2016) Biomechanical fixation properties of cortical versus transpedicular screws in the osteoporotic lumbar spine: an in vitro human cadaveric model. J Neurosurg Spine 25:467–476. https://doi.org/10.3171/2016.2.SPINE151046
13. Oshino H, Sakakibara T, Inaba T, Yoshikawa T, Kato T, Kasai Y (2015) A biomechanical comparison between cortical bone trajectory fixation and pedicle screw fixation. J Orthop Surg Res 10:125. https://doi.org/10.1186/s13018-015-0270-0
14. Perez-Orribo L, Kalb S, Reyes P, Chang S, Crawford N (2013) Biomechanics of lumbar cortical screw-rod fixation versus pedicle screw-rod fixation with and without interbody support. Spine 38:635–641
15. Takenaka S, Mukai Y, Tateishi K, Hosono N, Fuji T, Kaito T (2017) Clinical outcomes after posterior lumbar interbody fusion: comparison of cortical bone trajectory and conventional pedicle screw insertion. Clin Spine Surg 30:E1411–E1418
16. Chin K, Pencle F, Coombs A, Elsharkawy M, Packer C, Hothem E, Seale J (2017) Clinical outcomes with midline cortical bone trajectory pedicle screws versus traditional pedicle screws in moving lumbar fusions from hospitals to outpatient surgery centers. Clin Spine Surg 30:E791–E797
17. Lee GW, Ahn MW (2018) Comparative study of cortical bone trajectory-pedicle screw (cortical screw) versus conventional pedicle screw in single-level posterior lumbar interbody fusion: a 2-year post hoc analysis from prospectively randomized data. World Neurosurg 109:e194–e202. https://doi.org/10.1016/j.wneu.2017.09.137
18. Marengo N, Ajello M, Pecoraro MF, Pilloni G, Vercelli G, Cofano F, Zenga F, Ducati A, Garbossa D (2018) Cortical bone trajectory screws in posterior lumbar interbody fusion: minimally invasive surgery for maximal muscle sparing—a prospective comparative study with the traditional open technique. Biomed Res Int 2018:7424568. https://doi.org/10.1155/2018/7424568
19. Marengo N, Berjano P, Cofano F, Ajello M, Zenga F, Pilloni G, Penner F, Petrone S, Vay L, Ducati A, Garbossa D (2018) Cortical bone trajectory screws for circumferential arthrodesis in lumbar degenerative spine: clinical and radiological outcomes of 101 cases. Eur Spine J. https://doi.org/10.1007/s00586-018-5599-8
20. Sakaura H, Miwa T, Yamashita T, Kuroda Y, Ohwada T (2016) Posterior lumbar interbody fusion with cortical bone trajectory screw fixation versus posterior lumbar interbody fusion using traditional pedicle screw fixation for degenerative lumbar spondylolisthesis: a comparative study. J Neurosurg Spine 25:591–595. https://doi.org/10.3171/2016.3.SPINE151525
21. Sakaura H, Miwa T, Yamashita T, Kuroda Y, Ohwada T (2018) Cortical bone trajectory screw fixation versus traditional pedicle screw fixation for 2-level posterior lumbar interbody fusion: comparison of surgical outcomes for 2-level degenerative lumbar spondylolisthesis. J Neurosurg Spine 28:57–62. https://doi.org/10.3171/2017.5.SPINE161154
22. Chen YR, Deb S, Pham L, Singh H (2016) Minimally invasive lumbar pedicle screw fixation using cortical bone trajectory—a prospective cohort study on postoperative pain outcomes. Cureus 8:e714. https://doi.org/10.7759/cureus.714
23. Furlan AD, Malmivaara A, Chou R, Maher CG, Deyo RA, Schoene M, Bronfort G, van Tulder MW, Editorial Board of the Cochrane Back NG (2015) 2015 Updated method guideline for systematic reviews in the cochrane back and neck group. Spine (Phila Pa 1976) 40:1660–1673. https://doi.org/10.1097/brs.0000000000001061
24. Stang A (2010) Critical evaluation of the Newcastle–Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. Eur J Epidemiol 25:603–605. https://doi.org/10.1007/s10654-010-9491-z
25. Hung CW, Wu MF, Hong RT, Weng MJ, Yu GF, Kao CH (2016) Comparison of multifidus muscle atrophy after posterior lumbar interbody fusion with conventional and cortical bone trajectory. Clin Neurol Neurosurg 145:41–45. https://doi.org/10.1016/j.clineuro.2016.03.005
26. Lee GW, Son JH, Ahn MW, Kim HJ, Yeom JS (2015) The comparison of pedicle screw and cortical screw in posterior lumbar interbody fusion: a prospective randomized noninferiority trial. Spine J 15:1519–1526. https://doi.org/10.1016/j.spine.2015.02.038
27. Malcolm JG, Moore MK, Choksh FH, Ahmad FU, Refai D (2018) Comparing cortical trajectory transforaminal lumbar interbody fusions against pedicle trajectory transforaminal lumbar interbody fusions and posterolateral fusions: a retrospective cohort study of 90-day outcomes. Neurosurgery. https://doi.org/10.1093/neuros/nyx619
28. Orita S, Inage K, Kubota G, Sainoh T, Sato J, Fujimoto K, Shiga Y, Nakamura J, Matsuura Y, Eguchi Y, Aoki Y, Toyone T, Yamauchi K, Sakuma Y, Oikawa Y, Suzuki T, Takahashi K, Hynes RA, Ohtori S (2016) One-year prospective evaluation of the technique of percutaneous cortical bone trajectory spondylodesis in comparison with percutaneous pedicle screw fixation: a preliminary report with technical note. J Neurol Surg A Cent Eur Neurosurg 77:531–537. https://doi.org/10.1055/s-0035-1566118
29. Peng J, Zhan Y, Liu Y, Zong Y, Mao Y (2017) Comparison of effectiveness of cortical bone trajectory screw fixation and pedicle screw fixation in posterior lumbar interbody fusion. Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi 31:1341–1345. https://doi.org/10.7507/1002-1892.201706075
30. Xi YH, Wang Y, Yu JM, Liu XL, Xie N, Ye XJ (2016) Curative effect of cortical bone trajectory screw combined with pedicle screw in internal fixation for senile osteoporosis lumbar degenerative disease. Acad J Second Mil Med Univ 37:879–883. https://doi.org/10.16781/j.0258879x2016.07.0879
31. Lee GW, Shin JH (2018) Comparative study of two surgical techniques for proximal adjacent segment pathology after posterior lumbar interbody fusion with pedicle screw: fusion extension using conventional pedicle screw versus cortical bone trajectory-pedicle screw (cortical screw). World Neurosurg. https://doi.org/10.1016/j.wneu.2018.05.218
32. Zeng ZL, Jia L, Xu W, Yu Y, Hu X, Jia YW, Wang JJ, Cheng LM (2015) Analysis of risk factors for adjacent superior vertebral pedicle-induced facet joint violation during the minimally invasive surgery transforaminal lumbar interbody fusion: a retrospective study. Eur J Med Res 20:80. https://doi.org/10.1186/s40001-015-0174-9
33. Lau D, Terman SW, Patel R, La Marca F, Park P (2013) Incidence of and risk factors for superior facet violation in minimally invasive versus open pedicle screw placement during transforaminal lumbar interbody fusion: a comparative analysis. J Neurosurg Spine 18:356–361. https://doi.org/10.3171/2013.1.SPINE12882
34. Niosi CAWD, Zhu Q, Keynan O, Wilson DR, Oxland TR (2008) The effect of dynamic posterior stabilization on facet joint contact forces: an in vitro investigation. Spine 33:19–26
35. Kim JY, Ryu DS, Paik HK, Ahn SS, Kang MS, Kim KH, Park JY, Chin DK, Kim KS, Cho YE, Kuh SU (2016) Paraspinal muscle, facet joint, and disc problems: risk factors for adjacent segment degeneration after lumbar fusion. Spine J 16:867–875. https://doi.org/10.1016/j.spinee.2016.03.010
36. Okuda S, Nagamoto Y, Matsumoto T, Sugiura T, Takahashi Y, Iwasaki M (2018) Adjacent segment disease after single segment posterior lumbar interbody fusion for degenerative

spondylolisthesis: minimum 10 years follow up. Spine (Phila Pa 1976). https://doi.org/10.1097/brs.0000000000002710
37. Tian H, Wu A, Guo M, Zhang K, Chen C, Li X, Cheng X, Zhou T, Murray SS, Sun X, Zhao J (2018) Adequate restoration of disc height and segmental lordosis by lumbar interbody fusion decreases adjacent segment degeneration. World Neurosurg. https://doi.org/10.1016/j.wneu.2018.07.075
38. Zhong ZM, Deviren V, Tay B, Burch S, Berven SH (2017) Adjacent segment disease after instrumented fusion for adult lumbar spondylolisthesis: incidence and risk factors. Clin Neurol Neurosurg 156:29–34. https://doi.org/10.1016/j.clineuro.2017.02.020
39. Rodriguez A, Neal MT, Liu A, Somasundaram A, Hsu W, Branch CL Jr (2014) Novel placement of cortical bone trajectory screws in previously instrumented pedicles for adjacent-segment lumbar disease using CT image-guided navigation. Neurosurg Focus 36:E9. https://doi.org/10.3171/2014.1.focus13521
40. Chen CH, Huang HM, Chen DC, Wu CY, Lee HC, Cho DY (2018) Cortical bone trajectory screws fixation in lumbar adjacent segment disease: a technique note with case series. J Clin Neurosci 48:224–228. https://doi.org/10.1016/j.jocn.2017.11.008
41. Pull ter Gunne AF, Cohen DB (2009) Incidence, prevalence, and analysis of risk factors for surgical site infection following adult spinal surgery. Spine (Phila Pa 1976) 34:1422–1428. https://doi.org/10.1097/brs.0b013e3181a03013
42. Shousha M, Cirovic D, Boehm H (2015) Infection rate after minimally invasive noninstrumented spinal surgery based on 4350 procedures. Spine (Phila Pa 1976) 40:201–205. https://doi.org/10.1097/brs.0000000000000690
43. Parker SL, Adogwa O, Witham TF, Aaronson OS, Cheng J, McGirt MJ (2011) Post-operative infection after minimally invasive versus open transforaminal lumbar interbody fusion (TLIF): literature review and cost analysis. Minim Invasive Neurosurg 54:33–37. https://doi.org/10.1055/s-0030-1269904
44. Smorgick Y, Baker KC, Herkowitz H, Montgomery D, Badve SA, Bachison C, Ericksen S, Fischgrund JS (2015) Predisposing factors for dural tear in patients undergoing lumbar spine surgery. J Neurosurg Spine 22:483–486. https://doi.org/10.3171/2015.1.SPINE13864
45. Takahashi Y, Sato T, Hyodo H, Kawamata T, Takahashi E, Miyatake N, Tokunaga M (2013) Incidental durotomy during lumbar spine surgery: risk factors and anatomic locations: clinical article. J Neurosurg Spine 18:165–169. https://doi.org/10.3171/2012.10.spine12271
46. Cheng K, Li J, Kong Q, Wang C, Ye N, Xia G (2015) Risk factors for surgical site infection in a teaching hospital: a prospective study of 1138 patients. Patient Prefer Adher 9:1171–1177. https://doi.org/10.2147/ppa.s86153
47. Wang H, Zhang Z, Qiu G, Zhang J, Shen J (2018) Risk factors of perioperative complications for posterior spinal fusion in degenerative scoliosis patients: a retrospective study. BMC Musculoskelet Disord 19:242. https://doi.org/10.1186/s12891-018-2148-x
48. Zhang XN, Sun XY, Hai Y, Meng XL, Wang YS (2018) Incidence and risk factors for multiple medical complications in adult degenerative scoliosis long-level fusion. J Clin Neurosci 54:14–19. https://doi.org/10.1016/j.jocn.2018.04.070
49. Kim B, Hsu W, De Oliveira G, Saha S, Kim J (2014) Operative duration as an independent risk factor for postoperative complications in single-level lumbar fusion: an analysis of 4588 surgical cases. Spine 39:510–520
50. Phan K, Kim J, Capua J, Lee N, Kothari P, Dowdell J, Overley S, Guzman J, Cho S (2017) Impact of operation time on 30-day complications after adult spinal deformity surgery. Glob Spine J 7:664–671

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